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NET4SENERGY

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Content

China's energy policy in alignment with the Paris Agreement

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Abstract

The emission of greenhouse gases increased significantly since the industrial revolution in the 18th century, but the environmental results can be seen only in the last decades. To mitigate the effects of such a negative spiral the countries united in 2015 and signed the Paris Agreement. The aim of this agreement is the same for everyone – decrease the emission of greenhouse gases, especially CO_2 - but the road how they plan to achieve it is very different. Since most of the emission comes from burning coal, in order to make energy seems obvious to shut down these coal-fired power plant, and find some alternative solutions to make up for the missing energy. Developed countries are in a better situation since they lack neither the will nor the resources for that process, while still developing countries, like China, have fewer options if they do not want to suffer an economic decline in the meantime, even if they are responsible for the bulk of the emissions. For that reason, reaching carbon neutrality has a different timescale for every country. Some of them are in a hurry to achieve it, some of them not really. I guess the only question that truly matters in this case: Can we do it in time, or it will be too late?

Keywords: Paris Agreement, coal-fired power plants, coal phase-out, China's energy policy,

JEL Classification: P18

1. Introduction

In the last decades, the human species intervened in the physical environment in many ways. Just to mention some of them, overpopulation, deforestation, and burning fossil fuels are all responsible for climate change and for the continuously deteriorating chances of leaving a liveable Earth to our grandchildren.

One of the key elements of climate change is the increasing number of greenhouse gases in the atmosphere, especially CO_2, which is responsible for 76% of all GHG emissions on Earth (C2ES 2021).

Unfortunately, as it can be seen in the figure, the CO_2 particles are increasing in the air year by year, and the current quantity is almost 50% more than it was before the industrial revolution (until 1750 it was around 280 parts/million (CO2 levels 2021)).

To decrease the negative effects of GHG emissions, or even turn the trend the Paris Agreement is considered a milestone in history, which was announced in 2015 and signed by 195 countries. The goal of this agreement is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. (United Nations Climage Change 2021)

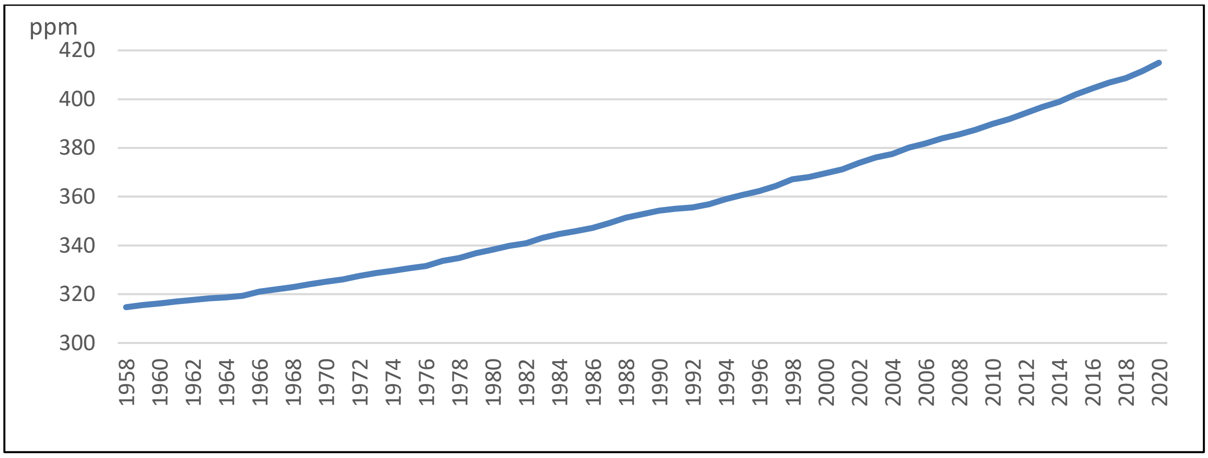

Figure 1. CO_2 parts/million in the air in between 1958-2020

Source: Own elaboration based on DataHub 2021

To make that happen it is crucial to cut coal-fired power plants from the energy mix of the countries, which seems troublesome due to the fact that it gives about 25% of the global energy consumption, and even more in some of the developing countries.

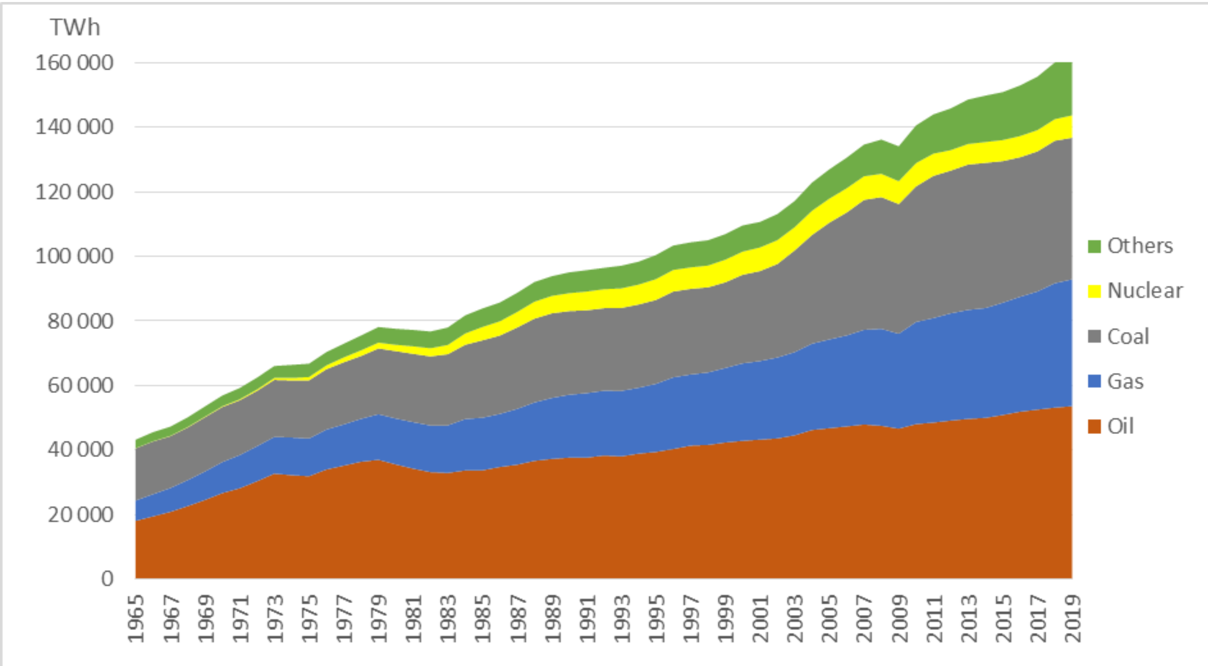

Figure 2. Global energy consumption by source in between 1965-2019

Source: Own elaboration based on Our World in Data 2021a

2. The role of the EU in the coal phase-out process

The European Union has a leading role to meet the expectations of the Paris Agreement thus it is not surprising that the European countries are more advanced in the coal phase-out process than the developing countries.

Out of the EU27, 9 countries are already exiled coal-based energy from their energy mix (Austria, Belgium, Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, Sweden), while most of the remaining member states committed themselves to finish the phase-out process before 2030 (Portugal in 2021, France in 2022, Hungary in 2025, Italy in 2025, Ireland in 2025, Greece in 2025, Denmark in 2028, Finland in 2029, Netherlands in 2029, Slovakia in 2030, Spain in 2030). (Europe Beyond Coal 2021)

The positive results of this joint effort are already noticeable in the coal plant capacities of the EU states, such as in the decreasing CO_2 emission.

Table 1. CO_2 emission of EU27 countries in 2015 and 2020

Country	CO_2 Emission in 2015 (million tonnes)	CO_2 Emission in 2020 (million tonnes)
Austria	2 359 765	371 094
Belgium	1 904 278	-
Bulgaria	27 247 811	10 435 216
Croatia	2 030 760	1 021 767
Czech Republic	44 695 870	34 739 780
Denmark	6 849 523	2 263 079
Finland	5 379 547	3 001 314
France	10 889 473	2 971 832
Germany	266 569 010	138 006 975
Greece	29 404 777	9 095 208
Hungary	6 794 914	4 193 652
Ireland	4 528 857	862 922
Italy	39 461 293	12 838 576
Netherlands	32 762 840	6 879 432
Poland	129 322 335	102 897 682
Portugal	12 299 753	2 112 608
Romania	19 144 716	8 315 459
Slovakia	3 177 695	1 756 219
Slovenia	4 357 172	4 236 180
Spain	52 094 501	6 680 817
Sweden	608 308	4 521
Total	701 883 198	352 684 333

Source: Own elaboration based on Beyond Coal 2021

In less than 5 years the EU was able to halve the CO_2 emission by coal-fired power plants, and this is not only the result of a few countries, but as it can be seen in Table 1. everyone took their part of it.

3. China's coal dependency

As European citizens, we tend to focus on the European Union, however regarding the coal-fired power plants, it is more important to look to Asia, and within that, especially to China, since this country alone gives the 51% of the worldwide capacities with it's 1082 operating powerplants.

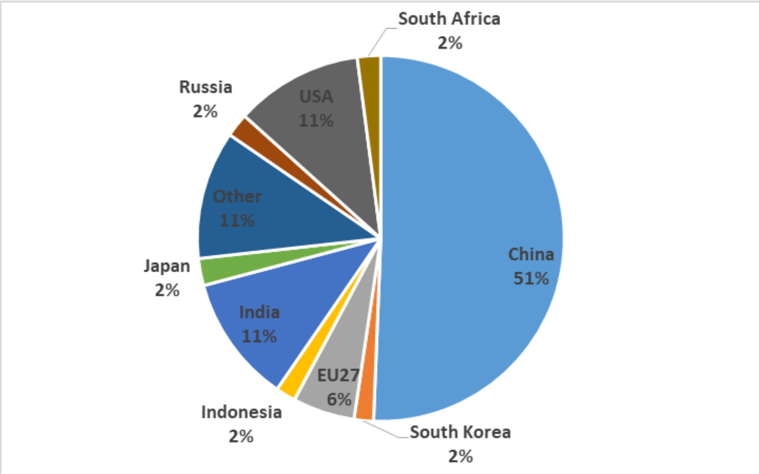

Figure 3: Capacity share of the world coal-fired power plants in 2021

Source: Own elaboration based on Global Energy Monitor 2021

But not just the capacities, which are remarkable in China, but unfortunately their energy mix is also interesting. In contrast with the EU, they heavily rely on coal-based energy, which still gives around 55% of their consumption, while renewables are only responsible for 12%, however slightly increasing.

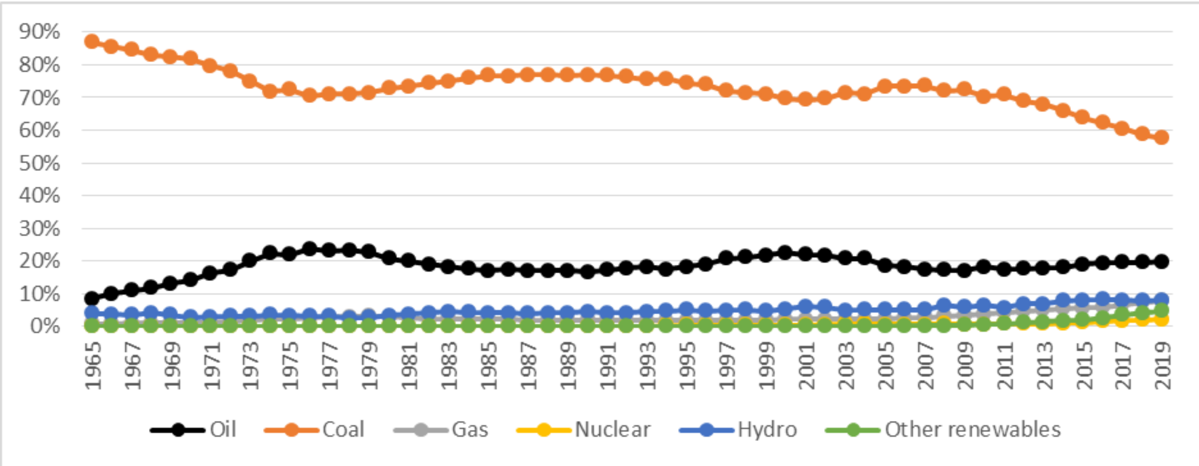

Figure 4. Share of energy consumption by source in China between 1965-2019

Source: Own elaboration based on Our World in Data 2021b

In addition to that, the Chinese economy is still expanding, thus their need for energy is continuously growing (39.300 TWh in 2019). Since China is also signed the Paris Agreement, somehow they are committed to reducing their GHG emission however, the level of their actions reflects that it is a long-term goal, instead of a sudden, rapid change.

For the government it is still imperative to support growth in the industry sector, thus this aim sometimes overrules the evironmental costs of such progression.

This fact is buttressed by the Cap and Trade system in China, which is similar to the European ETS system, where companies get a cap of their annual CO_2 emission and if they go beyond that number, they have to buy the quota from the market. In the 14th Five Year Plan, the starting price of CO_2 emission per ton is 41 yuan (about 6,5$) and it goes up to 66 yuan (about 10$) till 2025. This price seems very modest in light of the fact, that according to economists, CO_2 emission is supposed to be priced between 40-80$ per ton in 2021 and between 50-100$ per ton by 2030. In fairness, the EU ETS prices stands at around 75 $ in November 2021. (TradingEconomics 2021)

But not only the pricing method seems problematic, but also important to note, that the current cap and trade system covers only 30% of China's total emission now, which leaves about 7 billion tonnes of CO_2 emission uncharged. (Kleinman Center 2021, Our World in Data 2021c)

In 2020, Xi Jinping announced that his country's carbon emission would begin to decline by 2030, and it will reach carbon neutrality by 2060 but to achieve that it is not enough to change the energy mix of the country, but they have to change the way they use energy too.

In the 11th Five Year Plan (2006-2010) China already announced the „dual control policy" with a plan to set a five-year target of energy consumption and energy intensity for most of the provinces, in an effort to reasonably manage the total energy consumption of the country, but unfortunately, this idea was implemented only in 2016 in the 13th FYP.

At the beginning of the period, China was able to steadily bring down its energy intensity level and enhance its energy efficiency, but due to the COVID outbreak, this trend has been interrupted. The energy consumption shifted again to the high-intensity manufacturing activities in order to recover from the economic shock of the pandemic situation, which resulted in a record high, 17% increase in the energy consumption in the first half of 2021. In this period the coal accounted for 62% of the country's total power generation, which is 5% more than it was 2 years ago, and still with these results the country's hunger for energy could not be satisfied. (IHS Markint 2021, CGTN 2021)

If the production rush to bounce the Chinese economy back to normal, would not be enough, last year, due to political reasons China stopped buying coal from Australia, which was its number one supplier in 2019.

Thanks to that, the coal prices in October tripled in China if we consider the last 12 months, which forced electricity producers to curb their output. (Reuters 2021)

From that moment, long-term environment protection goals were out of the table and the main question was that whether they can meet the demand of the Chinese economy or not.

In August and September, power cuts were announced in more than 20 provinces across the country and caused a crisis in production. The power cuts had different extent but it was enough to halt production at many factories and disrupt global supply chains. (CNBC 2021a)

In Guangdong province (which gives about 23% of China's exports by value) the sudden drop in production has cut the demand for shipping goods overseas, making a lot of capacities unused thus reducing the shipping fees from 15.000$ to 9.000$ per container. (CNBC 2021b)

These outages will probably have a serious impact even in a short term. The world biggest banks already cut China's GDP forecast by at least 0,2% points, but some of them even with 0,5-0,6% points for 2021.

The prospects are not brighter in long term neither. If the outages remain, it will send a negative message to the investors, that production cannot be held steadily in China, and then maybe they will choose a different location for new factories. That would have unpredictable consequences for the current economic status quo. (CNBC 2021c)

While external effects are evident, we must not forget about internal effects, which can further worsen the situation. Winter is coming and heating will be crucial for Chinese people, which will require the country to burn even more coal.

In this situation, even without a real chance to decrease the demand for energy, at least they have to ease the price of thermal coal to avoid further shortages or minimize the risks.

To achieve that, the Chinese government issued more than 70 power-related documents in October 2021 in pursuit of increasing the mining and transportation activities of thermal coal.

At the same, time they released the restrictions of Australian coal import and also increased their import from Mongolia, which at last resulted in a sudden drop in coal prices. (Reuters 2021b)

In a long-term, probably solar power could be a replacement for coal-fired power plants in China, but due to the technological reasons of producing it is not an option now. Manufacturing solar panels require an enormous amount of electricity, which in the current state would further worsen the energy situation of the country. For that reason, the cost of building solar panel farms has increased more than 25% in 2021. (The New York Times 2021, Reuters 2021a)

Even if the country is economically thriving, at the end of the day Chinese people pay the price of the vast amount of burned coal. Poor air quality became a serious issue in the last few years especially in winter, causing about a half million people's premature death in a year. (IQAir 2021)

When burning coal, fine particles, known as PM 2.5 (two and one-half microns or less width) fill the air, which are able to travel deeply into the respiratory tract, reaching the lungs. Exposure to these tiny particles can have serious health issues such as coughing, eye or nose irritation, asthma, heart disease, and cancer. (New York State 2021)

In China, burning coal is responsible for about 40% of the fine particles getting into the atmosphere making breathing sometimes unbearable even with masks too.

Due to the heavy usage of coal-fired power plants in the last months, the air pollution in Beijing hit a very unhealthy level again at the beginning of November. While the recommended limit by WHO for PM 2.5 particles is 15, the air quality devices measured a value more than 230. The haze was so thick that highways had to be closed due to the bad visibility, and schools were ordered to stop physical education classes and outdoor activities. (NDTV 2021)

4. Conclusion

As it can be seen, the Paris Agreement, which was announced in 2015, has no legal obligations to any country, so no wonder that the interpretation and the deadlines to reach the goals in it are also depending on the countries themselves. The EU pays a lot of attention and money to meet those criteria, while other developing countries think otherwise. For China, since coal-fired power plants give a chunk of their energy mix, and economic growth has a higher value than environmental protection, they are not really keen to suddenly decrease their capacities, until suitable alternatives are not available. Probably just like some of the European countries already did, China will achieve carbon neutrality in the future, but the road towards this goal will be much longer since the Chinese government made it clear in the last months, that economic growth comes first.

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Interface for energy monitoring using Arduino modules

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Abstract

To control and reduce energy consumption, it demands to install a network of sensors and using a dashboard to monitoring data acquisition from its. Energy monitoring is necessary to keep track of energy consumption according to the season, weather conditions and the flow of use of electrical appliances in the institution. The paper presents a universal WEB application smart-MAC Dashboard base on Arduino modules, to monitor the sensors used. The main advantage of using the universal smart-MAC Dashboard WEB application is that the user is able to flexibly configure indicator and chart widgets and create an unlimited number of boards and devices connected to the same account. After an analyze of date can be take measurements for efficiency use of energy in public institution.

Keywords: Energy management, monitoring, Arduino, sensor, energy efficiency.

1. Introduction

Energy management is affecting organizational, technical and behavioral actions in an economically sound manner with the objective to improve the energy performance of the organization. Energy is a controllable resource, using it efficiently helps to increase profits by reducing costs. Access to energy is becoming more costly and environmentally damaging. The era of cheap energy is coming to an end in many countries. The effective use of the energy management system will help organizations of all sizes to manage their energy use in a sustainable way. This will result in reduced costs, reduced environmental impact and increased competitiveness. [1-3]

Do we use energy wisely or waste it? What will we do when the resources we get, oil and coal, are depleted? The conversion and use of energy lead to climate change, to greenhouse gas emissions. The problem of energy is of humanity, of Europe, of Romania and has been insistently taken over by European bodies and has been transposed into Romanian legislation. Europe has no energy resources and has decided that efficient use and saving of energy is an excellent way to reduce energy dependence. Energy audit is a systemic procedure: to obtain data about the existing energy profile of a system, an activity and/or industrial installations; identification and quantification of measures to achieve energy savings; reporting results.

Following the real energy balance, a plan of measures for the optimization of energy consumption is drawn up, which includes: reduction of losses in power lines; reducing losses in electrical transformers; flattening the load curve; improving the power factor; efficient operation of several transformations in parallel; use of idling limiters; replacement of poorly loaded asynchronous motors; rational use of lighting installations; adopting an appropriate pricing system. The optimized balance sheet considers the minimum losses of the installations and the effect of the efficiency increase measures identified by the real balance sheet. [2]

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Electrical Systems	Temperature Measurement	Combustion Systems	Steam Systems	HVAC Systems	Buildings	Compressed Air	Data Loggers	LPHW and CHW
• Multimeter • Voltmeter • Ammeter • Power Meter	• Surface Pyrometer • Portable Electronic • Thermometer • Thermocouple Probe • Infrared Thermometer • Infrared Camera	• Combustion Analyser	• Ultrasonic Leak • Detectors • Steam Trap Tester	• Manometer • Psychrometric • Anemometer	• Light Meter • Measuring Tape • Thermal Image Camera	• Ultrasonic Leak • Detectors	• 4-20Ma Logger • 0-10V Logger • Digital Logger • Vibration Logger • Light Sensor	• Ultrasonic Flowmeters

Figure 1 Monitoring, measurement, analysis and evaluation

An image of the possibilities of increasing energy efficiency is obtained if we succeed to monitoring all installations of building (figure 1) and correct the errors in building design. For this purpose, it is need equipment for data acquisition of values given by all installations and Arduino is coming with cheap sensors and easy platform for control and monitoring these.

Portable measuring instruments may be needed to substantiate the accuracy of existing permanent instruments where there is a question in relation to their accuracy. Modern portable metering can store data collected for a number of days and can then be uploaded either directly or remotely for analyses off site. Other systems can be installed wirelessly or wireless broadband technology utilized; where real time data can be collected from a web platform thus avoiding the necessity to be on site. Portable measuring equipment for various systems that could be tested during an energy audit. [4-6]

2. Energy building monitoring using Arduino modules

The utilization of this system allows to maintain a balanced energy consumption, detection of electricity, temperature losses, online monitoring of utilities and data storage, temperature and electricity control on each area and calculating the specific consumption much more accurately.

In order to assess the actual consumption of energy resources a pilot system of energy monitoring (https://dash.smart-mac.com/sharedash4813279715) for the university building was designed and partially implemented.

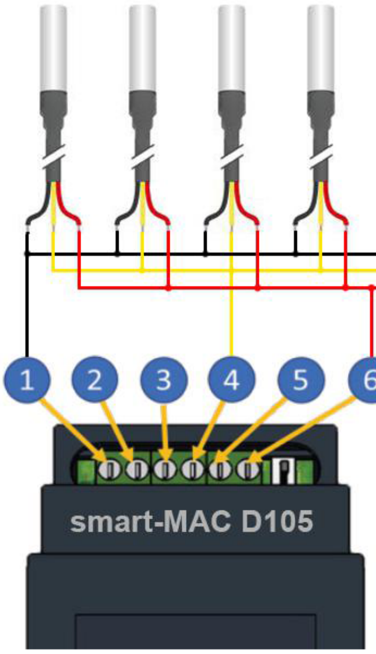
2.1 Sensors in building monitoring

Temperature sensor

You can connect up to 5 pcs DS18b20 temperature sensors or one DHT22 temperature and humidity sensor to the universal smart-MAC D105 meter. [7-8] DS18b20 are digital 1-Wire temperature sensors, all of them are connected to one contact, terminal 4. Black (or White) wire all sensors combine and connect to terminal 1: GND (Ground or -5B). Red wire all sensors combine and connect to the terminal 6: 5B. Yellow (or Blue) wire all sensors combine and connect to terminal 4: Data 1-Wire

Temperature sensors such as DS18x20 can be connected by 3 wired circuit (described above) or 2 wire. Pay attention, there are many low-quality sensors on the market that work unsustainably not only on the 2-wire circuit but also on 3 wired when connecting more than one sensor. The sensors from our store are of proven quality and work sustainably on any connection scheme.

When connecting multiple Sensors such as the DS18x20, they all need to be connected the same way, using a 2 or 3 wired connection.



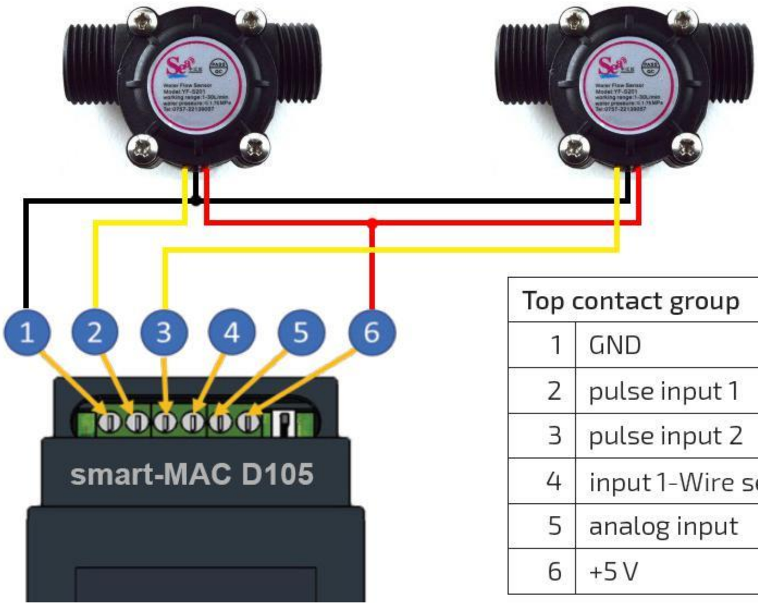
Top contact group		
1	GND	
2	pulse input 1	Ch1
3	pulse input 2	Ch2
4	input 1-Wire sensors	T1 - T5
5	analog input	ADC
6	+5 V	

Figure 2 3-wire connection to smart-MAC D105 [8]

Counters (flow meters) with impulse output

Two flow meters with a impulse output can be connected to one smart-MAC D105. It can be meters for water, gas, heat, fuel, milk, beer and many others. Two types of impulse outputs must be distinguished: The meter with a impulse output of the type "Dry contact" (mechanical meters). The meter with a impulse output of the type “n-p” (electronic meters).

High precision meters are equipped with an “n-p” type impulse output and are connected in a three-wire circuit with separate power supply. If the power supply voltage of the flowmeter is + 5V, then it can be obtained to contact 6 (+ 5V) of the D105 device. Any other supply voltage to the flowmeter will require a separate power supply. Connection diagram of a flowmeter with a impulse output of the "n-p" type: connect the GND flowmeter black wire to contact 1: GND (Ground or -5V). Connect the red wire + 5V of the flowmeter to contact 6: + 5V. Connect yellow wire the impulse of the flowmeter to contact 2 or 3: Ch1 or Ch2.



Top contact group		
1	GND	
2	pulse input 1	Ch1
3	pulse input 2	Ch2
4	input 1-Wire sensors	T1 - T5
5	analog input	ADC
6	+5 V	

Figure 3 Three-wire circuit for connecting a flow meter to smart-MAC D105 [9]

Wind Speed and Wind Direction sensors

Figure 4 Speed and Wind direction sensors

The Wind Speed and Wind Direction sensors (figure 4) can be connected to the universal D105 meter. Dashboard with examples widgets of monitoring wind speed and direction can be see in figure 5.

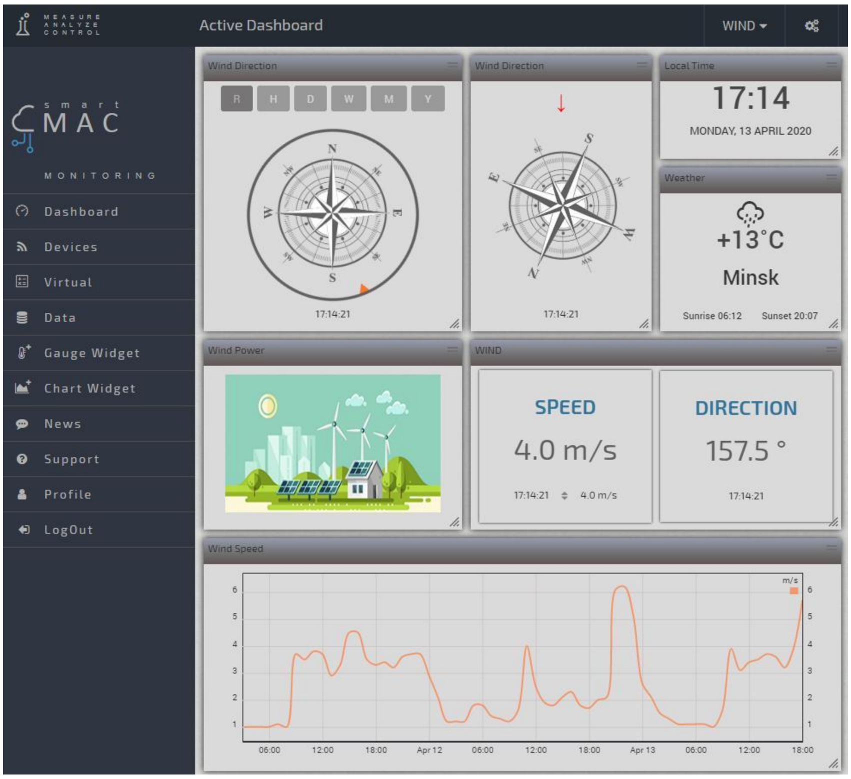


Figure 5 Dashboard for Speed and Wind direction with smart-MAC D105 [10]

Wind speed and wind direction sensors transmit information via the RS485 bus (figure 6). This interface is notable for its stable working at large distances, up to 100 meters. Through the RS485-1Wire interface, which comes in a box from smart-MAC only, the sensors are connected to the digital input (4) of the smart meter smart-MAC D105. Specify the colors of the wires in the description for the sensor. [10]

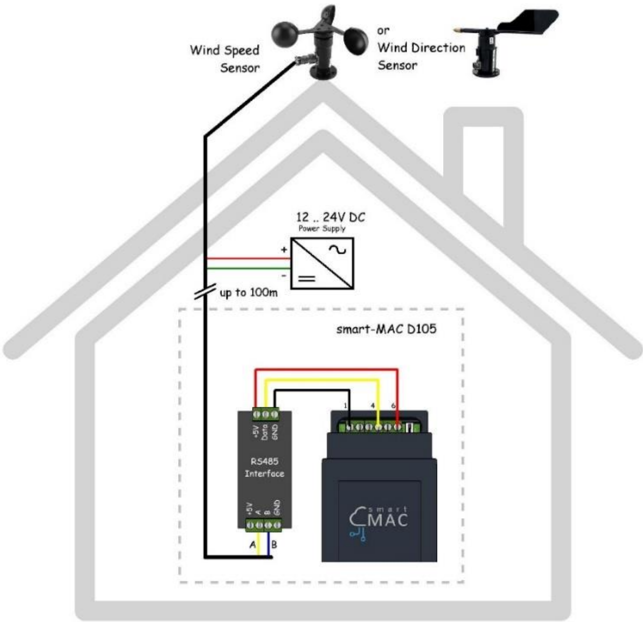


Figure 6 Sensors transmission information via the RS485 bus

2.2 Monitoring interface for Arduino modules

The monitoring system is created on the basis of "smart" devices of energy monitors of the Ukrainian company smart-MAC (https://smart-mac.com/) (Figure 7). All data obtained in the course of the monitoring process are available for viewing in real time on any device (PC, tablet, smartphone) and stored for further analysis in the cloud storage. The web application of the system makes it extremely convenient to present monitoring data with excellent visualization.

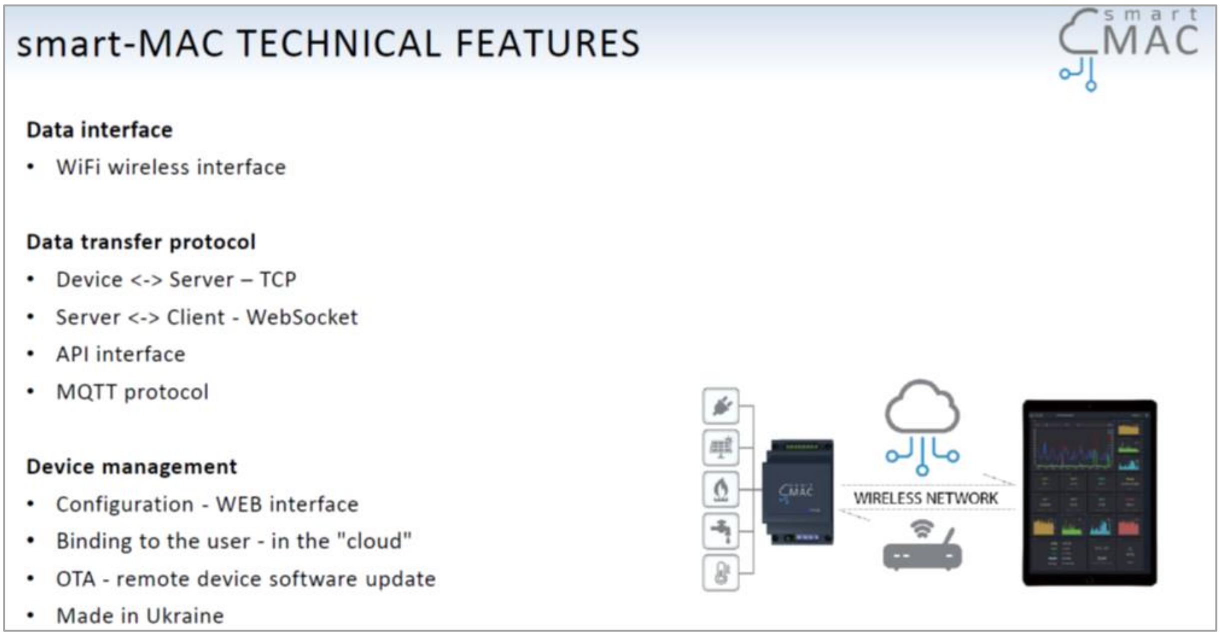
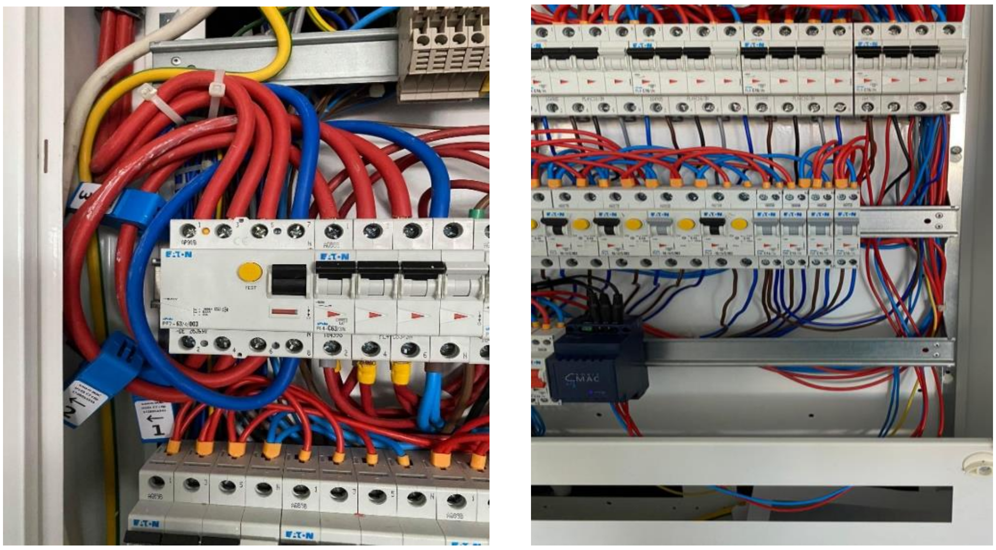


Figure 7 Smart-MAC system characteristics

The obtained data on actual energy consumption, after the installation of the pilot monitoring system, during the calendar year will allow to estimate the specific thermal characteristics of the building, determine the actual energy consumption to ensure regulatory microclimate in the building, assess the rationality and trends of energy consumption. Also, such data will help to assess the real effect after the implementation of energy efficiency measures to reduce energy consumption in university buildings.



a) b)

Figure 8 - Reconstruction of the electrical distribution cabinet

The pilot energy monitoring system for the university building is being deployed on the basis of the Department of Electric, Electronic and Computer Engineering of TUCN-NUCBM. The Department of Electric, Electronic and Computer Engineering occupies a third part of the academic building C of the university and is located on one floor of the building. Accordingly, based on the premises of the department it is possible to completely model the energy monitoring system, which can then be extended by analogy to other university buildings.

Installation of Building Management System (BMS) will allow to maintain a balanced energy consumption through detection of electricity consumption, temperature losses, monitoring of utilities and data storage on each area where are installing the sensors, and also, calculating the specific consumption much more accurately;

Figure 9 - Display of energy consumption and microclimate parameters

D103 smart-MAC power monitors with clip-on current transformers (figure 8) were used to monitor electricity consumption. Structurally, the energy monitors were placed in plastic switchboards and connected to a Wi-Fi network for remote data transmission. The display of energy consumption and microclimate parameters and analysis of the collected data is performed in the web application of the energy monitoring system, which is supported by the manufacturer - smart-MAC company. For each room and node of energy consumption measurement its own page in the web application with digital and graphic representation of character of the current data of energy consumption and change of energy consumption during observation time (figure 9-12) is developed.

Figure 10 - Display of energy consumption and microclimate parameters

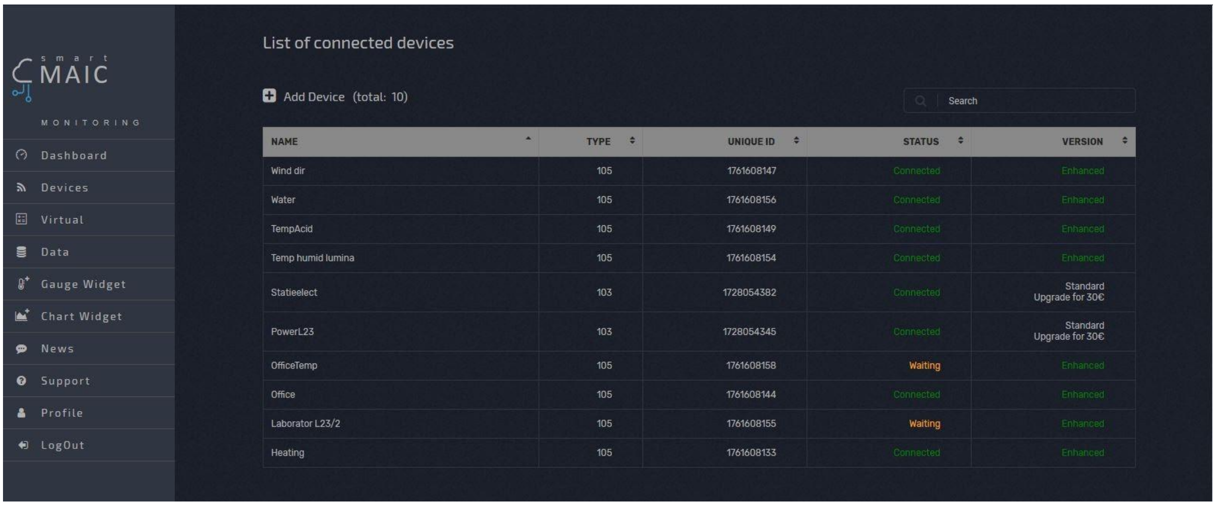
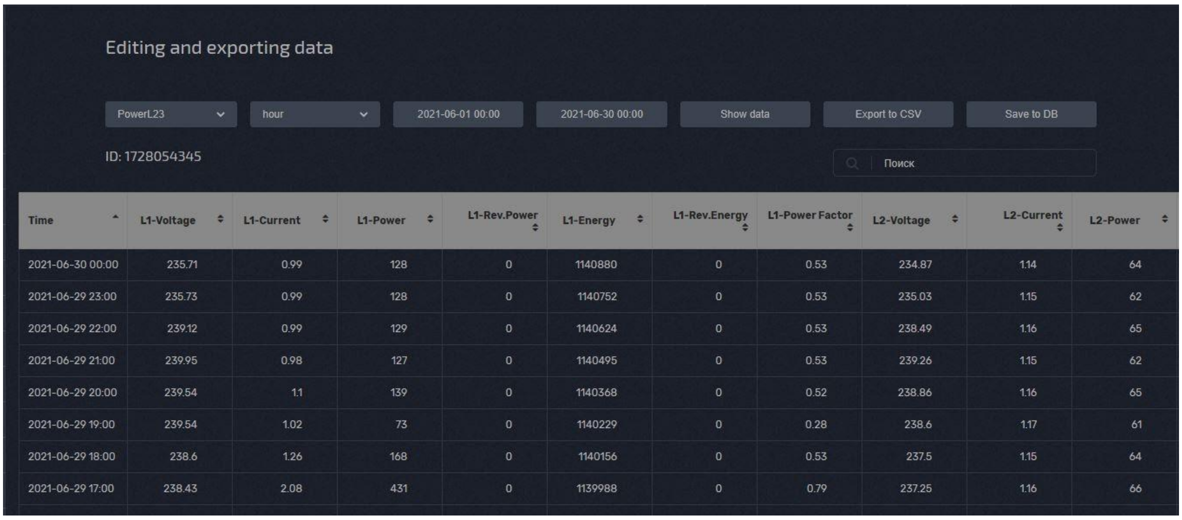


Figure 11 – Setting the devices which are monitoring in Dashboard



Editing and exporting data

PowerL23 | hour | 2021-06-01 00:00 | 2021-06-30 00:00 | Show data | Export to CSV | Save to DB

ID: 1728054345

Поиск

Time	L1-Voltage	L1-Current	L1-Power	L1-Rev.Power	L1-Energy	L1-Rev.Energy	L1-Power Factor	L2-Voltage	L2-Current	L2-Power
2021-06-30 00:00	235.71	0.99	128	0	1140880	0	0.53	234.87	1.14	64
2021-06-29 23:00	235.73	0.99	128	0	1140752	0	0.53	235.03	1.15	62
2021-06-29 22:00	239.12	0.99	129	0	1140624	0	0.53	238.49	1.16	65
2021-06-29 21:00	239.95	0.98	127	0	1140495	0	0.53	239.26	1.15	62
2021-06-29 20:00	239.54	1.1	139	0	1140368	0	0.52	238.86	1.16	65
2021-06-29 19:00	239.54	1.02	73	0	1140229	0	0.28	238.6	1.17	61
2021-06-29 18:00	238.6	1.26	168	0	1140156	0	0.53	237.5	1.15	64
2021-06-29 17:00	238.43	2.08	431	0	1139988	0	0.79	237.25	1.16	66

Figure 12 – Values of electrical parameters given by electricity module

3. Conclusion

Energy monitoring is necessary to keep track of energy consumption according to the season, weather conditions and the flow of use of electrical appliances in the institution. The universal WEB application smart-MAC Dashboard base on Arduino modules, to monitor the sensors give the main advantage for flexibly configure indicator and chart widgets and create an unlimited number of boards and devices connected to the same account.

The user is able to be flexible to configure indicator and graph widgets; create an unlimited number of cards and devices connected to the same account; provides easy monitoring of the sensors used; monitoring of sensors for reduce consumption and quite significant energy consumption costs.

Energy management in public institution depends by the control and monitoring of energy consumption and demands network sensors and dashboard to monitoring data acquisition from network create. After an analyze of date can be take measurements for efficiency use of energy in public institution.

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Study about integrating Industrial Internet of Things (IIoT) into compress air system

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Abstract

The study is presenting energy efficiency improvements related to a comprehensive compressed air system retrofit based on the Industry 4.0 concept. The project was motivated by potential energy savings and better compress air system performance, resulting in improved system reliability, reduced energy consumed by over 71,990 kWh annually, reduced maintenance cost by nearly $7,000 annually, and reduced electric utility bills by nearly $15,000 annually (a 12% savings). This project used Industrial Internet of Things (IIoT) approach to evaluate both the supply and demand sides of the compress air system, to develop the most comprehensive and cost-effective solution for providing high-quality compressed air to the manufacturing processes. The project contained several actions including piping retrofits, equipment upgrades, pressure control changes, software for compress air system and compressor retrofits. The study presents the digitalized Sigma Air Manager command and control solution for a compressed air system consisting of six compressors. Initially the six compressors had an inefficient independent operation and by implementing the digital Sigma Air Manager system the following improvements were obtained: control of the operating parameters of the compressed air system, reducing the idle operation of the compressors, power consumption optimization for the compressors, reducing maintenance costs, and automatic and real-time generation of energy efficiency charts and reports.

Keywords: Energy management, monitoring, Sigma Air Manager, energy efficiency

1. Introduction

Sigma Air Control is a visualization and data archiving system. It runs on Sigma Air Manager and saves data on a PC card hard disc. With the help of a PC and an internet browser it is possible to visualize current and archived data of the compressed air system such as system pressure, power consumption, costs, etc. All data can be displayed graphically and, in part, in tabular form, over a long period of time. This provides, in an easy way, an overall view of the behavior of the compressed air system. Because of the capability of Sigma Air Control plus to store data over the long term, it is possible to carry out compressed air audits efficiently. In the same way, the user can process and evaluate the information supplied by Sigma Air Control plus as required and draw on it for constant optimization of the compressed air system. A further Sigma Air Control plus specialty is that with the help of the internet browser all data archive sizes can be stored elsewhere in raw data format or in standard text format. This creates a high potential for further processing of data with the help of standard Microsoft tools, such as, for example, MS-Excel.

Compressors in multi-unit systems works on their individual control signals and are not well correlated. Energy is wasted by running more machines than necessary and at higher pressures than needed. Other problems include fluctuating pressure, as well as increased maintenance and repair costs due to excess valve cycling and motor starts.

Sigma Air Manager 4.0 ensures complete compressed air system management for industrial plants by connecting the compressors, blowers, or vacuum units together into a secure Sigma Network. SAM 4.0 can also balance load hours for more effective maintenance scheduling. The 3D advanced control optimizes pressure stability and system reliability, while the built-in Connect web server provides remote monitoring and ongoing energy audit information according to ISO 50001 the energy management system standard.

2. Description of current situation

Compressed air is used for the pneumatic system of production equipment in a manufacturing environment (max. Pressure 8 bar, rated pressure 8 bar, min. Pressure 5 bar).

The compressed air system consists of six Kaeser compressors (one ASD40 and 5 ASD37). These six compressors are interconnected and monitored through the Sigma Air Manager digital system.

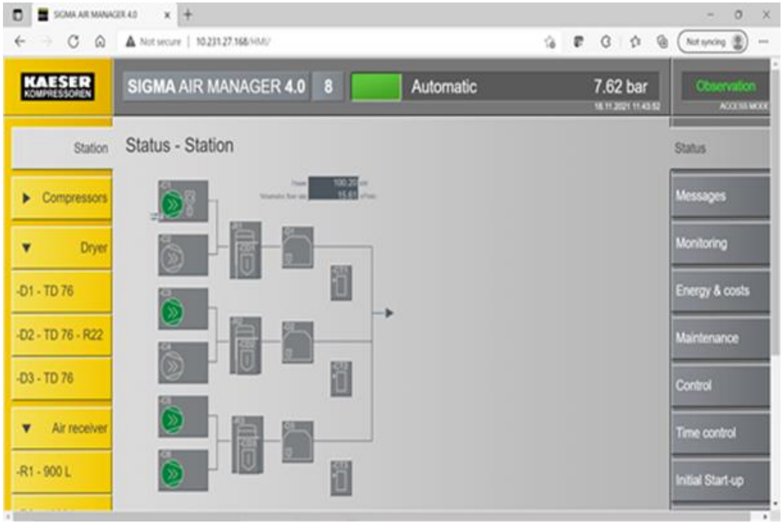

Figure 1 Compressed air system overview

Figure 2 Compressed air equipment's

Sigma Air Manager 4.0's pipework and instrumentation (P&I) flow diagram shows all the components in compressed air system. Data can also be displayed for subsequently installed equipment and is available in SAM 4.0. All of the connected components are visible and can be quickly identified via clear, individual, designation.

The live P&I diagram displays the following parameters:

- Operational status, alarm, and maintenance messages of individual components
- Flow rate
- Power
- Pressure
- Additional measurement signals, such as pressure, dew point, and ambient temperature can also be processed.

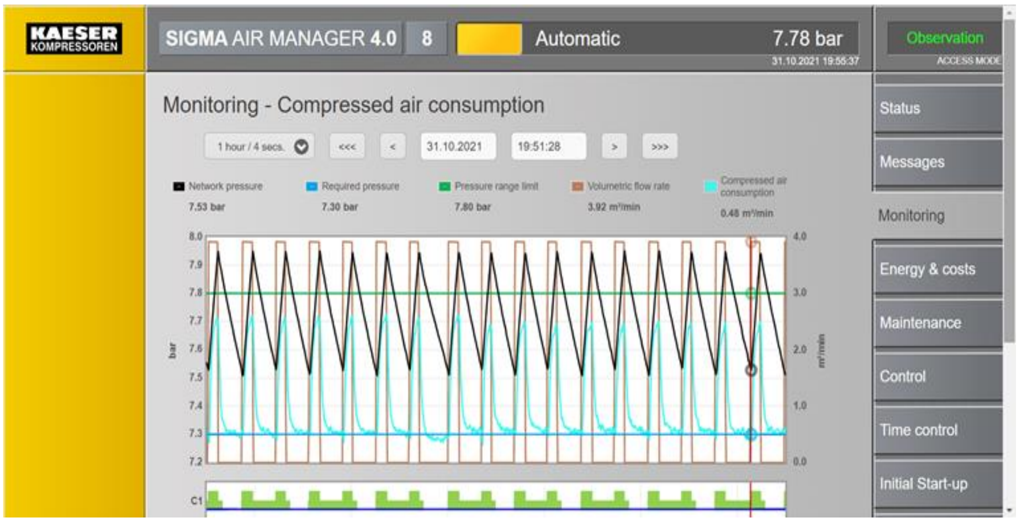

Figure 3 Compress air system in a live P&I diagram

Sigma Air Manager 4.0 allows to store and analyze all relevant energy related data from the compressed air supply, and then create specific energy performance reports.

To reduce both the environmental impacts and costs for the business, ISO 50001 outlines how businesses should systematically and continuously improve their energy efficiency and rewards them accordingly through tax incentives and renewable energy surcharge rebates where available.

The following information is provided:

- Performance figures for the compressed air system or individual components for energy management certification in accordance with ISO 50001
- Compressor load data, air delivery, performance, specific power
- Total costs
- Graphical display of cost overview (with the possibility of manually adding costs such as maintenance and repair)
- Operating data from the long-term memory for measuring signals (over an elapsed period of up to one year)
- Energy cost settings
- • Compressed air performance figures up to 6 years. Furthermore, a report can also be sent to a user defined e-mail address.

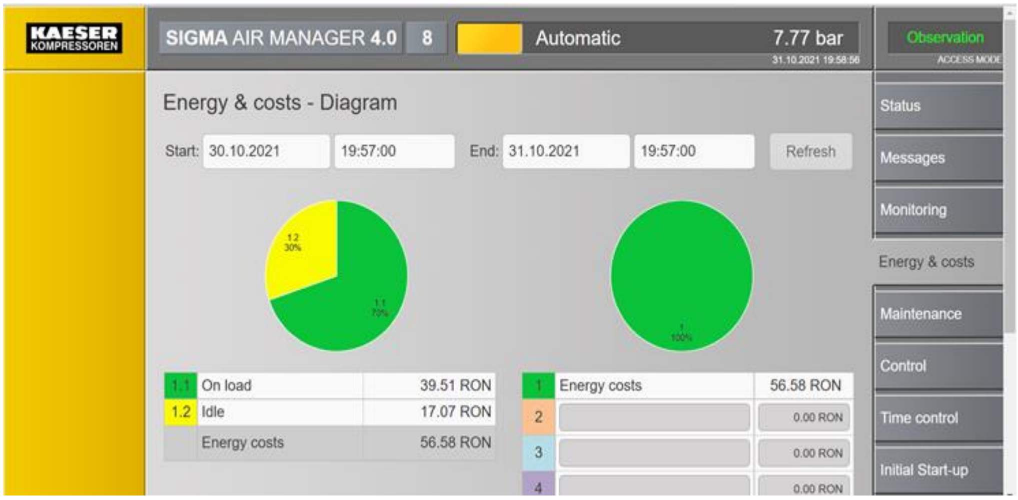

Figure 4 Real-time energy reports

With the installation of SAM 4.0 where obtained the following improvements:

System Parameters	Results obtained
Annual Energy Cost	49,492 $
Peak Power	95.97 kW
System Specific Power	19.21 kW / 100 cfm
Equipment Cost	62,500 $
Annual Parts Cost	1,610 $

3. Operation of sigma air manager

It is specially adapted industrial PC with powerful "Quad Core" processor, featuring an operating panel, control, and processing unit, communications interfaces, and integrated web server, Sigma Network ports, digital and analog input and output signals.

Sigma air manager has an intuitive operation, LED-backlit 12.1-inch TFT, 16:10 ratio industrial color display with capacitive touch technology. 1280 x 800 pixel resolution, four LED backlit touch keys, RFID read / write device for Equipment Cards and RFID keys. 30 selectable languages.

The communication interface has a Gigabit Ethernet for remote visualization (web server), e-mail, slot for communications module (for connecting to control center), SD HC/XC card slot (e.g. for updates).

The control cabinet is from stainless steel for wall mounting, dust and splash proof to IP 54, CE, cULus, international radio licenses.

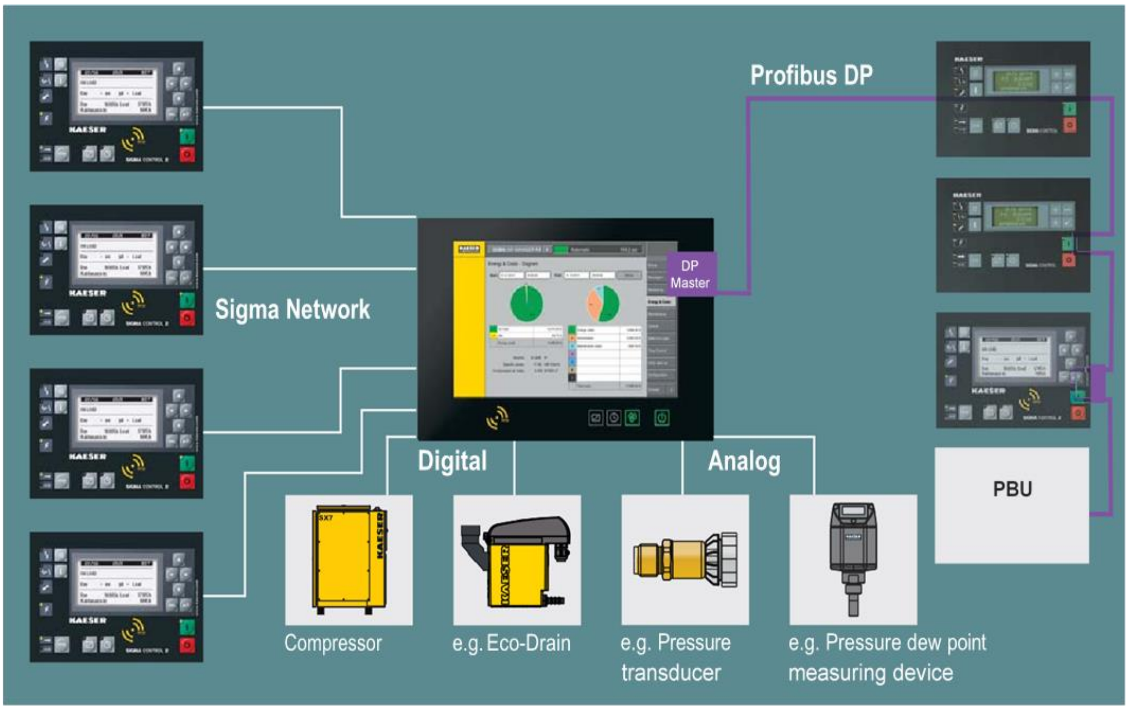

Figure 5 Compressed air system with Sigma Air Manager 4.0

Technical Specifications

	SAM 4.0 - 4	SAM 4.0 - 8	SAM 4.0 - 16
Pressure Control			
Adaptive 3D*advanced* Control	Standard		
Possible air system interconnections			
Maximum number of controllable compressors	4	8	16
Compressors with Sigma Control 2 via Sigma Network	4	7	7
SNW Port RJ 45	Standard: 7 ports		
Available input signals			
Digital 24V DC (e.g. Eco-Drain, compressors without Sigma Control, remote On-Off)	6		
Analog 4-20 mA (e.g. Pressure dewpoint measuring device, pressure transducer)	4		
Available output signals			
Relay outputs (e.g. third party compressors, compressors with Sigma Control Basic, group alarm)	5		
Equipment			
Visualization via integrated web server	Standard		
Operating data long-term memory 1 year	Standard		
Pressure transducer	Standard		
Communications interfaces			
Gigabit Ethernet for remote visualization (web server)	Standard		
Slot for communications module (e.g. Profibus DP, Profinet IO, Modbus TCP)	Standard		
SD HC/XC card slot (e.g. updates)	Standard		
Plug in Profibus DP, Profinet IO, Modbus TCP, EtherNet/IP communications adapter	Option		
Dimensions, weight			
W x D x H (in.)	$21^{1}/_{4}$ x $11^{3}/_{16}$ x 19		
Weight (lbs.)	44.1		

The component parts of sigma air manager:

Sigma Network - System components can easily be connected to the secure Sigma Network.

Upgrade compressed air system - A simple software upgrade allows to expand the control capability. There's no need to change master controller hardware.

3D advanced control - Monitors and controls compressed air system operation and proactively calculates the most efficient performance solution from numerous potential options.

Sigma smart air - The unique combination of remote diagnostics and service ensures supply dependability and significant cost savings.

RFID access - The integrated RFID interface ensures secure login for authorized personnel— without the need for passwords.

Live P&I diagram - The entire system shown as a P&I diagram on a 12”, color touch screen display.

Industrial Internet of things (IIoT) - Real-time data exchange enables continuous energy and cost optimization for efficient plant operation.

Energy Management per ISO 50001 - SAM 4.0 generates reports in accordance with ISO 50001.

SAM 4.0 Logic - Individually programmable, system- specific functions, for example the temperature dependent control of inlet, circulation, and exhaust air vents, can be implemented using this planning tool, without the need for additional PLC's.

Connect network - All operational and energy consumption data, as well as cost information, can be called up on any network-compatible device anytime, anywhere.

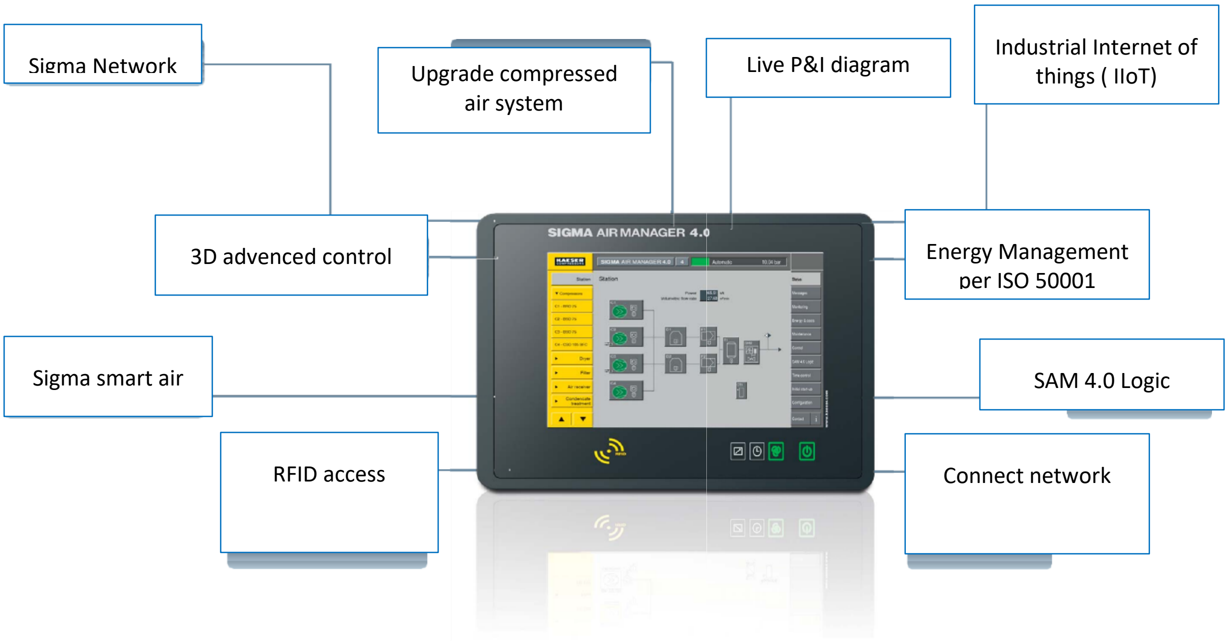

Figure 6 Component parts of Sigma Air Manager

4. Results

The digital solution Sigma Air Manager was implemented for a compressed air system consisting of six compressors. In the previous situation the six compressors had an independent operation that was energy inefficient and by implementing Sigma Air Manager the following results were obtained:

- compressed air system connected and integrated by the digital Sigma Air Manager solution
- digital recording and control of the operating parameters of the compressed air system
- real-time viewing of energy efficiency charts and reports
- reduced energy consumed by over 71,990 kWh annually
- reduced maintenance cost by nearly $7,000 annually
- reduced electric utility bills by nearly $15,000 annually (a 12% savings)
- reduce idle operation of the compress air system by 33%

Sigma Air Manager digital solution ensures the integration of the Industrial Internet of Things (IIoT) concept into compress air system operation and energy improvement measures to achieve business sustainability and meet the requirements for Industry 4.0.

Table1: Power consumption for compress air system from 2020

Start:	01.01.2020	0:00	**End:**	31.12.2020	0:00		
		Power consumption/kWh			Energy costs /RON		
Compressors:		On load	Idle	Total	On load	Idle	Total
C1		157031.61	1012.10	158043.71	36117.27	232.78	36350.05
C2		86319.23	4123.63	90442.86	19853.42	948.44	20801.86
C3		127246.05	1451.81	128697.86	29266.59	333.92	29600.51
C4		85821.05	3889.89	89710.94	19738.84	894.68	20633.52
C5		37476.29	1291.46	38767.75	8619.55	297.04	8916.59
C6		57875.76	2383.9	60259.66	13311.42	548.30	13859.72
Compressed air generation		551769.99	14152.79	565922.78	126907.09	3255.16	130162.25
Total		551769.99	14152.79	565922.78	126907.09	3255.16	130162.25

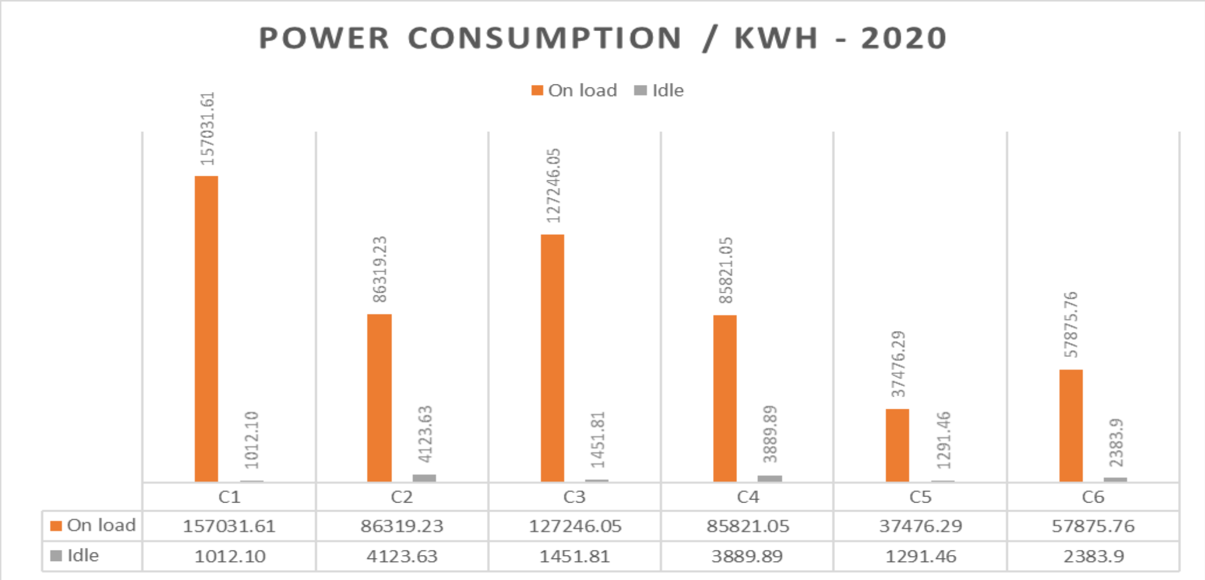

Figure 7 Compress air system power consumption (kWh) for 2020

Table 2: Power consumption for compress air system from 2019

Start: 06.02.2019	1:00	**End:**	31.12.2019	0:00		
	Power consumption/kWh			Energy costs /RON		
Compressors:	On load	Idle	Total	On load	Idle	Total
C1	137323.07	1211.17	138534.24	31584.31	278.57	31862.88
C2	97526.61	3304.94	100831.55	22431.12	760.14	23191.26
C3	81973.29	2270.17	84243.46	18853.86	522.14	19376.00
C4	97760.59	3212.10	100972.69	22484.94	738.78	23223.72
C5	9603.62	1233.37	10836.99	2208.83	283.67	2492.50
C6	80626.34	1869.55	82495.89	18544.06	430.00	18974.06
Compressed air generation	504813.52	13101.30	517914.82	116107.12	3013.30	119120.42
Total	504813.52	13101.30	517914.82	116107.12	3013.30	119120.42

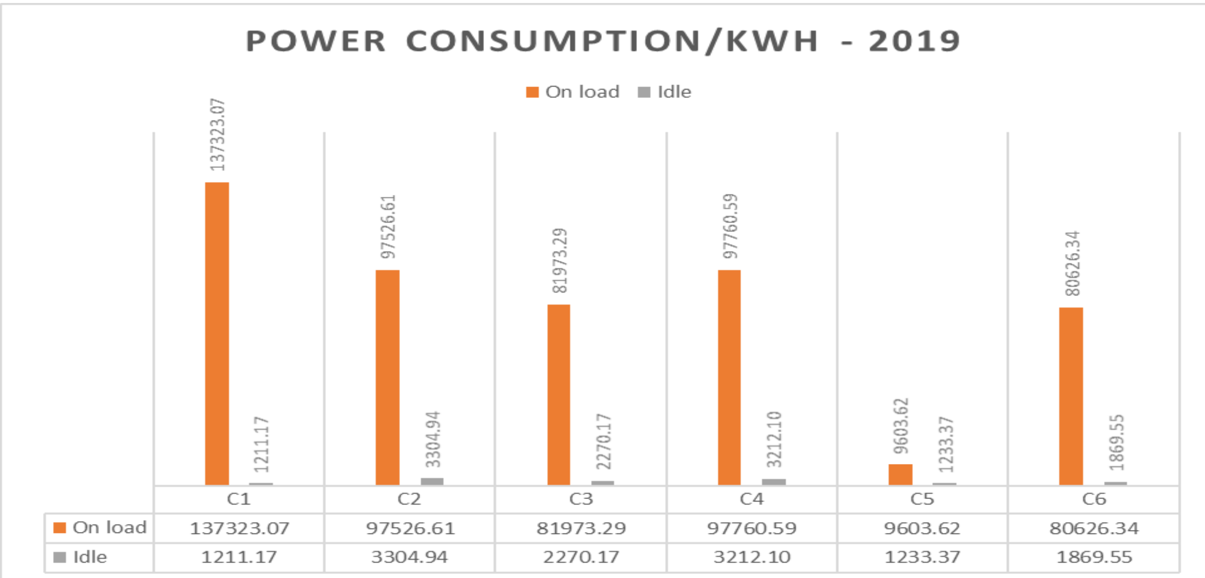

Figure 8 Compress air system power consumption (kWh) for 2019

5. Conclusion

This case study paper described a digital compressed air system command and control solution for energy efficiency improvement and business sustainability based on Industry 4.0 concept. This project used a system approach to evaluate and implement changes on the supply side and demand side of the compress air system to improve the compressed air system efficiency, rather than focusing on one or two specific components.

The result was an annual energy savings of 12% of the baseline system electricity use, which reduced the annual utility cost by $15,000 annually.

Additionally, the compress air system maintenance cost was reduced by nearly $7,000 annually. The project simple payback was just under 3 years; the Net Present Value of the project was nearly $30,000.

In conclusion, using a digital system approach when improving a compressed air system can lead to higher overall energy and maintenance savings by considering the interaction between components rather than simply implementing the energy efficiency measures that have low simple payback periods when considered individually. The interaction of potential measures should be considered to guarantee that individual measures will provide the stated benefits and economic viability that are expected. This digital system approach can and should be applied to other energy consuming systems in industrial and commercial facilities, such as pump systems, fan systems, process heating systems, steam systems, and HVAC systems.

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POSSIBILITIES OF UTILIZING SOLAR ENERGY

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Abstract

Nowadays the utilization of solar energy is not just an environmental but an economic question as well. Solar power systems are more efficient and have longer operating period than any time before due to the engineering developments in the past few decades. At recent times the only barriers for implementing a solar power system are the investment cost, payback time and the expected savings or even profit. To compensate the rather high investment costs governments often offer financial incentives to encourage private or corporate investments. Payback time highly depends on the chosen system features and the local environmental conditions. The savings are even a more complex question because we not only need an in-depth knowledge of the system and the environment but of metering and billing regulations and possibilities.

Keywords: solar power systems, renewable energy sources,

JEL Classification: "O" – Economic Development, Innovation, Technological Change, and Growth

1. Introduction

Nowadays the utilization of solar energy is not just an environmental but an economic question as well. Solar power systems are more efficient and have longer operating period than any time before due to the engineering developments in the past few decades. At recent times the only barriers for implementing a solar power system are the investment cost, payback time and the expected savings or even profit. To compensate the rather high investment costs governments often offer financial incentives to encourage private or corporate investments. Payback time highly depends on the chosen system features and the local environmental conditions. The savings are even a more complex question because we not only need an in-depth knowledge of the system and the environment but of metering and billing regulations and possibilities.

1.1 Trends

The energy which is the basic need of society is produced by two sources: non-renewable (its volume is constantly decreasing due to production) and renewable energy sources (it can be utilized sustainably).

Energy gained from non-renewable sources are the most common ones. Nowadays mainly fossil fuels are used, which are the coal, natural gas and oil. These type of energy sources also renews over a long period of time as the process of hydrocarbon formation is permanent. If the production capacity is higher of them than the regeneration capacity they can be depleted, which is the case in the past few decades.

This three type of non-renewables (coal, natural gas, oil) covered the ¾ of the world energy demand, respectively (Sembery-Tóth, 2004):

- 29% - power plant burning, fuels
- 22% - propellants, fuels
- 39% - propellants, fuels, lubricants, petrochemical products

This extended use of fossil fuels can cause the depletion of remaining reserves and also side products from burning, such as CO2, CO and SOx cause extensive air pollution and contributes to global climate change.

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In Figure 1 the world primary energy production trend can be seen, where the above described facts can be recognized, namely that the non-renewable energy production is more dominant than the renewable energy production. It is self-evident that the total energy production is constantly growing from 1980 due to the increasing demand. Only in recent years the total production slightly decreased because of the reduction in coal production but today the coal production has reached its previous capacity. The contribution of renewable energy production (with nuclear energy) to the total energy production is constantly growing with an average yearly increase 15.7%.

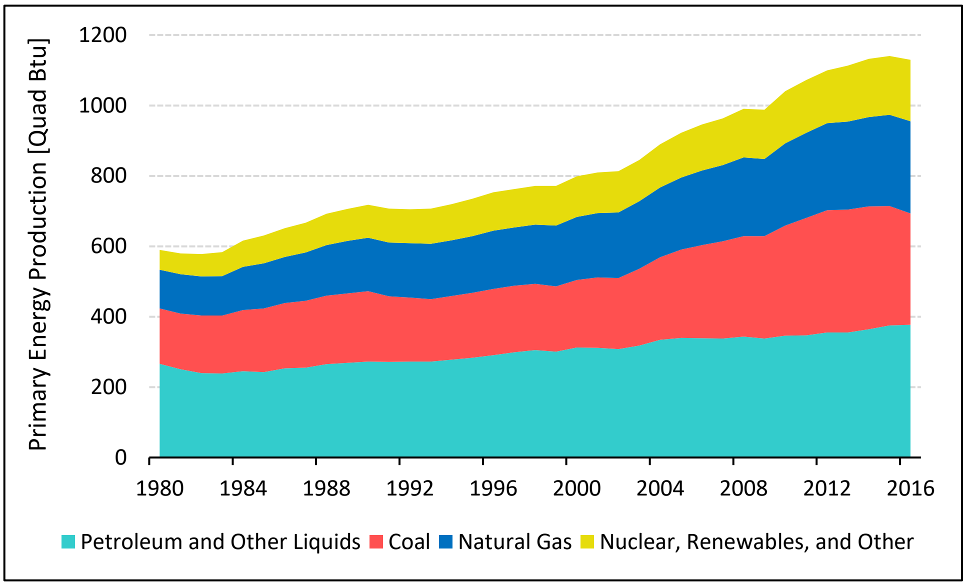

Figure 1 World Primary Energy Production by Source

Source: eia.gov

1.2 European Union Trends

The European Union set ambitious targets for decreasing the greenhouse gas (GHG) emission: its goal is to decrease the GHG emission by 40% (compared to 1990's value) and by the middle of the century this ratio will reach the 80-95%. For this purpose, the EU introduced several schedules which describe the decarbonisation possibilities of the EU's economy. Climate change is not the only reason why the European energy system needs major changes. Security of supply, increasing energy imports, growing integration of European markets and keeping European energy prices at the right level poses a serious challenge (Stefan et al., 2016).

28 European countries set a 2020 energy target which has been reached by 11 countries at 2016. This approach can be seen in **Figure 2.**

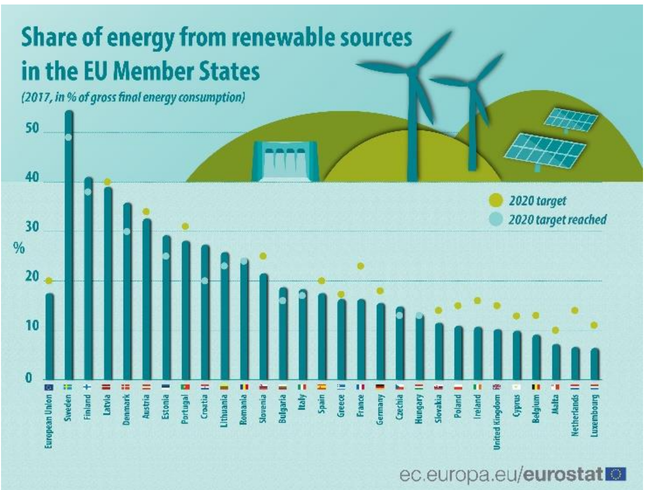

Figure 2 Share of Energy from renewable Sources in the EU Member States

Source: eurostat.com

The European Union's target is 20% share of renewable energy consumption. Hungary belongs to those 11 countries who already met its target and reached its 2020 goal which was a 13% share. Individual member states have set wildly varying targets in their respective national action plans, for example Latvia has not reached its own 40% but already reached 37.2% at the end of 2016. Due to this plan the primary energy production of the EU-28 has been changed drastically.

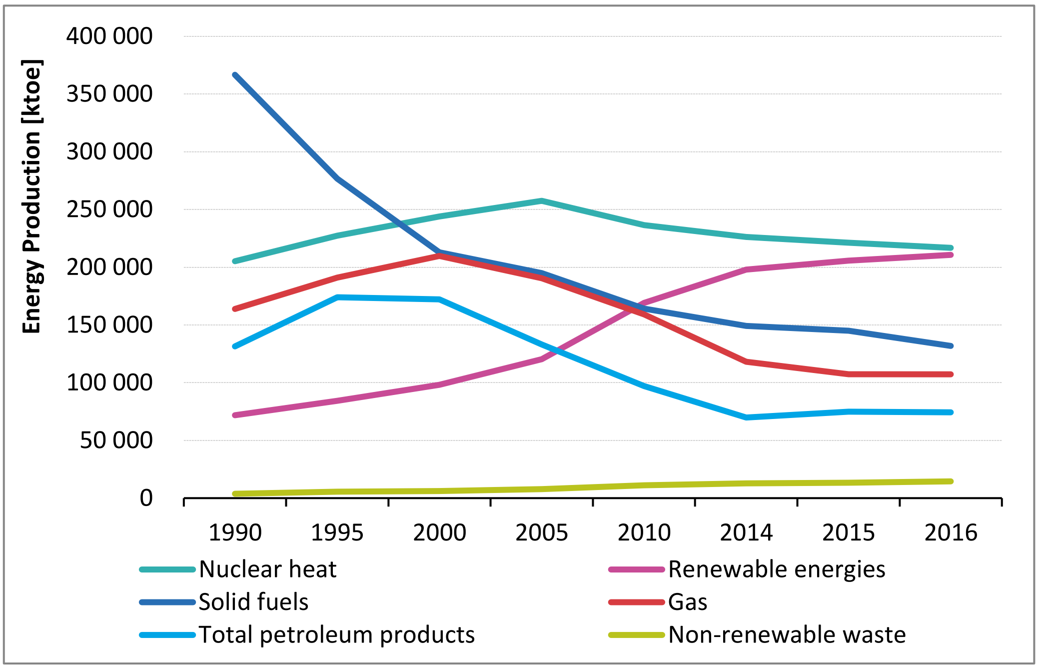

Figure 3 Primary energy production by fuel, EU-28, in selected years, 1990-2016

Figure 3 shows that the solid fuel production, such as coal has been reducing significantly from 1990. In 2016 it was only the 36% of the 1990's production capacity. The production of other types also decreased during the few decades in the EU-28 countries, namely: total petroleum products (2016's production was 57% of the 1990's production capacity), gas (2016's production was 65% of the 1990's production capacity). In this way the 2015 fossil fuel production of the European Union reaches the ½ of the production capacity of 1990 (and this value is still decreasing). Nuclear heat energy production capacity is slightly increased from 1990 to 2016, but it shows a permanent reduction from 2005. As the production of most energy sources has been decreased in the past few decades the missing capacity was replaced mostly by renewable energy sources. The production capacity of the EU almost triplicated from 1990 to 2016, making this fuel type dominant besides nuclear heat power.

1.3 Hungarian Trends

The primary energy production of Hungary has been decreasing from 1980 due to depletion of hydrocarbon resources. To keep the energy dependency at a reasonable level Hungary's energy policy has been changed in the past few years. Primary energy consumption also decreased from 1980 (but with a milder pace) slowing down the growing energy dependency. The country own production covered the 45% of the consumption in 1980, while in 2016 this index was only 37% (**Figure 4**). To keep the balance and meet the European Union's requirements the country increased its renewable energy utilization.

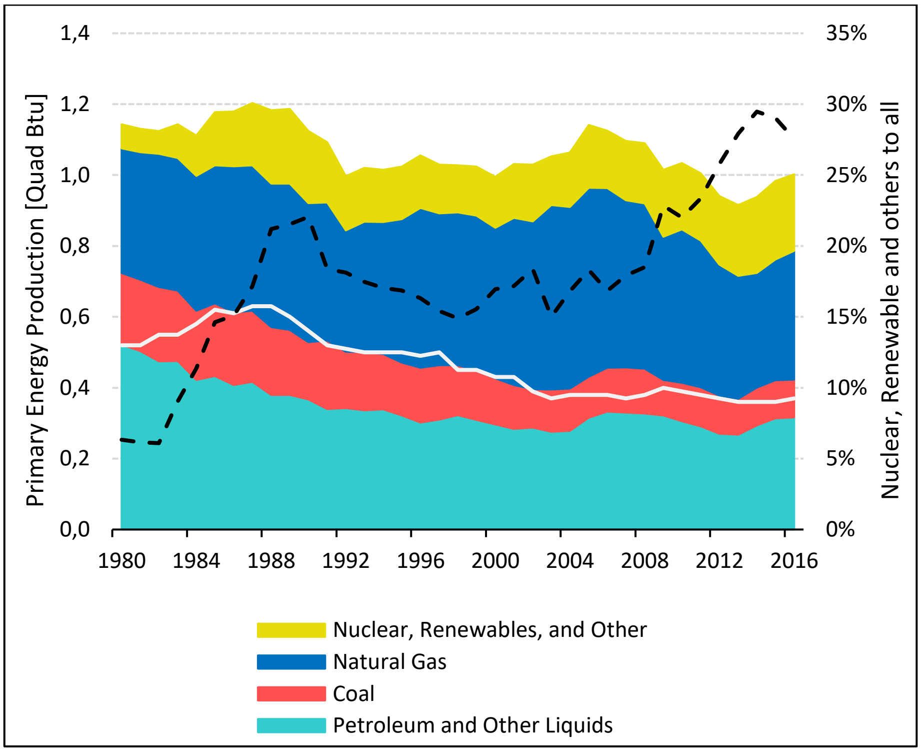

Figure 4 Hungary Primary Energy Consumption and Production by Source

Source: eia.gov

The energy consumption by source is shown on the **Figure 3** with a cumulated graph, while the total production with a light grey line. It indicates that the energy dependency constantly growing but the growing share of renewable energy utilization (black dashed line) slowing down this trend. The share of renewable energy consumption to all primary energy consumption grow from a 5% value (1980) to almost the 30% value (2016), but this also contained the nuclear energy consumption. **Figure 5** shows that the renewable electricity production (without nuclear energy) had a reasonable share only at 2004, with a 2.3% and reaches the 7.6% at 2017.

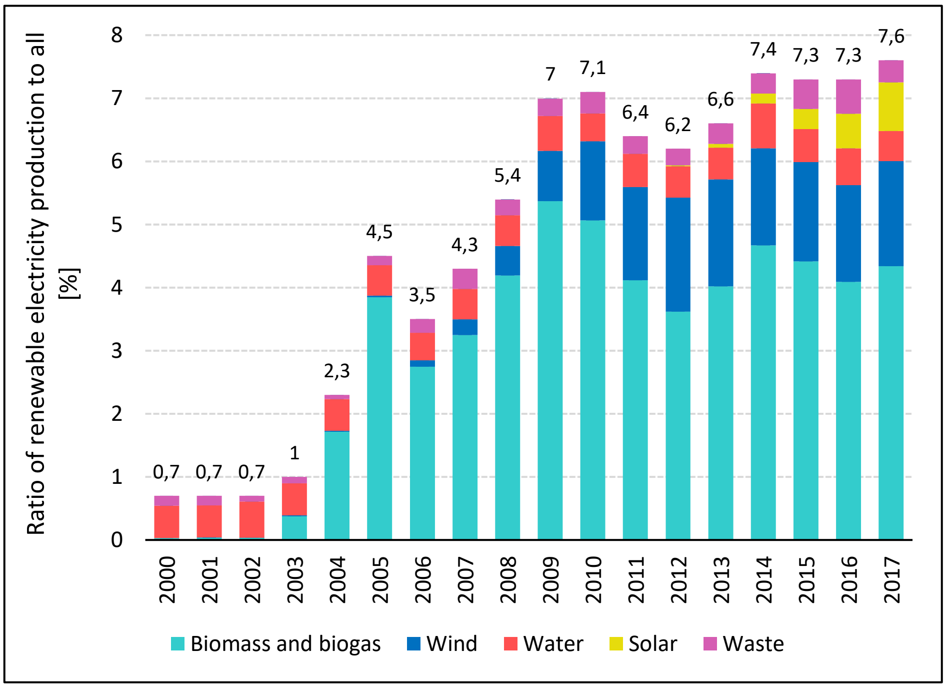

Figure 5 Ratio of Electricity Production from Renewable Sources in Hungary

Source: ksh.hu

The electricity production utilizing solar source only appeared in 2012 and has been significantly growing since then. Electricity generation from photovoltaic technology in Hungary shows an exponential growing since 2012 (**Figure 6**), due to the above mentioned economic and environmental goals and regulations.

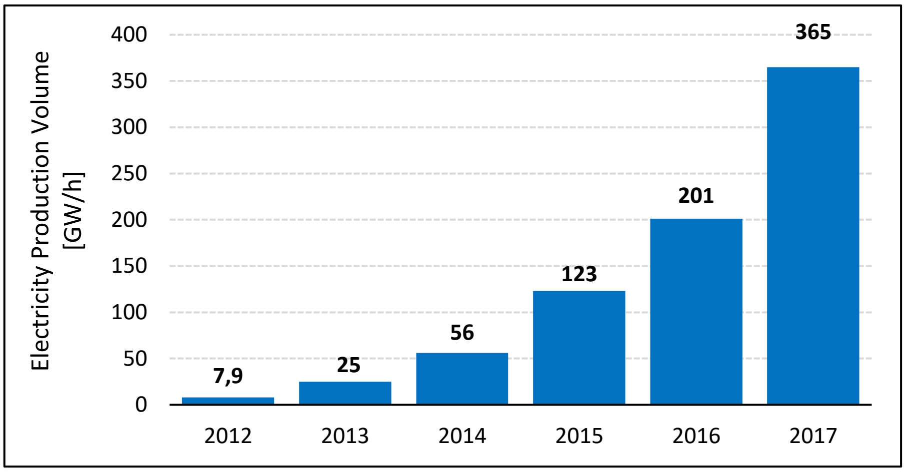

Figure 6 Electricity Production Volume from Solar Photovoltaic Power in Hungary

Source: statista.com

It is self-evident from this chapter that the World including Hungary makes powerful efforts to increase the renewable energy utilization and solar power generation has a growing role in this process.

2. Solar Energy

Solar energy is our most abundant renewable energy source. Solar energy is generated by nuclear fusion processes in the Sun, part of which is scattered by radiation in the surrounding space. The Sun radiates as much energy to the Earth every 20 minutes as all humanity uses in a year which means a 50 billion kWh in each second. The solar radiation power is 4×10^{23} kW, of which the share of land surface is 173×10^{12} kW. The perpendicular radiation to the Earth atmosphere is about 1 353 W/m^2, this is called *solar constant* (Iqbal, 1983). During the penetration in the atmosphere part of this power losses, so the terrestrial radiation power is maximum 1 000 W/m^2. A suggested approximation is that the radiation that reaches the surface is the 51% of the radiation on the atmosphere. It composed of 33% direct radiation and 18% of scattered radiation. 10% reflected back by the surface so the product of them is 41%.

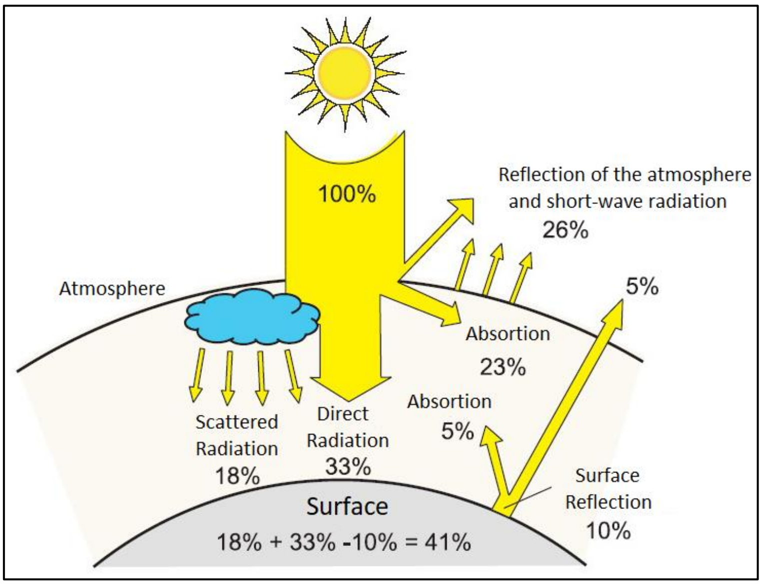

Figure 7 Surface Energy Balance of Solar Radiation

Source: Rodek, 2012

The degree of irradiation depends on the weather conditions (less radiation reaches the surface in cloudy, humid weather) and the latitude (near the equator the level of irradiation is greater). In the figure below the average irradiation of Hungary can be seen (2000-2009).

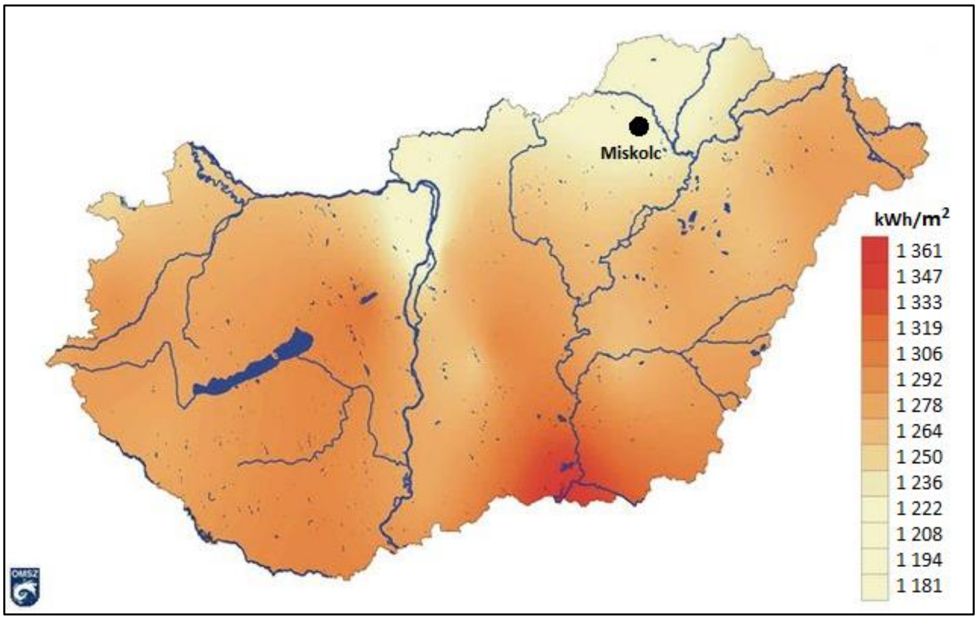

Figure 8 The Average Irradiation of Hungary

Source met.hu

It is obvious from **Figure 8** that the investigated region (Miskolc) is not placed at the best location in point of solar irradiation.

2.1 Utilization

The most widespread use of solar energy can be divided into two main groups, **indirect** and **direct**.

Indirect utilization is the case when the solar energy appears in different form of natural phenomena, like wind energy, marine energy, warming the atmosphere and surface and the natural cycle of water.

The direct utilization can be divided into two groups as well, **active** and **passive**.

- The active, direct utilization when the solar energy is converted to heat or electricity with a special equipment (solar collector, solar panel).
- The passive, direct utilization is considered when the solar energy is utilized directly without any equipment (passive house).

In the following chapters the solar panel technology is detailed as this is the core topic of this study.

2.2 Solar Panels

Solar panels or in other name photovoltaic cell (PV-cell), utilize the solar energy as it produces electricity from it with the *photoelectric effect*.

"*Photoelectric effect*, phenomenon in which electrically charged particles are released from or within a material when it absorbs electromagnetic radiation." (Gregersen, 2019)

Brief History: In 1839 Becquerel discovered the photovoltaic effect. Later Adams and Day observed the photovoltaic effect in solid Selenium (Singh, 2013). The first photovoltaic cell was developed by Fritz in 1883 and its efficiency was less than 1% (Zweibel-Herch, 1984). Albert Einstein published a paper about photovoltaic effect in 1904 for which the Nobel Prize was awarded. In 1927, a new type of photovoltaic cell was developed using copper and semiconductor copper oxide. This device also had an efficiency of less than 1%. Ohl in 1941 developed the silicon photovoltaic cell. Further refinement of the silicon photovoltaic cell enabled researcher to obtain 6% efficiency in direct sunlight that was further increased to 11% by Bell laboratories in 1954 (Singh, 2013). In 1958, the Vanguard satellite employed the first practical photovoltaic generator producing a modest 1W. Later during the space program, the technology was highly investigated and developed (in this era the money for research was not an issue). After this period the high energy demand and the need for green energy sources accelerated the further development of the technology.

Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon. Most of (90%) of solar panels consist of thin silicon inserts applied to a variety of carrier surfaces, providing rigidity. Silicon solar cells typically have two layers: a positive layer (p-type) with electron deficiency and a negative layer (n-type) with electron surplus. When the light-forming photons collide with an atom that has an electron surplus, the flow starts and the DC current flows in the closed network, **Figure 9** The produced electricity is with direct current (DC) and it can be stored in battery or converted to alternating current (AC) with an inverter and feed back to the grid.

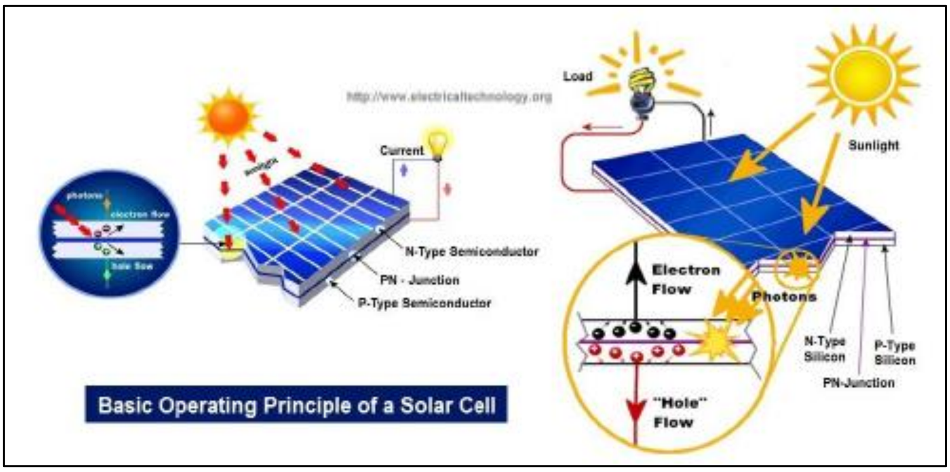

Figure 9 Working Principal of Solar Cells
Source: Sreega et al., 2017

2.3 Types of PV Cells

There are a wide range of PV cell technologies on the market today, using different types of materials, and an even larger number will be available in the future. PV cell technologies are usually classified into three generations, depending on the basic material used and the level of commercial maturity (Ranabhat, 2016).

First generation: Bell Laboratories developed the first silicon solar cell in 1954 with an efficiency of 6% (later improved to 11%). The earliest commercial solar cells are made from silicon, are currently the most efficient solar cells available for residential use and account for around above 80% of all the solar panels sold around the world. Silicon solar cells are the most efficient in terms of single cell photovoltaic devices, and silicon is the most abundant element on earth, only second to oxygen. It is a semiconductor material suitable for PV applications. Crystalline silicon cells are classified into three main types depending on how the Si wafers are made. The types are based on the type of silicon used, specifically:

- Monocrystalline
- Polycrystalline
- Amorphous Silicon Cell

Second generation solar cells are also known as thin-film solar cells because when compared to crystalline silicon based cells they are made from layers only a few micrometers thick. Second generation of solar cells they account around 20 % of the total panels sold in past year. There are basically three primary types of thin film solar cells that have been commercially developed:

- Amorphous silicon
- Cadmium Telluride
- Copper-Indium-Selenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS)

Third generation solar cells are inherently different from the previous two generations because they do not rely on the p-n junction design of the others. This new generation of solar cells are being made from variety of new materials besides silicon, including nanomaterials, silicon wires, solar inks using conventional printing press technologies, organic dyes, and conductive plastics. Types which are commercially available or expected to be available are:

- Dye sensitized (DSSC)
- Perovskite
- Organic (OPV)

The efficiencies can be identified on **Figure 10** where the Shockley-Queisser limit is a theoretical maximum efficiency that can be achieved a typical single-junction silicon solar cell.

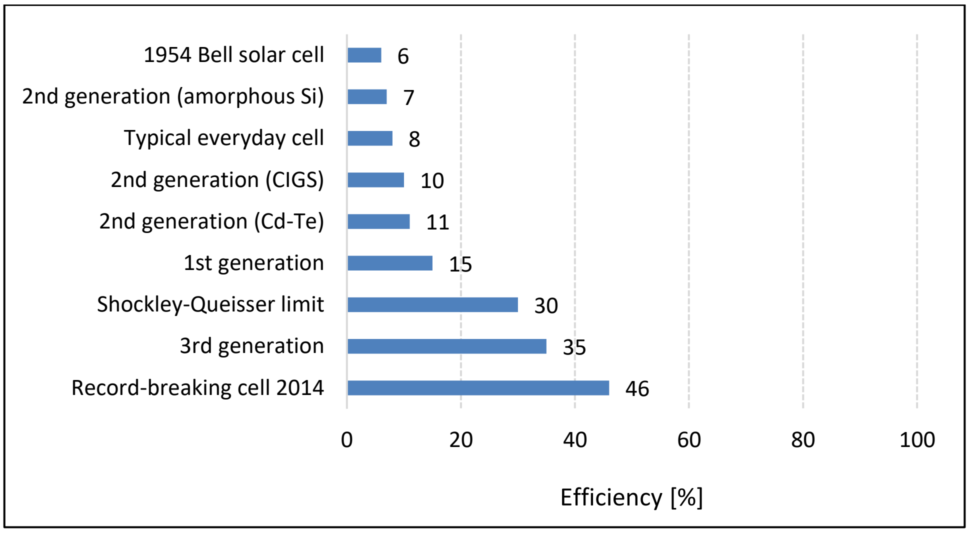

Figure 10 Efficiencies of solar cells

Source: Woodford, 2018

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.

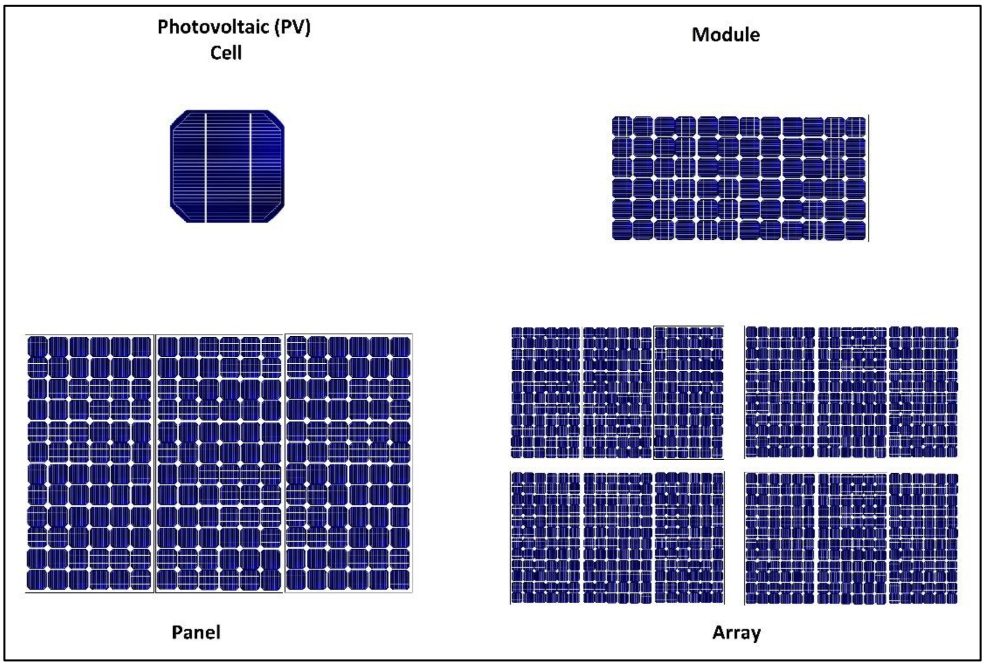

Figure 11 Photovoltaic cells, modules, panels and arrays

Source: Lacho-Dimi, 2015

In order to produce more power photovoltaic panels can be connected in series or in parallel.

A set of PV panels connecting in **series** is knowing as “string”. Solar panels are connected in series in order to obtain higher voltage. (If among panels connected in series a module has rated power lower than the rated power of the other panels, then that panel will drag down the output of the whole system)

Solar panels are connected in **parallel** in order to obtain higher output current. (If among panels connected in parallel there is a panel with lower power output it will not seriously affect the total output of the system)

3. Solar Power Systems

In case of a complete project there are a lot of different arrangements available which involve different components (often summarized as balance of system – BOS). A chosen arrangement can have a serious economic effect on the final project as well as a single component. The right selection of the basic types of the system and the appropriate equipment are indispensable. In this chapter the fundamental elements are detailed then the basic arrangements are presented.

3.1 Components

Besides solar array various different components are necessary for a proper solar power system. There are essential ones which do not depend on the different systems, there are system specific components and there are components which can optimize or maximize the system performance.

a) Mounting system

PV mounting systems (or solar module racking) are an essential part of the system that are used to fix the solar panels on different surfaces like on the ground, building facades or roofs.

1. **Ground-mounted** PV systems are usually large, utility-scale photovoltaic power stations. The PV arrays held in place by racks or frames that are attached to ground-based mounting supports, which are the followings (Pickerel, 2017a):
    - Pole mounts, are driven directly into the ground or embedded in concrete
    - Foundation mounts, such as prefabricated concrete slabs or poured footings
    - Ballasted footing mounts, such as concrete or steel bases that use weight to secure the solar module system in position and do not require ground penetration.

Table 1 Advantages and Disadvantages of Ground-mounted PV systems

Advantages	**Disadvantages**
Easy to access	Installation is more labor intensive
Easy to clean	Installation is more expensive
Easier to troubleshoot	Requires more parts and pieces
Stronger racking overall	Permitting process is more expensive
Not limited by the dimensions of the roof	Take up real estate
Cooler panel temperatures	Not aesthetically pleasing to everyone
No need to remove panels if roof is replaced	

Source: Johnston, 2018

2. **Roof-mounted** systems can be divided into two major groups according the mounting system is required for a sloped roof or a flat roof.
    - **Sloped roof mounting systems** are often required to residential installations. There are numerous mounting system options for these angled roofs, all of which require some kind of penetration or anchoring into the roof (Pickerel,2017b).
        - *Railed systems* attach the panel to two rails with clamps. The rails are installed to the roof by a type of bolt or screw with a watertight seal. (**Figure 12a**)

- *Rail-less systems* instead of attaching to rails, solar panels attach directly to hardware connected to the bolts/screws going into the roof. (**Figure 12b**)
- *Shared-rail systems* take two rows of solar panels normally attached to four rails and removes one rail, clamping the two rows of panels on a shared middle rail. (**Figure 12c**)
- *Ballasted and non-penetrating mounting systems* are essentially draped over the peak of a roof, distributing the system's weight on both sides of the roof. (**Figure 12d**)

Figure 12 Different Sloped Roof Mounting Systems

Source: Pickerel, 2017b

- **Flat roof mounting systems** often can be found on commercial and industrial environment such as on big-box stores or manufacturing plants. They can have a small tilt but not nearly as much as residential roofs. They are usually ballasted with few penetrations. As they are usually installed on large flat surfaces the installation process is quite easy and pre-assembled systems can be used as well. Most *ballasted mounting systems* for flat roofs use a "foot" as the base assembly. Panels are tilted at the best angle to capture the most sunlight. The amount of ballast needed is dependent on a roof's load limit. When a roof can't support a lot of extra weight, some penetrations may be needed. The best orientation for solar panels are the south (Barkaszi-Dunlop, 2001), if this is not possible than a so called *dual-tilt system* can be used.

Table 2 Advantages and Disadvantages of Roof-mounted PV systems

Advantages	Disadvantages
Less expensive	Hard to access
Requires fewer material to install	Harder to troubleshoot errors
Installation labor cost is lower	Higher panel temperatures
Utilizes unused space	Space constraints
Easier to permit	Remove panels if roof replaced
	Holes in your roof can lead water damage

Source: Johnston, 2018

b) Cabling

The interconnecting cable used in PV power generation is called the solar cable. Solar cables interconnect solar panels and other electrical components of a photovoltaic system. Solar cables are designed to be UV and weather resistant. They can be used within a large temperature range and are usually placed outside. As most of the PV systems are used outside, the cables and especially its insulation need to withstand high temperatures and UV radiation (due to exposure to sunlight) over a long period of time. The insulation should be sufficient against aging. The Arrhenius law for aging of polymers said that aging of polymers doubles for every 10°C rise (Maxwell et al., 2005).

c) Inverter

Photovoltaic solar panels generate direct current (DC) electricity. The produced electrical energy then can be:

- Used right away
- Stored in a battery
- Converted to alternating current (AC) electricity and then either used by home devices or exported to the utility grid

Nowadays the most common solution is the conversion of DC electricity to AC electricity. For this purpose, an equipment is used which converts the variable DC output from the solar panels into a utility frequency AC at the highest possible efficiency. This equipment is called the inverter. There are several types of inverters:

- **Standard String Inverter** is the most common type of inverters. It converts the DC electricity directly from solar panels to AC electricity.
- **Micro Inverter** is a small inverter which is installed on the back of each panel and converts the given panel DC output to AC. The required number of panels determines the number of inverters in this case.
- **Battery Inverter** is usually installed alongside a standard string inverter and a battery. The purpose of this type is to charge and discharge the electricity stored in a solar battery.
- **Hybrid Inverter** is the combination of the standard string inverter and the battery inverter. It is usually used when the option of implementing a battery later to the system is open.
- **Grid-Tie Inverter** is connected to the grid and allows to export any surplus electricity that the system has generated back into the grid at a given tariff (standard string inverters and hybrid inverters are usually grid-tie inverters as well).
- **Off Grid Inverter** is like standard string inverters except it does not have the ability to export excess solar electricity back to the grid.

d) Battery

Although still expensive, PV systems increasingly use rechargeable batteries to store a surplus to be later used at night. Batteries used for grid-storage also stabilize the electrical grid by leveling out peak loads, and play an important role in a smart grid, as they can charge during periods of low demand and feed their stored energy into the grid when demand is high.

The lithium-ion based batteries are the most common type nowadays. Without the description of the working mechanism of the different types only the most common types are listed:

- **Lithium Cobalt Oxide (LCO)** batteries are the most popular choice for phones and laptops as they are very stable and small compared to others. The short life cycle and limited load capabilities do not make the best choice for larger energy storage application, such as solar power systems.
- **Lithium Manganese Oxide (LMO)** batteries are typical type for medical devices and power tools because of fast-charging properties and increased thermal stability, which is able because the lack of cobalt. An example is the Sharp large-scale SmartStorage system.
- **Lithium Nickel Manganese Cobalt Oxide (NMC)** batteries are a common type within the lithium-ion industry. The combination of nickel and manganese provides high specific energy and stability, although the cobalt increase the risk of thermal runaway. Examples are the LG Chem batteries and Tesla Powerwall.
- **Lithium Nickel Cobalt Aluminum Oxide (NCA)** batteries are similar to the NMC type but the additional aluminum provides more stability. An example is the TrinaBESS range of systems.
- **Lithium Iron Phosphate (LFP)** batteries have increased safety and thermal stability because of the iron phosphate. It also provides additional life cycle. An example is the SimpliPhi Power's line of batteries.

There are other technologies that are used in solar power systems such as the **nickel-based**, **sodium-based** and **lead-acid** batteries.

PV systems with an integrated battery solution also need a charge controller, as the varying voltage and current from the solar array requires constant adjustment to prevent damage from overcharging.

e) Metering and Monitoring

In case of solar power systems, the metering device must be able to measure the energy units in both directions (bidirectional metering) or two meters must be built into the system. Besides metering photovoltaic systems need to be monitored as well to detect breakdown and optimize their operation. There are several photovoltaic monitoring strategies depending on the output of the installation and its nature.

f) Tracker

One great challenge about a solar power system is how to position the PV panel so that the solar resources can be used in the most effective way. Two important parameters have to be understood, the orientation and the tilt angle. **Orientation (azimuth)** is the angle between the direction perpendicular to the array's surface and the True North. **Tilt (elevation)** is the angle measured between a mounted PV module and a horizontal ground surface. These terms can be visualized in the following figure.

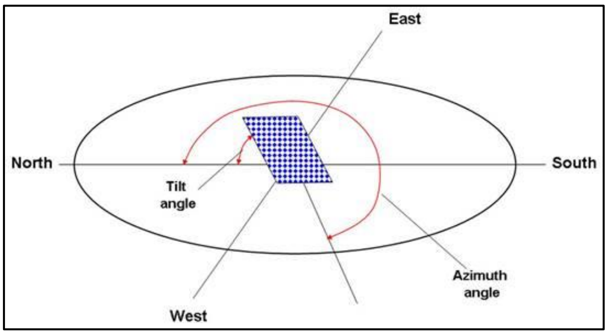

Figure 13 Tilt Angle and Azimuth Angle of a Solar Array

Source: Lacho-Dimi, 2015

It is obvious that a solar power can produce more energy if the sunlight reaches its surface nearer to perpendicular. During the year the position is changing and also the position of the sun is changing continuously during a day. Some basic statement about the best orientation of a solar panel are that a panel facing southward is the best with a tilt of the location latitude (in Miskolc this is about 48°) to the location latitude minus 15° (Lacho-Dimi, 2015). An interesting result during the simulations was that the best orientation was 150° and the best tilt angle was 40° which are slightly different from the above mentioned, **Figure 14**. This results can be described by the location's environmental specialties, such as wind, cloudiness, reflections, etc (as all relevant weather and climate data was integrated in the model).

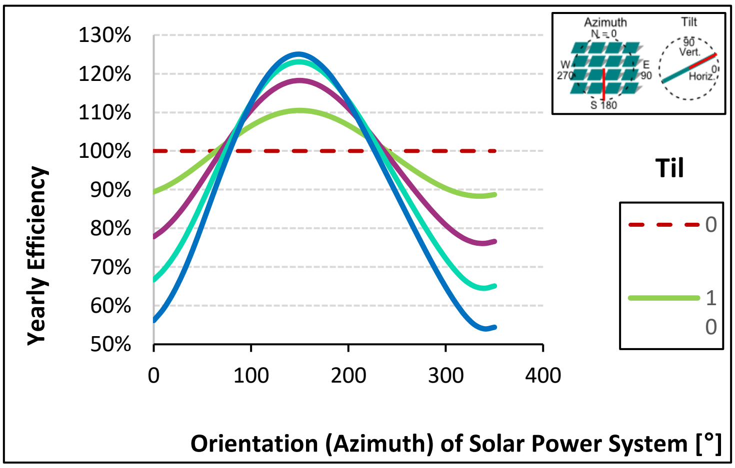

Figure 14 Yearly Efficiencies of the Same System with Different Orientations and Tilt Angles

Source: own figure

To be able to get the highest possible energy from a solar system the panels must be positioned at the best direction. For this purpose, different types of tracking systems are developed. The simplest tracking systems are the single-axis trackers where only one degree of freedom that acts as an axis of rotation.

(1) Horizontal Single Axis Tracker (**HSAT**) is where the axis of rotation is horizontal with respect to the ground.
(2) Vertical Single Axis Tracker (**VSAT**) is where the axis of rotation is vertical with respect to the ground.
(3) Tilted Single Axis Tracker (**TSAT**) is the name of all type of single axis tracker where the axis of rotation is between horizontal and vertical.

Dual-axis tracker (DAT) can be considered the upgrade of single-axis trackers, where the freedom of movement is extended to two separate directions. The different types are listed below.

(1) Tip-Tilt Dual-axis Tracker (**TTDAT**) is so-named because the panel array is mounted on the top of a pole. Normally the east–west movement is driven by rotating the array around the top of the pole. On top of the rotating bearing is a T- or H-shaped mechanism that provides vertical rotation of the panels and provides the main mounting points for the array.
(2) Horizontal Dual-Axis Tracker (**HDAT**) is where the primary axis is parallel to the ground and the secondary axis is like in case of HSAT.
(3) Azimuth-Altitude Dual-Axis Tracker (**AADAT**) has its primary axis (the azimuth axis) vertical to the ground and the secondary axis is typically normal to the primary axis.

The different types can be distinguished on the figure below.

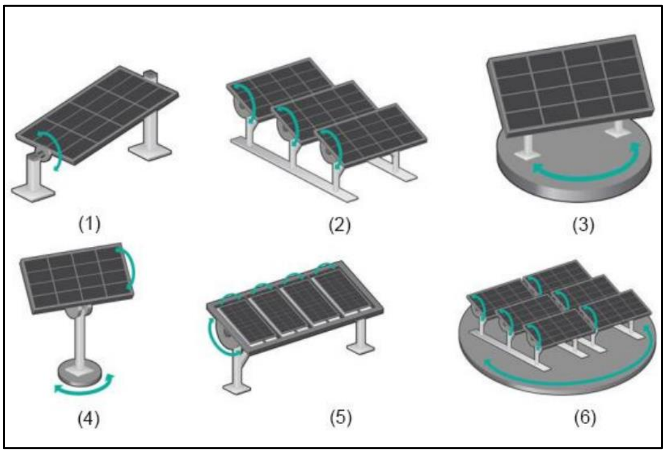

Figure 15 Different Types of Solar Tracker

Source: Nguyen, 2016

With the utilization of solar tracking system as high as 40% efficiency increase can be reached (Rajan, 2016).

3.2 Arrangements

All solar power systems work on the same basic principles. Solar panels first convert solar energy into DC power which can be stored in a battery or converted by a solar inverter into AC power which can be used to run home appliances. Depending on the type of system excess solar energy can also be fed into the electricity grid to provide credits and further reduce electricity costs. There are three basic types of solar power systems which are the followings (Martin, 2014):

- **On-grid** - also known as a grid-tie or grid-feed solar system
- **Off-grid** - also known as a stand-alone power system (SAPS)
- **Hybrid** - solar plus battery storage with grid-connection

In the following subchapters the different types are detailed without the thorough presentation of their parts as they were detailed in the previous chapters.

a) On-Grid Solar Power Systems

On-grid or grid-tie solar systems are the most common and widely used systems by homes and businesses. These systems do not need batteries and use common solar inverters and are connected to the public electricity grid. Any excess solar power that you generate is exported to the electricity grid and you usually get paid a feed-in-tariff or credits for the energy you export.

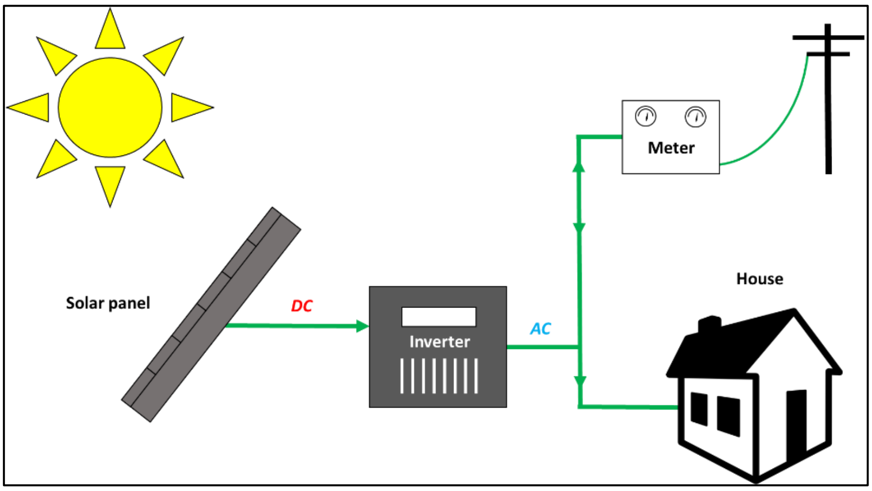

Figure 16 On-Grid Arrangement

Source: own figure

The advantages and disadvantages of this type of arrangement come with the fact that it does not require batteries to store the produced electricity. The advantages are that it is cost effective and easy to install, offsets the electricity bill, does not require expensive batteries and so it can operate for a longer period (as batteries are the bottleneck of operating time). The disadvantages that during a blackout there is no available electricity and the system is dependent from the utility.

b) Off-Grid Solar Power Systems

An off-grid system is not connected to the electricity grid and therefore requires battery storage. An off-grid solar system must be designed appropriately so that it will generate enough power throughout the year and have enough battery capacity to meet the home's requirements, even in the depths of winter when there is less sunlight.

The high cost of batteries and inverters means off-grid systems are much more expensive than on-grid systems and so are usually only needed in more remote areas that are far from the electricity grid. However battery costs are reducing rapidly, so there is now a growing market for off-grid solar battery systems even in cities and towns.

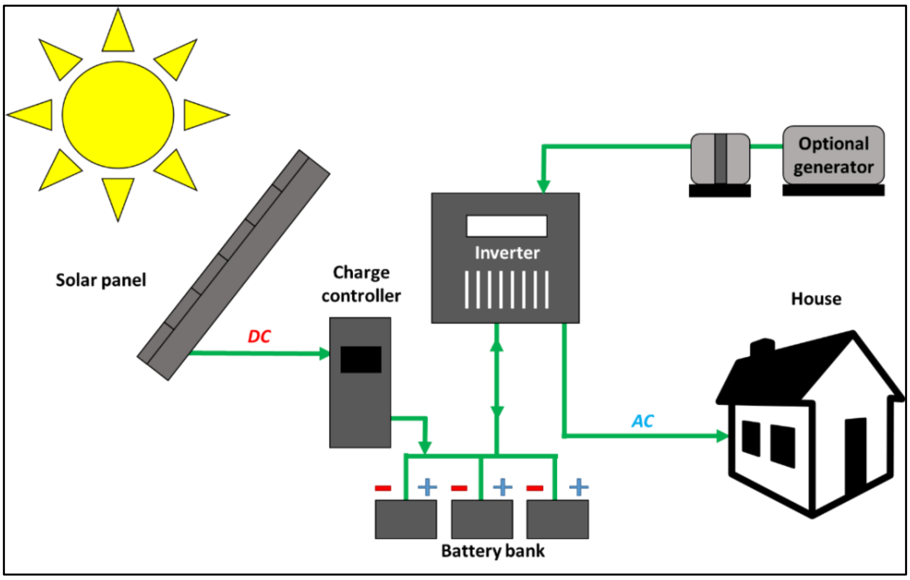

Figure 17 Off-Grid Arrangement

Source: own figure

c) Hybrid Solar Power Systems

Modern hybrid systems combine solar and battery storage in one and are now available in many different forms and configurations. Due to the decreasing cost of battery storage, systems that are already connected to the electricity grid can start taking advantage of battery storage as well. This means being able to store solar energy that is generated during the day and using it at night. When the stored energy is depleted, the grid is there as a backup, allowing consumers to have the best of both worlds. Hybrid systems are also able to charge the batteries using cheap off-peak electricity (usually after midnight to 6am).

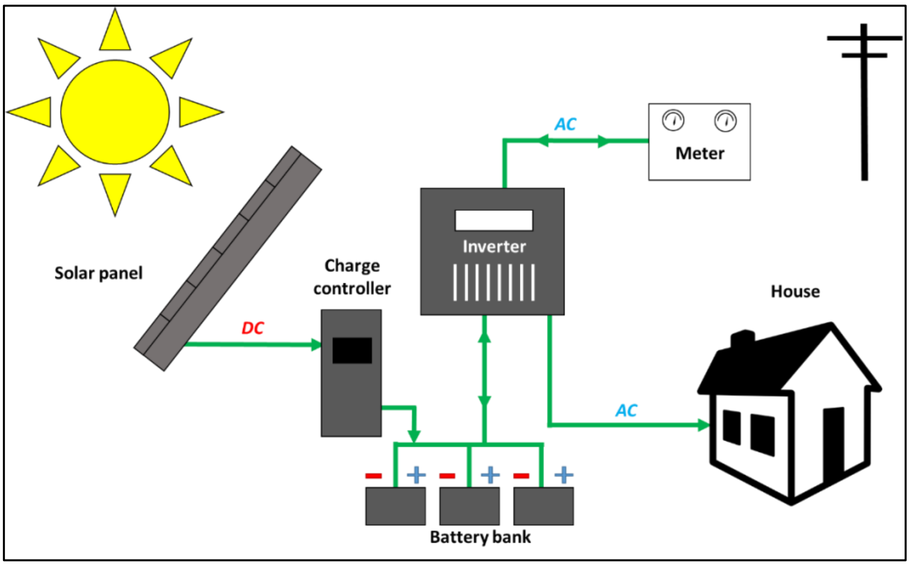

Figure 18 Hybrid Arrangement

Source: own figure

4. Conclusion

Nowadays, nearly 100,000 Hungarian households have small solar power plants. The spread of domestic solar power plants was not curbed by the coronavirus pandemic either, as their number and installed power increased by 1.5 times compared to the data at the end of 2019. In addition, the growth rate has accelerated further: while it was around 44% in 2019, it was close to 50% in 2020. Thus, by the end of 2020, 88 112 household-sized solar power plants had already produced electricity with a total installed capacity of 719.09 MW.

In Hungary, solar power plants of household size still mostly own natural persons: by the end of 2020, nearly 72,000 households already had small solar-powered power plants, compared with only about 47,000 at the end of 2019. At the end of 2020, the average power of residential solar power plants was 6.17 kW.

There are about 4 million households in Hungary, i.e. only 2% had solar power at the end of last year. That value is half that in Germany and only part of the twelfth of the Australian data, where a quarter of households already have a solar system. There is room for growth, and we will certainly see a strong year in 2022. When do we achieve 1 GW of power in Hungary?

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The impact of RES on a transmission system

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Abstract

This work is focused on the implementation of renewable sources in the Power transmission system. In the program NEPLAN is simulates 4 different cases when there is enough sunlight, enough wind and vice versa. In any case, oscillations, and max and min value - active and reactive power and voltage with current curve of the generators, turbines and PWM converters are observed at the three-phase short circuit.

Keywords: renewable sources, photovoltaic and wind sources, dynamic stability, transient phenomenon

1. Introduction

Power transmission system model was used for possible dynamics of events in real conditions. The data were created as technical data in Riga. In Fig. 1, there is a substitute diagram of said transmission system in which renewable energy sources have been stored. Model of wind turbine in the program NEPLAN connection of synchronous generator with regulator used in wind turbines. The model of the photovoltaic power plant block is composed of several reasons within the NEPLAN program. It is a photovoltaic panel, RC filter and PWM controller [2], [4], [5].

A 100 MW solar power plant and three wind farms (2x 21 MW, 1x 16 MW) were implemented in the grid. Subsequently, four situations have been created that may arise during normal operation: In each variation, a three-phase short-circuit was set at 0.1 s and removed at 0.25 s. Also, the transmission line connecting shown model with feeder who represent big transmission system was disconnected at 0.1 s.

a) Plenty of sunlight and wind

b) Plenty of sunlight, but lack of wind

c) Enough wind but lack of sunlight

d) Lack of sunlight or wind

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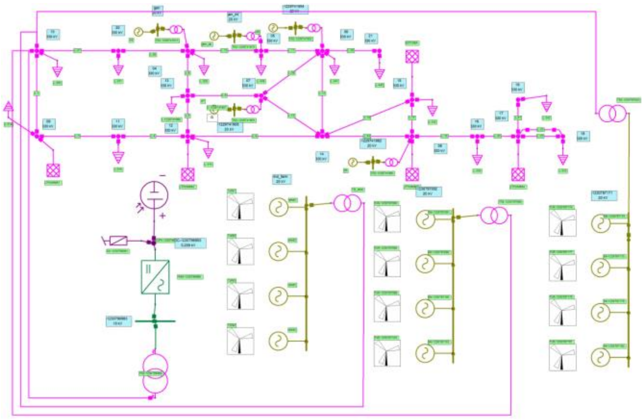

Figure 1. Scheme of transmission system with connected PV and WIND sources

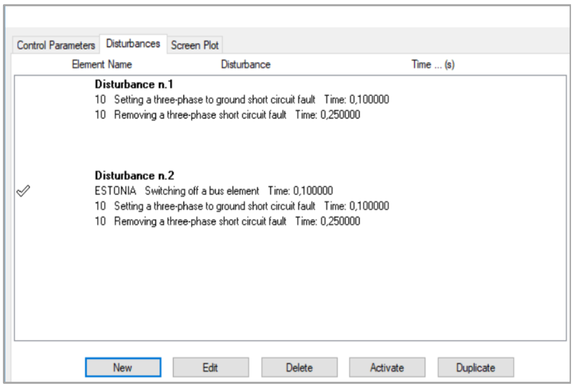

Figure 2. Setting a disturbance in NEPLAN

2. Scenario a)

The ideal situation is when there is enough power available from both the solar and wind farm. The network is “hard” enough to compensate for fluctuations after a short circuit has been rectified and to reach a steady state.

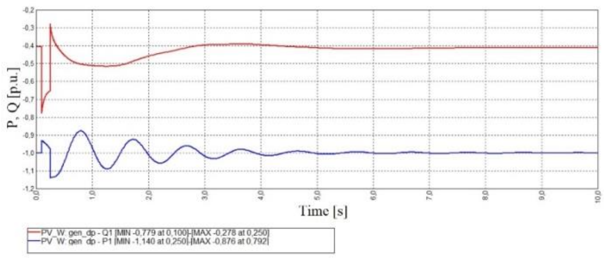

Figure 3. Curve of active („blue“) and reactive („red“) power of Generator

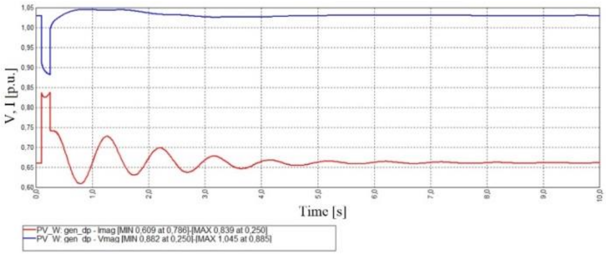

Figure 4. Current („red“) and voltage („blue“) of Generator

Fig. 3, it is apparent that after the initial oscillation, the active power gradually stabilized at about 5 s. The generator has stabilized the voltage and hence the reactive power with the exciter controller. The reactive power value dropped sharply at the moment of short-circuit and increased only after the fault was rectified. After a subsequent decrease, it also stabilized at 3 s [1], [3], [6].

The constant current at the moment of short-circuit increases steeply while the voltage has the opposite character. Therefore, any type of short-circuit must be eliminated as quickly as possible, as the short-circuit time increases, the more generators swing. After a certain amount of time has passed, it is possible that the generator or group of generators will not be able to stabilize and completely fall out of synchronism, which may result in complete disintegration of the system or part thereof. This time is called the critical time (determines the time until the short circuit must be eliminated) and determines the maximum time that the protections must respond to ensure the generators' ability to stabilize. In this case, the generator stabilized and the largest oscillations occurred within 5 s of the short circuit removal.

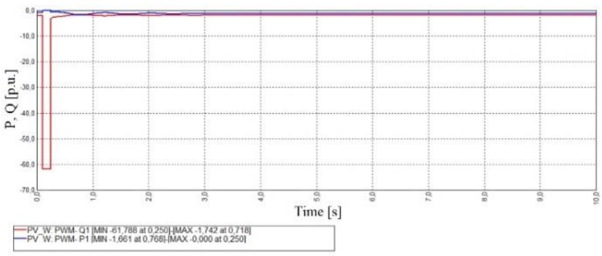

Figure 5. Curve of active („blue“) and reactive („red“) power of PWM converter

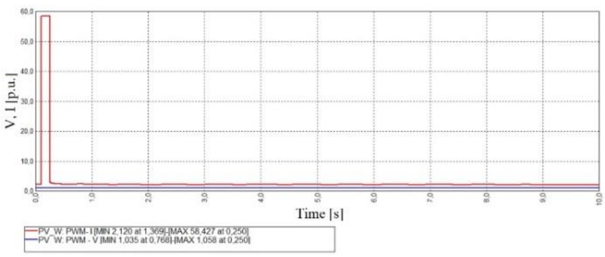

Figure 6. Current („red“) and voltage („blue“) of PWM converter

An interesting situation occurred when looking at Figure 5, where it can be seen that the active and reactive power flow never exceeded positive values. If positive values were recorded, this would mean that the plant is taking off. The converter is able to change the reversibility, but in the case of PWM it is blocked.

In Figure 5 shows the active and reactive power waveform of the PWM converter, which supplied power from the PV power plant to the grid and thus converted the DC voltage component to an AC component. Since converters are non-rotating devices, which consist of semiconductor components (transistors, thyristors) we assume a smaller transient event, since this system contains only static (non-rotating) elements. These types of converters are short-circuit protected by automatically disconnecting from the mains to protect expensive and sensitive semiconductor devices. In this case (Figure 6), the PWM converter would be disconnected from the mains due to the high short-circuit current. The short-circuit current would have fatal consequences for the cascades in the converter. Being just a computer simulation and observation of dynamic events, it was possible to leave the PWM converter unplugged and watch how it handled the situation. PWM converter controller is able to influence various changes in the connected network thanks to the advanced switching power semiconductor technology with extremely fast response.

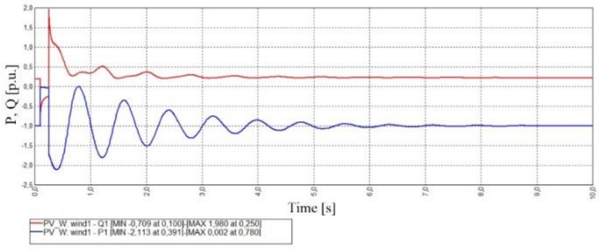

Figure 7. Curve of active ("blue") and reactive („red") power of Generator WT

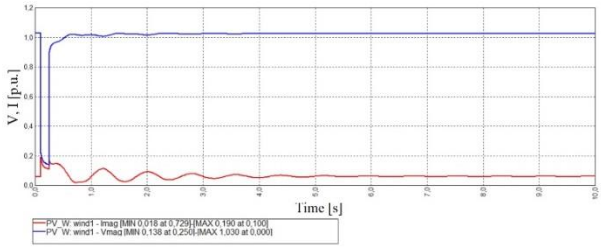

Figure 8. Current („red") and voltage („blue") of Generator WT

As wind turbines contain rotating generators, visible oscillations in disturbances can be observed. Due to the set fault in the NEPLAN program, the turbine regulator tried to stabilize the power as soon as possible after removing the short circuit. Figure 7, it can be seen that the generator did not fall out of synchronism at the original power as supplied before the short circuit.

As is known, there is a sharp drop in voltage during short-circuit and, on the other hand, the increase in current is no different.

Table 1 Table of measured value

	Generator							
	P [MW]	**t [s]**	**Q [MVAr]**	**t [s]**	**U [kV]**	**t [s]**	**I [kA]**	**t [s]**
MAX	- 55,188	0,792	-13,065	0,25	20,9	0,885	1,507	0,25
MIN	- 71,82	0,25	-36,611	0,1	17,64	0,25	1,094	0,786
	Generator VT							
	P [MW]	**t [s]**	**Q [MVAr]**	**t [s]**	**U [kV]**	**t [s]**	**I [kA]**	**t [s]**
MAX	0,042	0,78	44,925	0,25	20,6	0	1,935	0,1
MIN	-44,373	0,39	-16,087	0,1	2,76	0,25	0,183	0,729
	PWM converter							
	P [MW]	**t [s]**	**Q [MVAr]**	**t [s]**	**U [kV]**	**t [s]**	**I [kA]**	**t [s]**
MAX	0	0,25	-138,14	0,718	11,083	0,25	297,83	0,25
MIN	-195,41	0,768	-4899,83	0,25	10,842	0,768	10,81	1,369

3. Scenario b)

In this case, the simulated waveform indicates the state of the grid, where, after the induction and subsequent elimination of the three-phase short circuit, only the solar renewable energy source is connected to the grid.

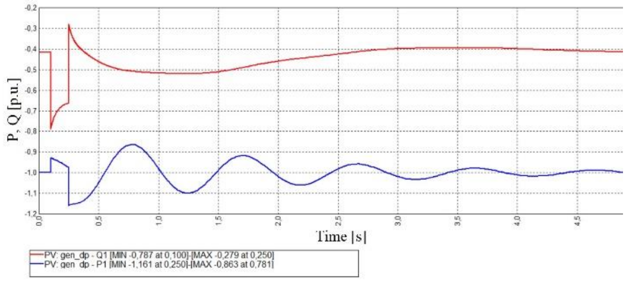

Figure 9. Curve of active ("blue") and reactive („red“) power of Generator

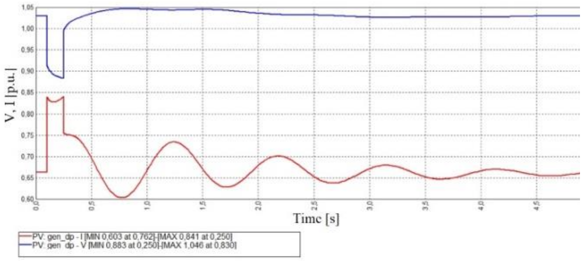

Figure 10. Current („red“) and voltage („blue“) of Generator

At 0.1 s, when the short-circuit is triggered, the active power value increases slightly and then decreases significantly afterwards, resulting in fluctuations in the active power values of the generator, which are not fully stabilized even at 5 s. On the contrary, the reactive power value dropped sharply at the moment of short-circuit. Therefore, the exciter regulator responded and stabilized the voltage value. As can be seen in Figure 9, the reactive power was therefore stabilized at approximately 3 s as a function of the voltage, depending on the voltage.

The generator current reached the highest value at the time of short-circuit removal of 2.34 kA. Subsequently, it dropped to 1.68 kA and was not able to stabilize completely within 5 seconds. In wind farms, the PWM system can minimize dynamic phenomena and generator oscillations.

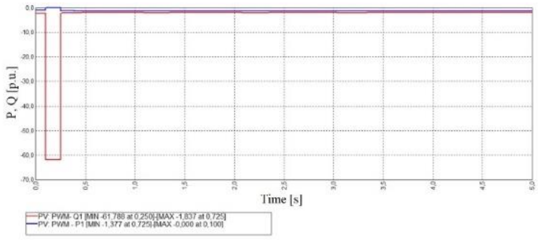

Figure 11. Curve of active ("blue") and reactive („red“) power of PWM converter

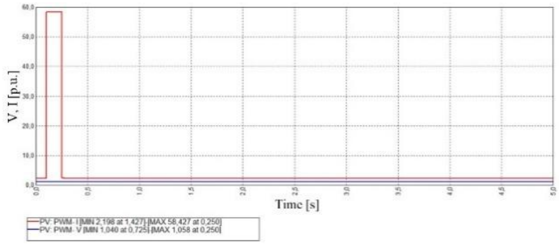

Figure 12. Current („red“) and voltage („blue“) of PWM converter

Power sources using PWM technology have much less visible oscillations than rotating machines due to fast switching and therefore rapid response. This is also because they have no inertia. On the other hand, rotating machines (for example synchronous generators) have a relatively high inertia during transient events, resulting in significantly higher power oscillations.

The high short-circuit current recorded in Figure 12 would cause the PWM converter to disconnect from the mains in real operation. The PWM converter again responded very quickly and stabilized the current to its original value. The situations shown in Figure 11 and Figure 12 cannot occur in actual operation as they would have devastating effects for the converter. The aim was to point out the ability of the converter to respond quickly to changes in the system and that it can eliminate network changes due to fast switching devices [7].

Table 2. Table of measured value

	Generator							
	P [MW]	**t [s]**	**Q [MVAr]**	**t [s]**	**U [kV]**	**t [s]**	**I [kA]**	**t [s]**
MAX	-54,369	0,781	-13,041	0,25	20,92	0,83	2,344	0,25
MIN	-73,143	0,25	-36,787	0,1	17,66	0,25	1,681	0,762
	PWM converter							
	P [MW]	**t [s]**	**Q [MVAr]**	**t [s]**	**U [kV]**	**t [s]**	**I [kA]**	**t [s]**
MAX	0	0,1	-142,28	0,725	10,555	0,25	281,535	0,25
MIN	153	0,725	-4785,7	0,25	10,375	0,725	10,591	1,427

4. Scenario c)

In the following situation, the circumstances were set so that the solar power plants were disconnected and only wind farms served as RES.

At the moment of short-circuit, the value of the constant voltage dropped while the current value increased critically. The swing of the generator was stable at 8 s. The maximum current value at the moment of short-circuit was 2.36 kA and the value was not significantly reduced until the short-circuit was removed. The time required to rectify the fault is crucial for the system due to the adverse effects of a long-term short circuit, such as the possibility of a complete blackout from synchronism. Figure 13 and Figure 14, it is clear that the generator behaves very similarly to the previous variant. The main changes are visible with the PWM converter respectively. VT generator.

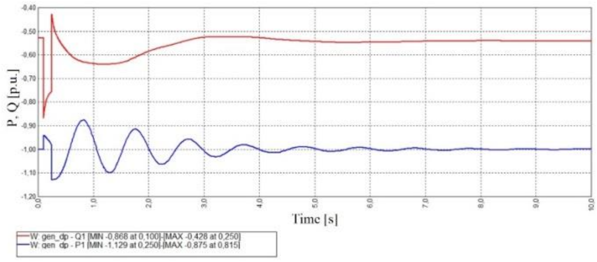

Figure 13. Curve of active ("blue") and reactive („red") power of Generator

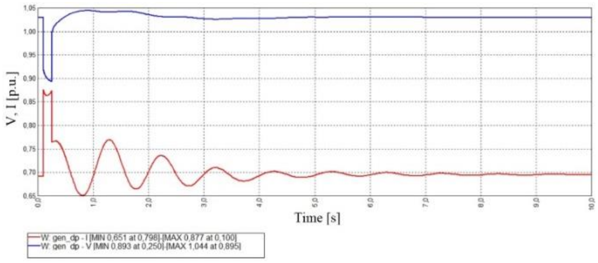

Figure 14. Current („red") and voltage („blue") of Generator

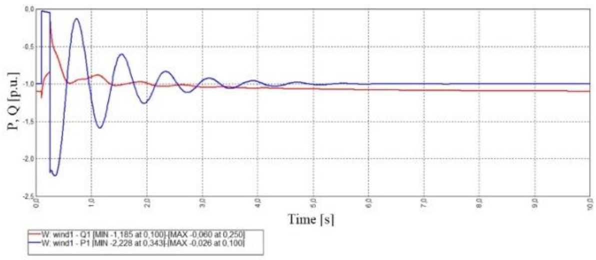

Figure 15. Curve of active ("blue") and reactive („red") power of Generator WT

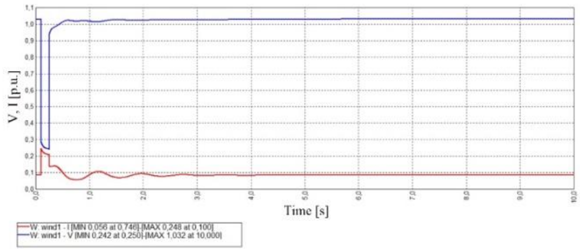

Figure 16. Current („red") and voltage („blue") of Generator WT

An interesting view is provided in the course of the active and reactive power of the VT generator in contrast to Figure 11, showing the active and reactive power of the PWM converter. Figure 15, it can be unambiguously confirmed that generators not using PWM technology face significantly higher power oscillations in the event of a fault or short circuit. At 0.1 s, at the moment of short-circuit, the generator delivers only 0.546 MW, while after short-circuit removal it is almost 47 MW. The value of the supplied power will stabilize in approximately 5 s to the original 21 MW [8].

The diametrically different behavior of the synchronous generator as opposed to the PWM technology is also visible in Figure 16 where the current and voltage of the VT generator is shown. At the time of short-circuit there was a significant drop in voltage up to 4.84 kV from the original 20.6 kV. On the contrary, the short-circuit current value reached three times the constant value up to 1.802 kA, while the value of the constant current before the short-circuit was only 0.654 kA.

Table 3. Table of measured value

	Generator							
	P [MW]	**t [s]**	**Q [MVAr]**	**t [s]**	**U [kV]**	**t [s]**	**I [kA]**	**t [s]**
MAX	-55,125	0,815	-17,089	0,25	20,88	0,895	2,361	0,1
MIN	-71,127	0,25	-34,657	0,1	17,86	0,25	1,753	0,798
	Generator VT							
	P [MW]	**t [s]**	**Q [MVAr]**	**t [s]**	**U [kV]**	**t [s]**	**I [kA]**	**t [s]**
MAX	-0,546	0,1	-0,556	0,25	20,64	10	1,802	0,1
MIN	-46,788	0,343	-10,989	0,1	4,84	0,25	0,407	0,746

5. Scenario d)

The Power transmission system model was constructed on the basis of real data. The connection of RES was created only for the purposes of this thesis. In the following case, the transmission system is shown, without the activity of renewable energy sources. Thus, the calculated values after the fault setting reflect the real behavior of the system.

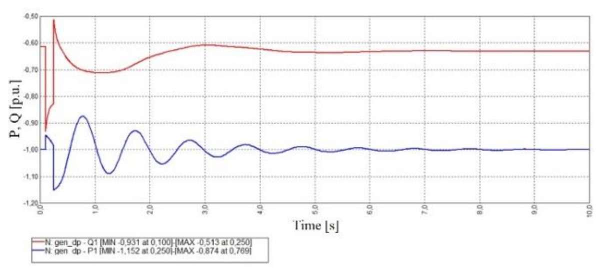

Figure 17. Curve of active ("blue") and reactive („red") power of Generator

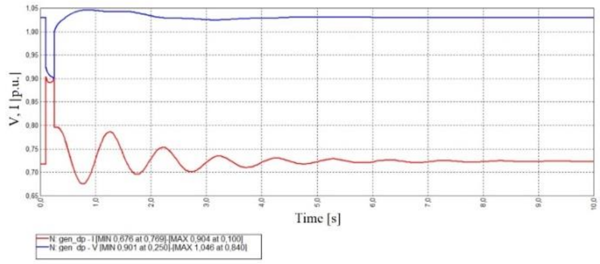

Figure 18. Current („red") and voltage („blue") of Generator

The reactive power value dropped significantly at the moment of short-circuit, and the exciter controller took a while to stabilize the reactive power as a function of voltage. The value of active power has stabilized on the originally supplied 63 MW for almost 10 seconds from the moment of short circuit. The constant current was 1.87 kA before the short-circuit and the constant voltage was 20.6 kV. At the moment of short-circuit the current reached its maximum of 2.35 kA. The voltage rose to its maximum of 20.92 kV after removal of the fault.

Table 4. Table of measured value

	Generator							
	P [MW]	t [s]	Q [MVAr]	t [s]	U [kV]	t [s]	I [kA]	t [s]
MAX	-55,062	0,769	-18,471	0,25	20,92	0,84	2,35	0,1
MIN	-72,576	0,25	-33,521	0,1	18,02	0,25	1,76	0,769

6. Evaluation and recommendations for practice

In this subchapter, the results of the investigation are summarized and structured.

Table 5. Comparison of measurements on the generator in all variants

	Generator											
	A			B			C			D		
	CONST	MIN	MAX	CONST	MIN	MAX	CONST	MIN	MAX	CONST	MIN	MAX
P [MW]	-63	-71,82	-55,18	-63	-73,14	-54,37	-63	-71,13	-55,13	-63	-72,58	-55,06
Q [MVAr]	-19,27	-36,61	-13,07	-19,49	-36,79	-13,04	-21,16	-34,66	-17,09	-21,96	-33,52	-18,47
U [kV]	20,6	17,64	20,9	20,6	17,66	20,92	1,86	17,86	20,88	20,6	18,02	20,92
I [kA]	1,85	1,09	1,51	1,84	1,68	2,34	20,6	1,75	2,36	1,87	1,76	2,35

In this case, the lowest active power fluctuations are observed for variant C, where only a wind farm is involved. On the other hand, variant B has the highest active power swing, with only a solar power plant included in the system.

Table 6. Comparison measured values of PWM

	PWM Converter					
	A			B		
	CONST	MIN	MAX	CONST	MIN	MAX
P [MW]	-100,00	-195,41	0,00	-100,00	153,00	0,00
Q [MVAr]	-166,49	-4899,83	-138,14	-170,39	-4785,71	-142,28
U [kV]	10,48	10,84	11,08	10,48	10,38	10,55
I [kA]	10,70	10,81	297,83	10,89	10,59	281,54

Table 7. Comparison measured values of WT

	Generator VT					
	A			C		
	CONST	MIN	MAX	CONST	MIN	MAX
P [MW]	21,00	-44,37	0,042	21,00	-46,79	-0,54
Q [MVAr]	-4,31	-16,09	44,930	10,20	-10,99	-0,56
U [kV]	20,60	2,76	20,600	20,60	4,84	20,64
I [kA]	0,60	0,18	1,940	0,65	0,41	1,80

As a result of the data processing we can say that the active power in the converters is stabilized fast enough with very small oscillations and an early stabilization to the required value. In the case of reactive power, to which the converter reacts very sensitively (in case of short circuit) and tries to supply more reactive power to the system due to a sharp voltage drop. In this way, reactive power and voltage oscillations are created in the converters, and these oscillations can pose a threat and destroy fragile semiconductor transitions in the devices. Oscillations are much milder than with conventional synchronous generator connections through a block transformer [7], [8], [9].

For practical use, this means that wind and solar power plants connected via converter converters do not pose a threat or higher danger to the dynamic stability of the system. On the contrary, this control can improve and reduce the oscillations and oscillations of the generators involved in their vicinity. The most important need for these converters is their protection. Given that the systems contain sensitive semiconductor devices, it is necessary to shut them down as quickly as possible from the mains where a fault has occurred which could pose a danger to these elements [10], [11].

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'Smart solutions' relating to residential properties and their direct environment with special regards on cloud-based services in the capitals of the European Union's countries

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Abstract

The development of our living environment is increasingly demanding the use of advanced technologies in view of the increasing range of tasks that need to be solved. While developing countries are dominated by problems identified by rapidly growing populations, developed countries, whose populations are mostly aging, are more focused on improving the quality of life, reducing social inequalities and developing sustainable structures In this article, we would like to give you a brief overview of how cloud-based and cloud-related technologies are affecting our living environment and residential real estate. In this study, we examine the current situation of the area, exploring the major domestic and international trends and we are looking for good practices, with particular reference to the countries of the European Union.

Keywords: cloud technology, living environment, real estate, smart city, smart, home,

JEL Classification: O0, O3, O5, R1

1. Introduction

We can talk about cloud technology since the 1960s, but it was only available in the military sphere at that time. Then in the 1990s the use of 'clusters' became widespread. A cluster is a type of parallel distributed system. A collection of interconnected stand-alone computers that work together as an integrated computer resource. This was followed by 'grid computing' in the early 2000s, a hardware and software infrastructure that allowed the development of computing capabilities that provide reliable, low-cost access by connecting geographically distributed resources such as supercomputers, clusters, and data warehouses. (Tibenszkyné F. K. 2011) (dataversity.net/brief-history-cloud-computing/#)

Modern widespread cloud technology was released around 2008 when Google made its service available for free. The point of cloud computing is that the user does not need to have a large in-house IT infrastructure (hardware, such as expensive hard disks). Technology has become increasingly widespread worldwide in the last decade, both in the private, business and public sectors. Cloud applications are also increasingly contributing to people's quality of life, enterprise competitiveness and public sector efficiency.

2. Definitons of cloud based computing

In this chapter, we have collected various definitions of cloud-based technology in my domestic and foreign literature searches. In order to get a credible idea of exactly what the so-called 'cloud' is about, we were curious about the definitions of the world's leading IT companies, such as Microsoft, SAP, or IBM.

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The term ‘cloud’ comes from the graphical representation and is actually a symbol. In the IT diagrams, this pictogram indicates the external services that the other elements of the diagram are in contact with, as shown in the diagram below (Fig. 1.), so these services can be accessed not from a specific location but from the ‘cloud’. (Lepenye T. 2010)

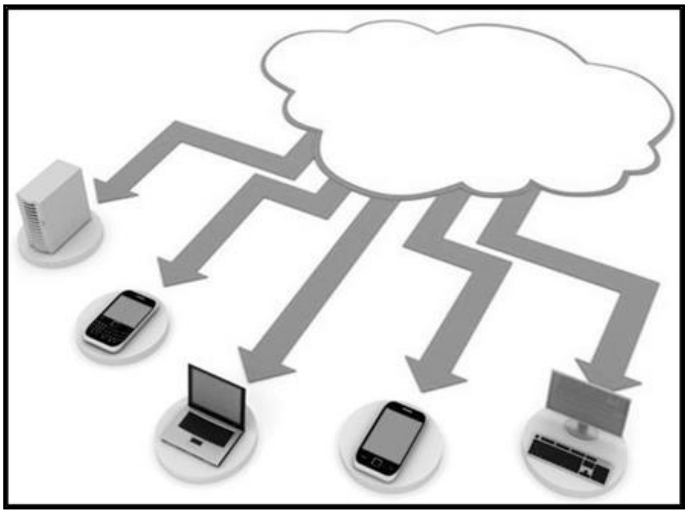

Figure 1. Cloud computing illustration

Source: 24.hu/tech/2014/09/10/szoval-akkor-mi-is-az-a-felho

The following definitions also indicate that there is already a common definition of cloud technology in the literature, even though it is a very young technology.

‘Cloud-based’ computing, often referred to as the ‘cloud’, carries computing resources - everything from applications to databases - through the Internet. Its main virtues are flexibility, its size can be tailored to demand, it only has to be paid for what we use or completely self-explanatory in the sense that we have access to all the IT resources we need (Figure 1) (ibm.com/cloudg).

To put it simply, making cloud computing services such as servers, storage, databases, networking, software, analytics, intelligence accessible over the Internet (in the cloud), for faster innovation, flexible resources and economies of scale (azure.microsoft.com/hu-hu/overview/what-is-cloud-computing).

‘Cloud computing enables users to access data, applications and services over the Internet. The cloud eliminates costly hardware such as hard drives and servers and lets users do their work from anywhere’ (sap.com/hungary/trends/cloud.html).

The cloud-based service is when you use the service on your own computer, but the infrastructure responsible providing the service is not internal and the servers take in another physical place. They are not our property, in many cases we do not know exactly where they are, but they are well defined, what they provide (availability, security, price) (humansoft.hu/Alkalmazas_szolgaltatas/Felho_megoldasok.html).

The most widely accepted and increasingly popular definition of cloud computing, developed by the American National Institute of Standards and Technology (NIST), is that ‘Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction’ (nvlpubs.nist.gov/nistpubs/legacy/sp/nistspecialpublication800-145.pdf).

3. Grouping of ‘cloud" based technologies’

Cloud computing can be divided into three major service categories: Provided Software (SaaS), Platform Service (PaaS) and Infrastructure Service (IaaS).

'SaaS - Provided Software' - is a way of providing applications over the Internet. Customers can access SaaS applications directly from their web browser, which means they do not need to purchase, install, maintain or upgrade any hardware or software. The SaaS provider takes care of everything and the client always gets the latest version of the application (sap.com/hungary/trends/cloud.what-is-saas.html#what-is-saas).

Advantages:

- innovative business applications are available right after login,
- applications and data can be accessed on any connected computer, smartphone, tablet and other IT devices,
- no data loss when computer suddenly shuts down or freezes due to data in the cloud (ibm.com/).

Platform Service (PaaS) provides a cloud-based platform and tools to help developers develop and deploy cloud applications. Users access PaaS through a web browser, so there is no need to purchase or maintain the underlying hardware and software. With PaaS, developers can choose the features they want on a subscription basis (sap.com/hungary/trends/cloud.what-is-paas.html#what-is-paas).

Advantages:

- developing applications and bringing them to market faster,
- developing new web applications in the cloud within minutes (ibm.com/).

With the ability to provide infrastructure services (IaaS), companies can use resources like servers, networks, storage, and operating systems. IaaS services provide the infrastructure and handle tasks such as system maintenance and backups so that the customer does not have to purchase hardware or use in-house experts to manage them (sap.com/hungary/trends/cloud.what-is-iaas.html#what-is-iaas).

Advantages:

- no need to invest in your own hardware,
- flexible, innovative services on demand (ibm.com/).

The other main typing of cloud services is grouping by deployment models. This is where accessibility comes into the foreground, which will make the clouds stand out. In essence, this means who, to whom and to what extent you share the use of services. The American National Standards Institute (NIST), already mentioned in the definitions, basically classifies cloud computing models into four groups:

- A private cloud is a cloud infrastructure that is solely reserved for a single owner or organization. This can be controlled internally by the user organization itself, externally by the service provider or a third party, or any combination of these. It can be physically located inside or outside the company premises. The benefit is guaranteed data protection and fast access to applications.
- The essence of community cloud is that computing, access, storage, etc. capacity is not publicly available, but only a few organizations share this infrastructure. There is a common interest between these organizations. A major benefit is economies of scale, as IT costs are shared across multiple organizations. The disadvantage is that if there are specific needs, companies have to compromise with each other.
- The public cloud is considered to be the best-known deployment model today. Public cloud infrastructure, by contrast, is accessible to even ordinary people, but the resources are owned by the service company, so they own and operate the infrastructure on their premises and provide access via the Internet, such as Google. With this model, users have no insight and no control over the location of the infrastructure,
- A hybrid cloud is a combination of two or more of the above clouds, where personalization applies. These unique units remain during use while they are connected due to patented and standardized technologies. In a hybrid cloud, we can deploy external cloud services, either wholly or in part, increasing the flexibility of the computer and the portability of data and applications (nvlpubs.nist.gov/nistpubs/legacy/sp/nistspecialpublication800-145.pdf).

4. Results and discussion

4.1 Use of cloud-based applications in European Union countries

The purpose of the study is to present „smart solutions” in the field of cloud applications in the capitals of the European Union countries in the field of residential real estates and their immediate environment. This is why we first examined how well the technology is known in the European Union Member States. Eurostat has collected and analyzed data on this field, with the most recent data which are covering 2018.

Figure 2 shows the proportion of people using the cloud services who had used the Internet in the 3 months preceding the survey. This represented one third of the EU population (35%) (Figure 3). During the reporting period, in Poland only 20% of users have used some kind of cloud services, even in Sweden nearly 60% of the people. Eurostat emphasizes in particular Hungary and Romania that the proportion of cloud users has increased compared to 2014 and these two countries are approaching to the EU average (ec.europa.eu/eurostat/cache).

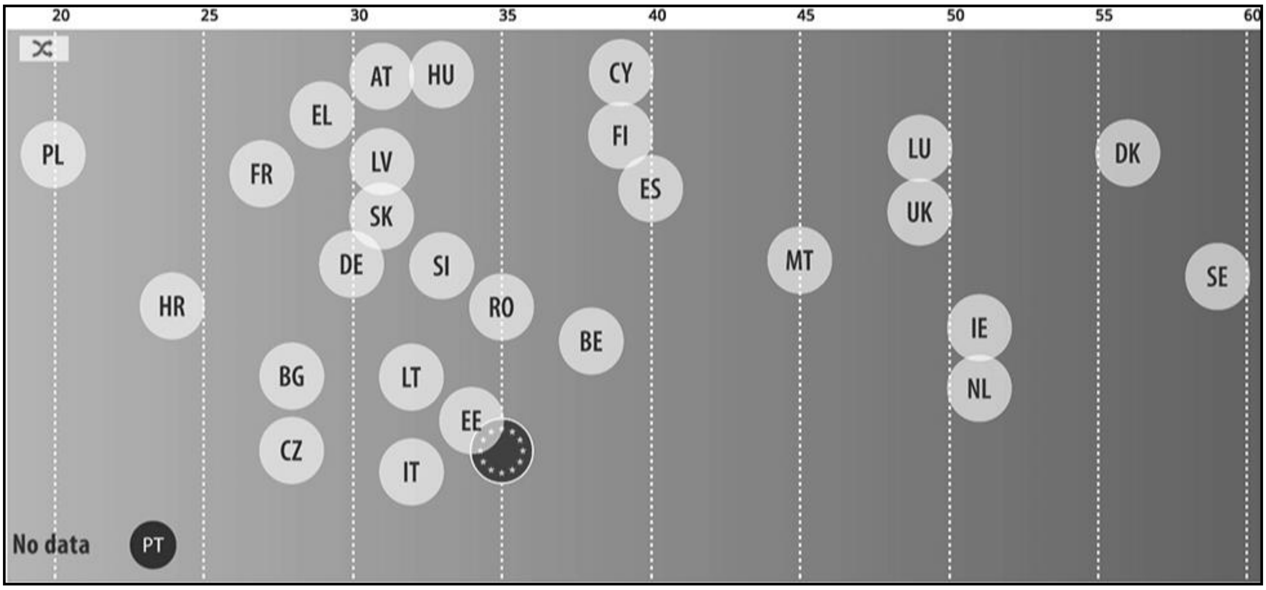

Figure 2. Proportion of people using cloud services within the population (% of people who have used the Internet in the last 3 months) in 2017

Source: ec.europa.eu/eurostat

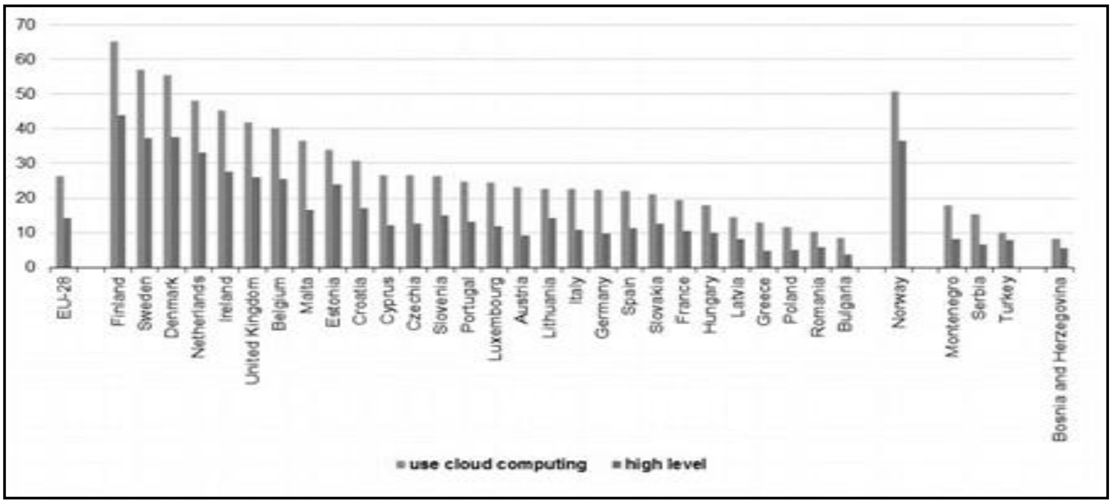

Figure 3. Proportion of users of cloud computing services in enterprises in 2018

Source: ec.europa.eu/eurostat

According to Eurostat, 97% of enterprises in the EU use the Internet, but only 22% of them purchased cloud-based services. Most of these companies only use the service to send / receive mail and store data electronically. Only 21% of companies use it to improve performance and run their own business software. The use of technology by companies is most widespread in the north-western states, least in Bulgaria, Romania and Poland (Fig.3.) (ec.europa.eu/eurostat).

4.2 "Smart solutions" for residential real estates and their immediate environment, best practices for cloud-based applications in capitals of European Union countries

As the previous chapter has shown, in the European Union, cloud technology services are not as widespread among the general public and companies, and besides their basic functions, the use of services is not typical. Nevertheless, many urban development projects use cloud-based applications / technology. Most municipalities already store and share their data on these platforms with local stakeholders (good examples are: Transformcity Amsterdam or Open Data projects). This technology is slowly becoming indispensable for developments, as it is the most convenient way to store and share data, and cost effectiveness is not the last consideration. Many sectors today use some kind of form of cloud technology, at least at on basic level (data storage or sharing), such as transport, energy management (eg: smart metering in homes) (Hall, R.E. 2000).

In the last part of the study, we gathered some good practices from EU capitals:

- “Wall of the House” (Budapest) is a cloud-based online service that provides tailor-made services to common representatives that simplify administration, improve operational efficiency and reduce costs. For residents, the system makes the house's finances more transparent, simplifies participation in the house's affairs, and creates a community space. It also help the communication between residents and community representatives and enhances the potential of local community partnerships. "Wall of the House" provides a solution for internal administration, communication and administration. Increases efficiency over common representatives, who can thus manage more houses with the same resource and operate more economically. It makes it easier for residents to control and has a community-building effect. The maintenance, beautification and livelihood of the house is in the interest of all residents. The purpose of the service is to bring together people with the same interests and help them in their community activities. The introduction of the House Wall is possible only by the common representative. The reason for this is that he is primarily responsible for the affairs of the house, only credible information can come from him. The system is closed to outsiders cannot see the common affairs. (volcsey.hu/smart-city-peldatar.pdf)
- EnerXi (Spain - Madrid) monitors and manages buildings in a cloud environment, providing users with real-time information on building energy use. This data is provided by smart meters based on various heating, cooling, domestic water and electrical systems. Users can use the software to intervene in processes, observe what changes these interventions are causing in the building's energy use, and what savings are made. The Xial Platform connects all relevant actors directly from an energy provider to the end user through an online interface. (volcsey.com/smart-city-peldatar.pdf)
- Transformcity (Netherlands - Amsterdam) is an online collaborative urban development platform that aims to develop sustainable and inclusive local partnerships and to help municipalities to collaborate with local stakeholders on an ongoing basis. Fully interactive online platform that connects all stakeholders and the municipality to share and discuss data, plans, ideas and resources directly and collaborate on local projects. (amsterdamsmartcity.com/projects/transform-city-zocity-pilot).
- The Dublin Dashboard (Ireland - Dublin) is a so-called "dashboard" that helps citizens and businesses access real-time information. It is a free, interactive portal that provides access to many datasets, visualizations, analytics tools and applications. These include real-time traffic, environmental, and other databases such as Census, Crime, Housing, etc. (smartdublin.ie/smartstories/dublin-dashboard/).
- the VitalSens project is developing a cost-effective wireless measurement tool for physiological measurements. The aim is also to develop a health monitoring platform that allows for the collection and monitoring of vital functions data. The app stores data that can be accessed by both a doctor and patients via a smart phone, making it easy to track a person's health for a lifetime. (helsinkismart.fi)

5. Conclusion

Our research has found that the use of cloud-based technologies is becoming increasingly important and inevitable for residential properties and their environment. These types of developments are mainly found in large cities, especially in the areas of digital administration, e-governance, community planning and (public) transport (Szendi, D. 2019, Kuttor, D. 2012). We also encountered a definition problem when examining this topic, since almost all of the applications require some kind of cloud-based backend process. Looking at the trends, it seems clear that technology will become essential for both businesses and individuals as our (residential) environment evolves.

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AUTOMATION OF A SELECTION AND PACKAGING PROCESS

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Abstract

Automation can be generally defined as a set of technical measures that are based on reducing or eliminating human participation through production processes. In this project is made an automated system for sorting, bottling and packaging of juice and water bottles using the EASY SOFT program, where you can see the economic and qualitative efficiency of sorting, bottling and packaging bottles, based on programmable machines. Sorting, bottling and packing bottles mechanically is a complex process, where certain factors must be taken into account, and these actions must be performed in an appropriate order. The tape role is to enhance the entire process of separation, bottling and packaging, reducing the number of people needed for such an operation. The automation process can be applied in a framework for the manufacture of juice and water bottling, in terms of the next steps of process technologies, programming automation, tracking of sensor performance and input data.

Keywords: sensor, EASY-SOFT, Proximity sensor, automation, color sensor

1. Introduction

The current economic standard was defined with the help of the development of information technology, which was materialized with the help of new computing systems being with great steps more efficient, the realization of high-performance technologies and equipment in general. This new evolution has allowed the mass introduction of modern automation solutions. Automation can be generally defined as a set of technical measures that are based on reducing or eliminating human participation through production processes.

The technological process itself is based on a succession of operations that are performed on raw materials, by-products, semi-finished products, in order to obtain a new product with a high degree of processing. The necessary operations will be performed in technological installations that involve a transfer of mass and energy. The information process will be defined by the totality of the operations of acquisition, processing, storage and switching of information indispensable for the technological process.

This automation of production processes has been implemented with a general effort made by industrial producers in order to achieve increased productivity, superior use of products, improving product reliability and quality, reducing production costs and improving working conditions.

Depending on the production volume, the optimal automation strategy will be applied (small series or series production, mass production), the economic efficiency of the investment will be taken into account, in order to ensure the highest possible flexibility, so that it can cope. with the rapid changes of market requirements.

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With the help of flexibility, it is possible to adapt systems without delay to a series of technological developments of manufacturing, these being used in the processing of improved or even new products. This flexible function can vary from one system to another, it being established based on the specifics of production and being in correlation with the economic efficiency of its realization.

In our country, it has recently been noticed companies with a production profile, these having an increasingly varied range, in order to find new refurbishment solutions by taking over new automation solutions. Most flexible automation solutions refer to programmable controllers with a fairly wide applicability in the industrial field. [3-5]

2. EASY-SOFT program

It is defined as a program used on a PC, through which it was possible to execute, store, simulate, and document all the connection schemes in EASY which can then be transformed into a specific device that will be programmed for operation. them. Likewise, the indication of the state of the current connection scheme will be made possible, moreover it will be possible to establish the functions associated with the relay parameters. Otherwise defined, this wiring diagram will constitute this program with which the mode of activity of the control relay will be set.

Given the representation, processing and printing of the program, the following types of representations may be used: a schematic representation characteristic of the device, which conforms to the display of the device, post-IEC representation based on contact and coil symbols, international rules, The American standard will be represented after A N S I.

With the inclusion of this program in the advanced connection scheme, selection menus can be used, which helps to facilitate connections. In this way this wiring diagram will be activated only by a simple selection of contacts or even coils, all functional relays or components that are functional in this window with instruction boxes, which can be displayed by selecting the DRAG function or DROP which will be located in the wiring diagram window. Moreover, in addition to making automatic connections, the connections between certain elements of a connection scheme can be reached through the mouse. With the help of the selection inside the connection scheme it will be possible to enter only the help of a keyboard. [1-7-8]

3. Sensors

The sensor can be a technical device that has been designed to respond qualitatively or quantitatively based on its own sizes. The sensor-component of a technical detector system or device can measure the values: pressure, magnetic field, acceleration, sound intensity, radiation force, humidity, etc.

The sensor is defined as a device for measuring physical quantities (mass, pressure, humidity) then being transformed into an impulse and sent for reading to an expert using an instrument and then can be processed.

In this field of automation, the qualitative / quantitative information to be measured is distributed through the sensors, helping to control and regulate the automatic technical systems.

The pressure sensor helps the electronic computing units in the tape component to know the amount of liquid in the bottle, and when it is full the sensor sends a signal to stop the procedure. [13-14]

3.1 Proximity sensor

It is a device that detects the presence or absence of an object on the tape, the properties of that object being then transformed into a signal and read by a simple electronic instrument, without coming into contact with it. An industry that uses proximity sensors is to pack bottles where we need to know when the bottle reaches the tape and the tape starts automatically.[12]

Figure 1 Proximity sensor

3.2 Color sensor

Color sensors They are intended for sorting, evaluation and examination in automation systems. In our project, for the sorting tape they help us to classify the colored bottles, the white ones, so that each of them goes in the right direction without the need for human intervention in the execution. [4-11]

Figure 2 Color sensor

3.3 Pressure sensor

The pressure sensor helps the electronic computing units in the tape component to know the amount of liquid in the bottle, and when it is full the sensor sends a signal to stop the procedure. [2-15]

Figure 3 Pressure sensor

3.4 The importance of the sensors used in the project.

The first sensor used is the weight sensor, the role of this sensor is to detect when the glass is on the tape, and it will start automatically. The tape will only start when the weight sensor transmits the pulse that shows that the glass has reached the tape, and when it no longer detects anything, the tape will stop automatically.

The color sensor, the role of this sensor is to make it easier and faster to sort the bottles according to their color, when the bottle reaches the sensor, it will start scanning the bottle, after which it will automatically send a pulse, and depending on the color of the separation piston bottle will be actuated or not without the need for human intervention.

The detection sensor, the role of this sensor is to detect when the bottle is at the solenoid valve so that it can be bottled, when the sensor detects the bottle it immediately sends a signal to the filling solenoid valve to be able to start the bottling process.

3.5 Description of the whole process.

The whole process consists in sorting, bottling and packing the bottles of water and automated juice, without the permanent need for the duties of a permanent worker.

These will only be set for the process that is needed, the working time that is needed will be set, and after activating the start button the tape will do its job automatically.

If at some point something doesn't work properly, we have the stop button that stops the whole band, without starting until our next impulse.

The first part of the whole process is the sorting process where the tape automatically sorts the bottles according to their color (colored for juice and white for water). These are sorted using the color sensor and the separation piston. When the tape starts, the bottles arrive in front of the weight sensor so that they can be partitioned. Arrived at the weight sensor, we have a timer that gives the sensor time to read the glass, if the glass is white the glass continues its path on that band, and if the glass is colored the sensor sends a signal to the separation piston, which is actuated and move the bottle on the juice tape, this operation continues until the last bottle on the tape.

The next well-defined process is the bottling process. With the help of the detection sensor we will be able to know exactly when the bottle is next to the filling solenoid valve, and then the sensor will send a signal to the filling solenoid valve to be able to start the bottling process. The time relay will help us count the bottles, so you can know when we have reached the number of 60 bottles of water. When the 60 bottles will be filled automatically, the switch will be made to the other strip to resume the same process but with the juice bottles, and when the juice bottles will be full, the bottling process will be finished.

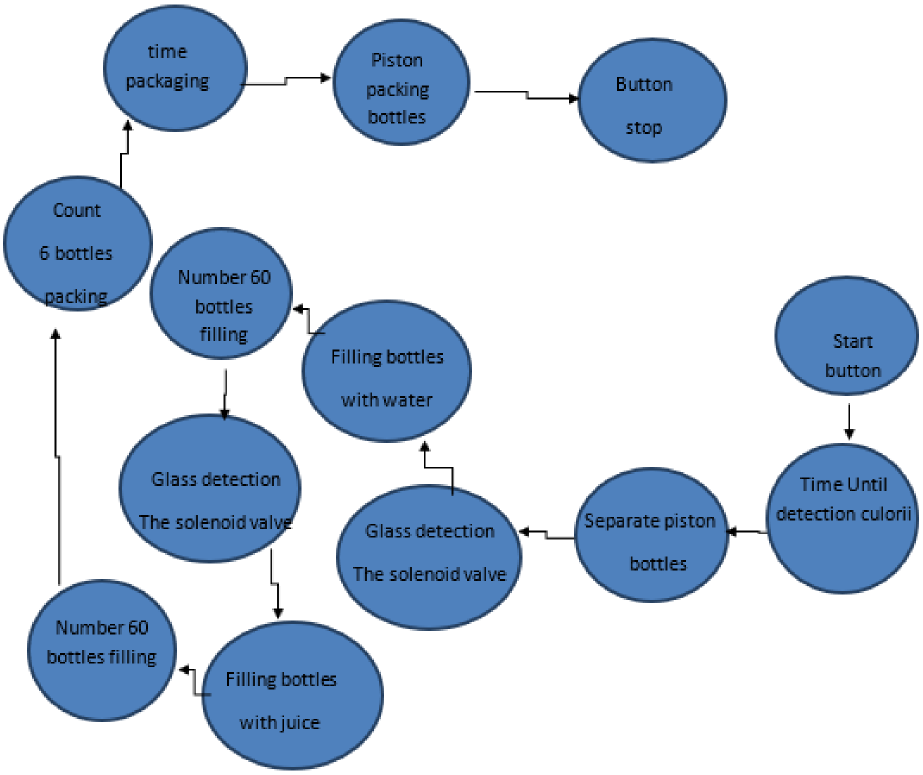

Figure 4 Block Scheme

The last process will be the process of packing the water and juice bottles, where after finishing the bottle bottling each water bottle will go through the time relay that will count 6 bottles, reaching the number of 6 bottles will automatically trigger the piston packing, and this process will be repeated 10 times until we reach a number of 6 boxes of water and all the water bottles will be packed. Once finished with the water bottles, the switch will be made to the next strip where the 60 juice bottles will be, and there the process will be identical to the one for packing the water bottles.

3.6 Actuation of automation

In the following figure the contact coil M01 is actuated, its contact on line 003 closes and signals the coil Q01, the band starts.

The time relay T01 is a normally closed contact that counts 5 seconds in which the glass reaches the color sensor.

T02 is an open norm contact, which flashes 2 by 1 while the sensor detects the color of the glass.

I16 is a weight sensor that on line 004 is normally closed because the weight it reads is not optimal, when it reaches the right weight the sensor on line 004 opens and the one on line 005 closes.

T04 is the time relay that activates the tape through flash 2 with 1, 2 seconds is the packaging time of the bottle, and one second is the waiting time for the next bottle to reach the packing line.

T06 is a time relay that works for 15 seconds, and in 15 seconds it reaches the number of 6 bottles.

Contact coil M03 when it receives a signal opens its contact on line 006 and the tape resets.

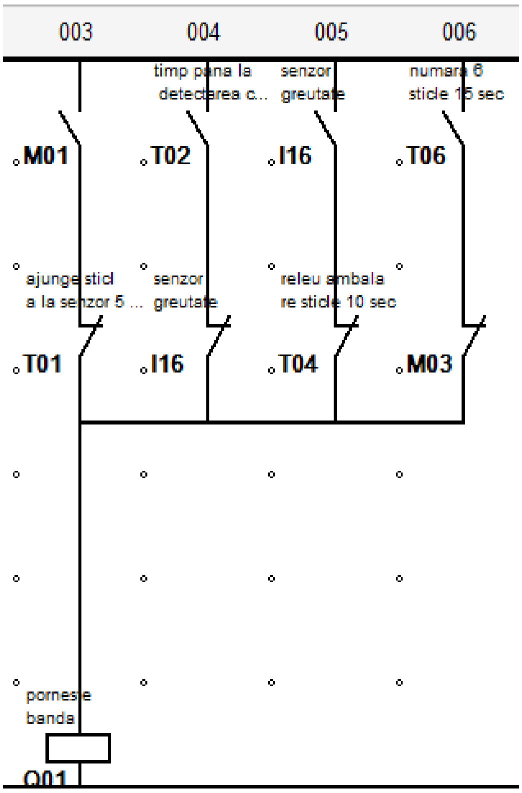

Figure 5 Tape is activated

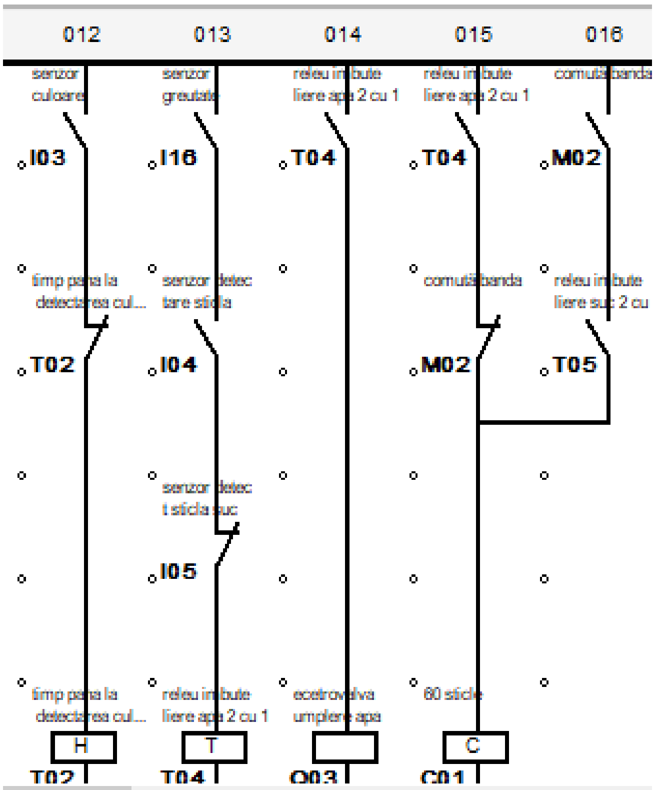

Figure 6 Filling botles

3.7 Separation of bottles on tape

The time relay coil T01 receives a signal from the contact of the coil M01, which counts 5 seconds the time for which the bottles need to reach the color sensor. The contact of the time relay T01 gives further contact to the coil of the time relay T02, through the flash 2 with 1, 2 seconds it analyzes the color of the bottle, and a second in which the next bottle is waiting next to the color sensor.

3.8 Bottling of bottles

The time relay T05 counts 60 bottles after which it commands the coil Q04, it operates the solenoid valve that bottles the 60 bottles of juice. T05 passes on the coil T06, in this time of 15 seconds the metering relay counts the 6 bottles, after 15 seconds it passes on the coil T07, through flash 2 with 1, 2 seconds packs the 6 bottles in a bax, one second wait for the next bax to be packed.

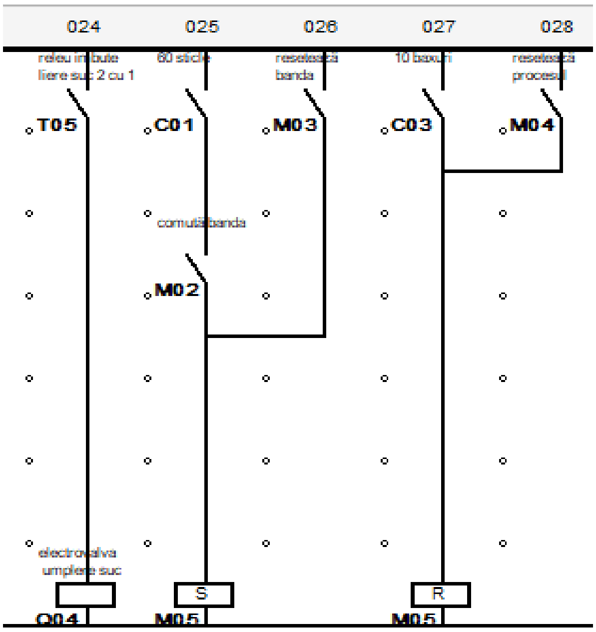

Figure 7 Bottling of bottles

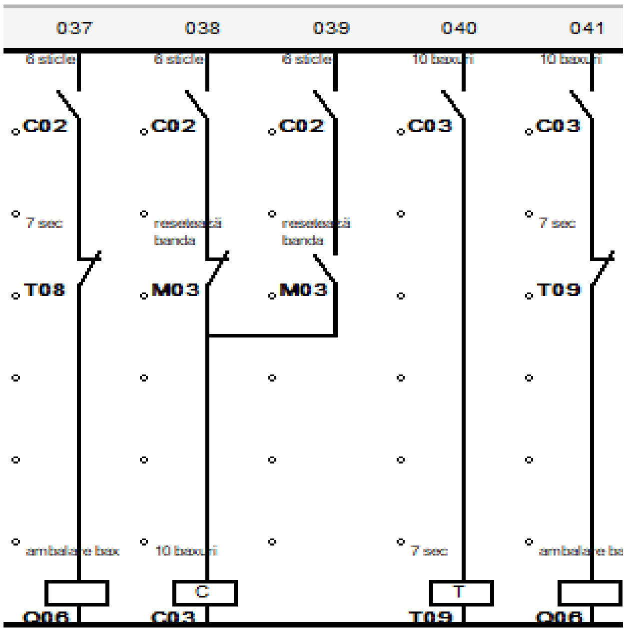

Figure 8 Packing the boxes

3.9 Packing the boxes

C02 is a normally open contact that counts the 6 bottles for 7 seconds, after counting the bottles the contact of the coil C02 gives a signal to the coil Q06 that starts the process of packing the boxes. C03 is the metering relay that counts the 10 boxes. T09 is the time relay for packing the boxes, for 7 seconds the boxes are shaken. After the process of packing the water bottles, the contact of the coil C02 gives an impulse to M03 which resets the strip, and the process is repeated for the juice bottles.

4. Conclusion

In this paper, an automated system for sorting, bottling and packaging juice and water bottles is created using the EASY SOFT program.

In this project you can see the economic and qualitative efficiency of sorting, bottling and packaging of bottles, based on programmable machines.

The advantages of carrying out the entire process that will be automated through the EASY SOFT program are:

- • Required fewer people.
- • Lower costs.
- • Accelerate the whole process.
- • Due to the high-performance machines, the probability of making a mistake during the operation is lower.
- • Working capacity is higher.

The EASY SOFT program is complex based on a lot of advantages, among them we mention, the design in a wide range in practice, the diversity of programming languages, using the language with LD contacts.

The automation process can be applied practically in the juice and water bottling plant, in which it follows the technological stages of the process, the programmable automata, closely following the sensors and the input data.

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Sustainability and green certification in built environment

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Abstract

The sustainability of our built environment is extremely important, because it uses a lot of resources, produces waste and responsible about 40 percent of global greenhouse gas emissions. Many goals of sustainable Development related to building sector and built environment so it is very important how to reach the requirements of zero or near zero energy should manage the energy usage. One possible answer for this question is the building certification system apply in a large field. Our paper gives a short review about two important and well-known certification system, about the LEED and BREEAM green building certification systems. Highlighting the advantages and disadvantages of methodologies and criteria systems related to energy and energy management.

Keywords: sustainability, build certification, LEEDs, BREAM,

JEL Classification: Q56

1. Introduction

Achieving sustainable development and sustainability has become a fundamental objective over the past decade. The main drivers are economic and consumption growth and the overuse of resources, the local and global consequences of which are being controlled with great efforts. The role of the built environment and buildings has proven to be significant. In terms of sectoral weight and the extent of the built environment, construction, architecture, and buildings are one of the most important areas for reducing environmental impacts and achieving sustainability goals, as they are the sector:

- the built environment is responsible for around 40% of global energy use, and therefore contributes significantly (30%) to greenhouse gas (GHG) emissions.
- It accounts for between half and one third of total material and goods consumption, making it one of the largest sectors for waste generation and natural resource use.
- It plays a key role in shaping positive health, disease prevention and occupational impact factors for people, as 90% of people spend 90% of their time in some form of building. Thus buildings and indoor quality play a critical role in the quality of human life.
- buildings provide 5-10% of world employment and 5-15% of GDP.

It is no coincidence that there is increasing pressure on the sector to engage with environmental and social issues. However, the sector's move towards sustainability is still hampered by limited coordination and information exchange between different actors, and the availability and accessibility of data for assessments.

2. Steps towards sustainability

The steps taken to ensure the sustainability of our built environment are extremely important, as the construction industry and our built environment are responsible for a large share of global energy, raw materials, and emissions. Nine of the 17 sustainable development goals (SDGs) set by the United Nations are

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directly linked to the built environment or construction sector (UN, 2015). The selection of materials, technology, energy efficiency, renewable energy, heating and cooling systems, active and passive houses, circular solution are all very important towards sustainability. The better and more energy efficient buildings improve the quality of citizens' life while bringing additional benefits to the economy and the society. Quality buildings maximize user benefits and minimize environmental impact. A consistent approach to assessing the quality of buildings against measurable criteria will allow evidence-based benchmarks and targets to be set, regulatory requirements to be met or exceeded, and comparisons between buildings to be made.

Building sustainability assessment methods have been in use worldwide for more than two decades. Their use initially spread slowly among the larger developed countries, but today many building quality certificates exist. In recent years, rapid development of new, regionally adapted methods has also been observed. The use of building valuation methods is limited as they are based on national legislation and local characteristics. These differ from region to region, in their rating processes, in the evaluation of the weighting and methodology of each rating category (factor).

The methodology and content of the performance assessment of buildings are defined by legislation, the practical implementation of which is supported by the relevant standards. Interoperability between energy audit and building energy certification cannot be interpreted. There may be similarities and overlaps between certification and auditing, as both include an assessment of the building for energy purposes, but the result of the activity is different. The Energy Performance of Buildings Directive (EPBD)**,** one of most important fundaments of the EU energy policy, as part of the Renovation Wave – the flagship initiative of the European Green Deal aiming at increasing the rate and depth of building renovation across the EU. In the 2018 revisions of the directive, there is an increasing need for energy management (energy management system) solutions in which automation and control technology based on information and communication technology and the operation of intelligent systems are required.

3. Green Building Certification

The certification of green building certification systems is a voluntary activity not required by law, which means compliance with a stricter system of requirements than the law. Responsible investors, contractors and operators will decide on the introduction of green building certification certificates, who will appreciate the savings potential of regulated design, construction and operation and its marketing and potential tax benefits.

The certified design and implementation of construction and operation is also positively assessed by the investor side: factors such as operating cost savings and lower risks of stricter legal compliance, better stakeholder management (eg less residential and resident dissatisfaction) but generally greater marketability and also through positive industry acceptance._According to experts, with the expansion of stricter legal regulations and the expansion of environmentally conscious thinking, in a few years' time an unqualified premium commercial property will be practically unsold in Hungary as well. It is becoming more and more noticeable that institutional investors rank environmental ratings much earlier than 5-8 years ago when valuing one such property. Depending on the investment policy, it is already common for projects or properties that are not certified to be short-listed.

Both LEED and BREEAM certifications require structural and design intelligence from builders, providing a well-designed design and technology that is important to tenants. In this way, it is also possible to keep service fees as low as possible and for tenants to populate their area as efficiently as possible. In a strong labor market environment, such as in Budapest today, well-designed, comfortable office space is also a means of retaining the workforce. All these factors result in cost savings. And that’s where qualified buildings really influence decisions. In the history of the Budapest office market, it has never been more important to create the most usable and healthy buildings than in 2019.

3.1 Some methodological aspects of green certification

It can be said that energy consumption in the LEED system has the greatest weight within the rating. The weight of energy can be measured in the fact that, in addition to making it a priority for the environment from tackling GHG emissions, much of the maintenance costs are related to energy consumption. There is a tendency that in the methodological revisions of 2018 the energy-related requirements have shifted to the category of the minimum requirement, and the number of credits obtained by fulfilling them has decreased. In the field of energy, both building certification systems require the assessment of the energy performance of a building as a minimum criterion. LEED use the American ASHARE standard, while BREAM use a custom-developed indicator. LEED also requires energy modeling, which is a more complex task that requires software support. The system is also the minimum energy monitoring in the buildings to be certified. In the case of LEED, the energy monitoring is without credit, a certification condition, but an additional 1 credit point (out of 100) is further developed for energy measurement and monitoring. In the case of BREAM, 2 credit points can be obtained by setting up the appropriate energy monitoring. LEED also places special emphasis on the topic of the local grid: it gives credit points if the building and the energy management system built in it can flexibly adjust consumption to price or other factors. Demand for flexibility applications requires an advanced energy management system the availability of data on the required energy, in appropriate breakdown and quality, can be analyzed and consumption can be controlled centrally (manual is not accepted). Although "Demand Response" (demand flexibility) does not work in all countries, buildings prepared for this change in the market have been positively assessed. The use of renewable energy sources is not a mandatory element, but it makes a significant contribution to the greening of buildings.

3.2 LEED

LEED (Leadership in Energy and Environmental Design) is a certification system that assesses the sustainability of a building or facility during the design, construction and operation of green buildings. The system is owned and operated by U.S. Pat. It was established by the Green Building Council in 1993 but is also gaining in popularity across Europe. LEED has now grown into the largest and most recognized system in the real estate market. The reason for the rapid spread is the large domestic market and that the certification operates in any country in the world without local accreditation. In most European countries, a national Green Building Council (GBC) oversees the use of LEED certification. In Hungary, this is done by the Hungarian Environmentally Conscious Construction Association (HuGBC), the first certification was issued in 2011.

Qualification levels

The evaluation itself consists of three parts. A preliminary review will be carried out on the basis of the documentation submitted in each category (prerequisites). After that, the documentation can be further developed. The final review consists of an evaluation of any documents that may have been added, resulting in a final score. The third stage is the appeal stage, when the documents submitted during the appeal are evaluated. Qualification will be based on accepted final points. No weighting is applied between the individual aspects and points. A building can receive a total of 100 points, with an additional 10 points available in the Innovation category. Based on this, the certification can be worth a total of 110 points, based on which it can be:

- • certified (over 40 points)
- • silver (above 50 points)
- • gold (over 60 points)
- • platinum (above 80 points).

3.3 BREEAM

The BREEAM (Building Research Establishment Environmental Assessment Method) is currently the most widely used building sustainability assessment and certification process in the UK. The valuation methodology was first introduced to the market in the world in 1990. It has quickly established itself as the industry standard in the UK. It was created by the BRE Research Institute, building on its 90-year history of building technology research.

BREEAM is the most important green building valuation method in the world, including Europe, with a market share of 80%. They are used in the basic design of projects, infrastructure and buildings. In 2018, more than half a million buildings in the UK were certified with it, AND assessments are being carried out internationally in more than 81 countries. In 2019, the number of buildings certified using the BREAM methodology exceeded 2 million 277 thousand buildings. For the first time in Hungary, a building received BREAM International certification in 2008, and today the number of certified buildings has increased to 99. 98% of the certified buildings in Hungary are located in Budapest, and one is registered in Hegyeshalom and Tata.

The system formulates the sustainability criteria grouped into 9 categories, thus measuring the performance of the qualified project in a holistic way. The criteria typically follow European and domestic standards. Different weighted categories determine the total score that results in rating levels marked with an asterisk. Newly built projects are typically graded in two stages, the design stage and post construction, while existing buildings are graded in one step through an online interface and require annual renewal.

4. Energy management

The energy management system any complex solution and task that aims to increase energy efficiency within the organisation by reviewing energy consumption processes, identifying savings potentials and thus realising cost reductions continuously in several steps, defining not only economic but also comfort functions. A fundamental starting point is the development of an energy policy for the organisation. The introduction of an energy management system is voluntary, based on an internal policy of companies taking environmental responsibility. The most widely used standard is the ISO 50001 family of standards, which defines the requirements for the development, implementation, maintenance, and improvement of energy management systems.

An energy audit is a procedure, using a defined methodology, to gather appropriate knowledge about the current energy consumption profile of a building or group of buildings, industrial or commercial operation or facility, or private or public service. It identifies and quantifies cost-effective energy saving opportunities and reports the results. It is characterised by high quality, transparent, non-discriminatory, accessible to all, cost-effective, independent, transparent and non-discriminatory minimum requirements”. In Hungary, the energy audit has been a legal obligation since 2015, which is intended to promote the spread of energy-conscious corporate governance and the competitiveness of economic operators. The energy audit measures the actual energy consumption of large companies, and its scope is comprehensive, not only for buildings. In addition, the scope of the energy audit has been extended by Government Decree 122/2015 (26 May 2015) to companies with significant energy consumption and public institutions. In the energy audit of these companies, in encouraging the development of an appropriate energy management system and in identifying energy savings, the specialised advisers and the National Energy Network provide an advisory role. The latter provides services to public institutions and SMEs on a non-profit basis.

5. Conclusion

In recent years, the assessment of building performance has become a focus of interest as the regulatory environment has become more stringent. Energy certification and property valuation practitioners have increasingly turned their attention to the definition of "green value" for the sustainability of buildings. This has brought a renewed focus on valuation methods related to the sustainability and energy efficiency of buildings and their practical applicability. The uptake of benchmarking methods in developed Western countries (USA, Western Europe) is more widespread than in our country, but attention to environmental and energy certification schemes is also growing in Hungary.

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Indoor climate and energy monitoring system at educational institutions

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Abstract

Buildings are one of the largest energy consumers. Accordingly, most energy is consumed in large public buildings, which include university campuses. Management of energy flows in such buildings and ensuring their energy efficiency begins with the control and analysis of energy consumption. The implementation of the pilot system of energy monitoring of the university building on the example of the educational building of Ivano-Frankivsk National Technical University of Oil and Gas is presented. The monitoring system is based on smart-MAC devices that measure electricity and heat consumption, consumption of cold and hot water, microclimate parameters in the building, and meteorological parameters. The energy monitoring system based on smart-MAC devices is easily deployed and configured, the connection of data transmission devices is carried out via the Wi-Fi network, which is already available in most buildings. All collected data in the system is stored in the cloud storage with minute detail and is available for further analysis and decision making in a convenient WEB application.

Keywords: building energy monitoring system, energy consumption, energy accounting, microclimate indicators.

1. Introduction

The buildings account for about 40% of world energy consumption, which causes about a third of all greenhouse gas emissions (Nejat et al., 2015). Energy costs for buildings in Ukraine are 2-3 times higher than similar costs in EU countries. Almost 90% of buildings in Ukraine do not meet modern energy efficiency requirements, which leads to overuse of energy for heating and non-compliance with the requirements for the microclimate of the premises (Shevchenko & Shovkaliuk, 2019). These buildings include a significant number of public buildings, from kindergartens and schools to universities, offices, health, and cultural facilities. Accordingly, a significant part of funds from local and state budgets is spent on the maintenance of such buildings in Ukraine (Parfenenko, Shendryk, Nenja & Vashchenko, 2014).

Continuous monitoring of heat, electricity, and water consumption in public buildings is the basis for effective energy management. In real operating conditions of buildings, the determination of their current energy consumption by different types of energy resources is carried out through the use of metering devices – heat, electricity, and water meters. The current practice operates only on monthly readings of buildings' energy consumption, which greatly complicates the process of operational analysis and, accordingly, complicates the decision-making process to reduce energy consumption in compliance with the regulatory conditions of the microclimate in buildings. Thus, it is important to develop an automated system for monitoring and managing energy supply, which should implement the task of determining hourly and daily energy consumption by different municipal buildings for different types of energy resources with fixing the parameters of the internal microclimate.

2. Pilot energy monitoring system for the university building

Currently, there are plenty of choices to select an energy monitoring system for buildings from the existing market (Baranyai & Kistelegdi, 2014; Ibaseta et al., 2021; Mataloto et al., 2021; Nguyen, Zhang & Mahmood, 2021; Zhao, Zhang & Liang, 2013). However, for public buildings, it is important to make such a monitoring system simpler, reduce its construction cost, integrate it with existing meters, and of course, make it more flexible and accessible in setting up visualization and storage of data without special skills. Everything mentioned above is really useful for public buildings taking into account its large areas and a large number of measuring points for energy and microclimate parameters.

Scientists from Ivano-Frankivsk National Technical University of Oil and Gas (IFNTUOG) conducted a thorough study to find optimal solutions for the implementation of energy monitoring systems of the university building, which meet the above requirements. To build a monitoring system, "smart" devices energy monitors of the Ukrainian company smart-MAIC were selected (Smart-MAIC, 2021). The range of smart-MAIC devices is represented by energy monitors for continuous measurement of electrical network parameters and electricity consumption, universal pulse meters for measuring water, gas, heat consumption, and appropriate sensors for measuring temperature, humidity, pressure, carbon dioxide concentration in the air, wind speed and direction, and other parameters (Figure 1).

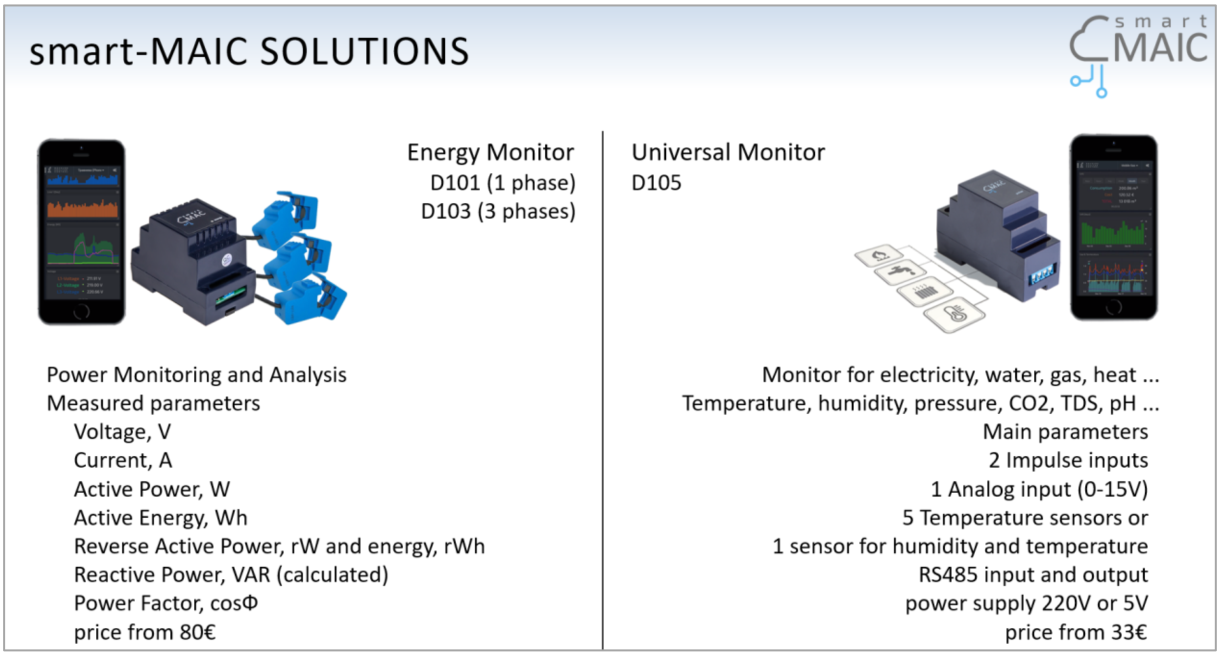


Figure 1 Model range of smart-MAIC devices

Smart-MAC devices are easy to install and connect. All devices are made in a universal housing with the possibility of mounting on a DIN rail. Once turned on, the device becomes available as a Wi-Fi access point. Initial setup of the device is possible from any mobile device and takes minutes. Special settings are not required for the device. The device is automatically connected to the cloud data server and provides bidirectional information exchange. After installation and initial setup, the smart-MAIC device will start converting the measured parameters into information that will be sent using Wi-Fi wireless technology to the cloud data server. For data analysis and visualization, the universal WEB-application smart-MAIC Dashboard is used, which is available in a regular Internet browser, as well as an application for Windows, Android, and iOS platforms. All collected data is stored on a cloud server with minute detail. When working in real-time, the readings from the meters are updated at intervals of 5 seconds. Smart-MAIC Dashboard allows you to monitor current readings and visualize historical data obtained from smart-MAIC devices, for example, to optimize consumption in dual-tariff or multi-tariff accounting. The user has a flexible configuration of indicator and graph widgets, an unlimited number of pages and devices connected to one account. Similarly, the current data is available on the WEB page of the device.

The pilot energy monitoring system for the university building using smart-MAIC devices has been installed at the Department of Energy Management and Technical Diagnostics (EMTD), IFNTUOG. The EMTD department occupies approximately 30% of the university academic building №9. It is location has been shown in Figure 2. Such an energy monitoring system can be simulated in the department's domain. The results of such simulation can be extended by analogy to the other university buildings in perspective.

a) *b)*

Figure 2 Educational building №9, IFNTUOG (*a*) and the auditoriums of the "Energy Management and Technical Diagnostics Department" (*b*)

The structure of the pilot energy monitoring system for the university building is shown in Figure 3. The energy monitoring system allows obtaining real data on the consumption of electricity and heat, cold and hot water consumption for the university building. In addition, in each classroom, there is the monitoring of the main indicators of the microclimate - temperature and humidity, carbon dioxide concentration. A separate component of the monitoring system is a meteorological module that will monitor the temperature and humidity of the outside air, wind direction, and speed, atmospheric pressure, intensity of solar radiation (insolation), the value and trend of changes in atmospheric pressure.

The product lineup of smart-MAIC devices is represented by solutions for monitoring any events, conditions, and processes, for instance, one- and three-lines power monitors with a ring or removable current transformers, pulse meters with temperature sensors, and analog input. The devices have a convenient design in the form of a DIN rail box in accordance with EN 60715:2017 standard. It gives a possibility to mount them in any new or already installed switchboard. Figure 4 shows an example of installing a segment of the energy monitoring system for the university classroom.

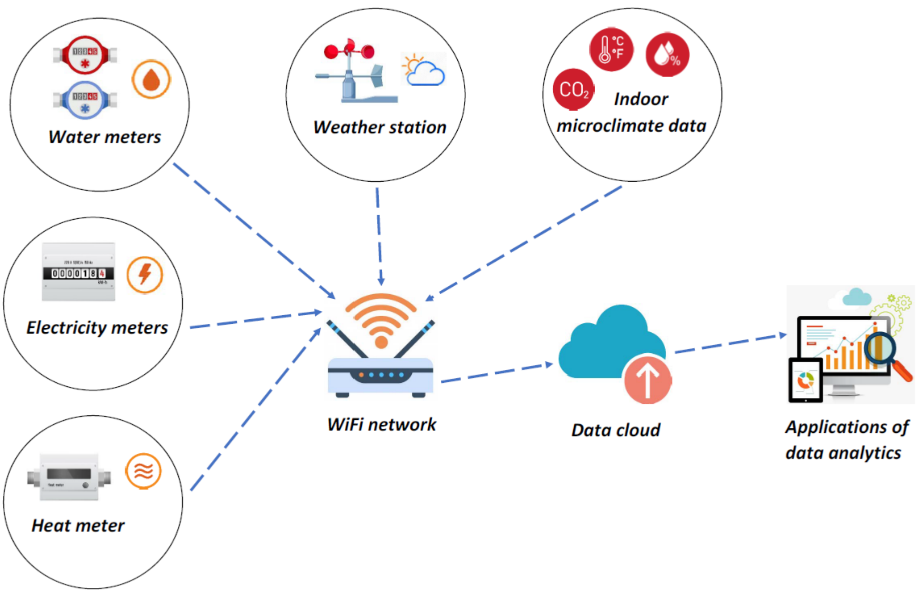


Figure 3 The structure of the pilot energy monitoring system for the university building

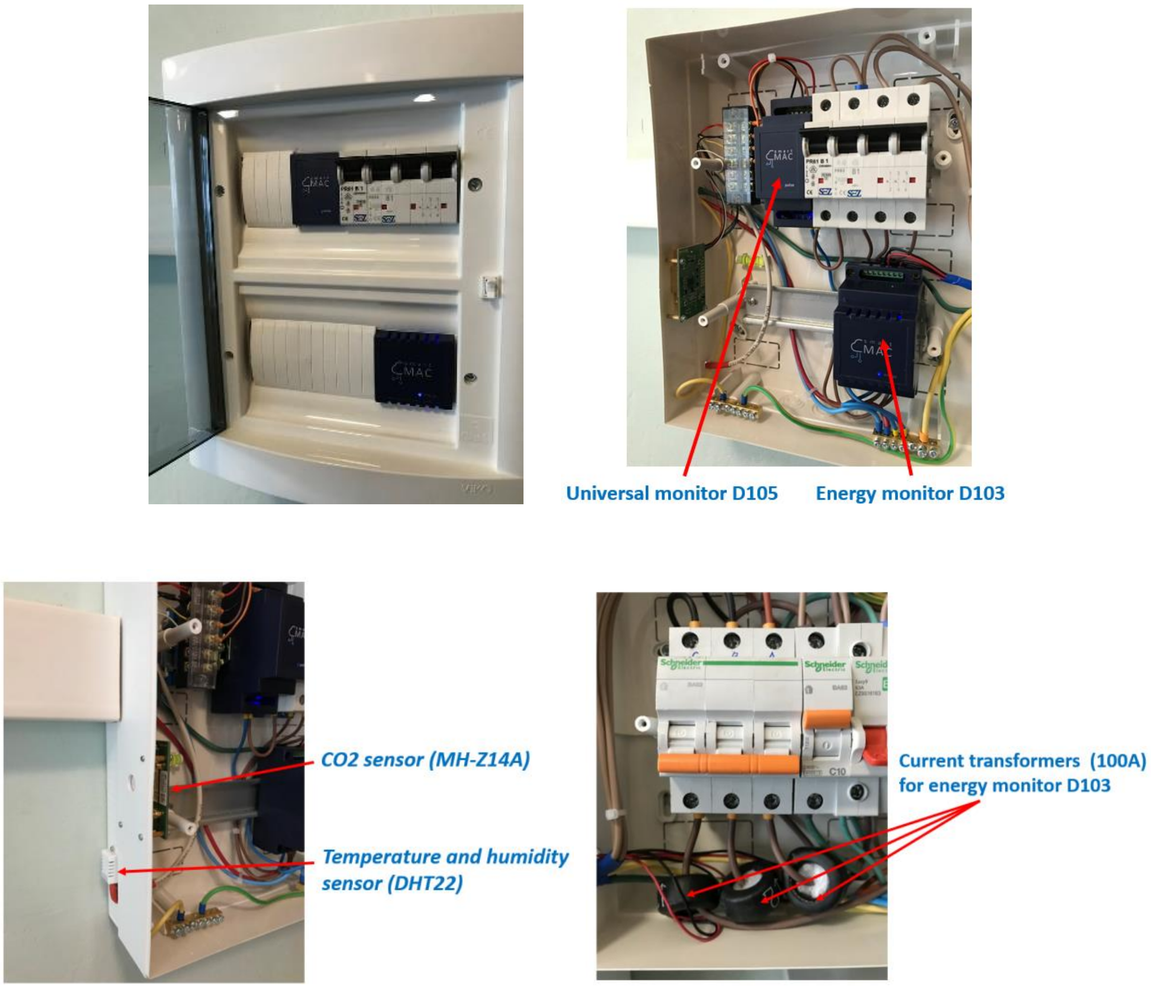


Figure 4 An example of installing a segment of the energy monitoring system at the educational audience

An energy monitoring system is used in the classroom to control the microclimate parameters such as temperature, humidity, and carbon dioxide level. For this purpose, it is used a universal monitor smart-MAIC D105 to which temperature-humidity (DHT22) and carbon dioxide (MH-Z41A) sensors are connected. To determine the level of electricity consumption in the room (room is equipped with electric heating) is used energy monitor smart-MAIC D103, which provides a connection to a three-phase power supply line by voltage and current (using ring current transformers at face value 100A). The data collected from the devices is stored in cloud storage and is available for viewing and analysis in real-time. Information aggregation on a specific room or other monitoring objects, its visualization, and further analysis are carried out in the cloud WEB-application smart-MAIC Dashboard. The user can customize the appearance of widgets of indicators, graphs, and tables for the information panel. Figure 5 shows an information panel example of a segment of the energy monitoring system for the educational room.

Figure 5 Dash-board of a segment of the energy monitoring system for the educational room

The dash-board information panel (Figure 5) displays the current values of temperature and humidity and the concentration of carbon dioxide in the room, voltage, current, power consumption for each phase of the power line. It is important to monitor the change of controlled parameters over time to analyze the energy consumption, temperature inertia of the building, the efficiency of the heating, air conditioning, and ventilation system. WEB-application smart-MAIC Dashboard allows you to build a variety of graphical dependencies with different time details (minute, hour, day, week, month, year) and with different types of the graphical display of trends (line, area, bar chart). Additionally, the user can configure the output of the required data in the table form. That can be used to detail consumption and costs, setting the cost for energy or hot/cold water, the consumption of which is monitored by the monitoring system. For further analysis, for example, in the Excel software, the data arranged in the table are exported in CSV format.

The smart-MAIC D103 energy monitor with appropriate current transformers is also used to estimate the electricity consumption of the whole house or part of it. The line of smart-MAIC devices uses current transformers from 100A to 1000A, which gives a possibility to control the load in the building up to 1MW. An example of installing an energy monitoring system segment to determine the electricity consumption of a part of a building is shown in Figure 6. In this case, the electricity consumption for the entire department occupying a part of the building is monitored. Accordingly, the smart-MAIC D103 energy monitor with capped ring current transformers at 300A is used. To visualize and analyze data on electricity consumption, the department forms a separate information page in the cloud WEB-application smart-MAIC Dashboard similar to the one shown in Figure 5.

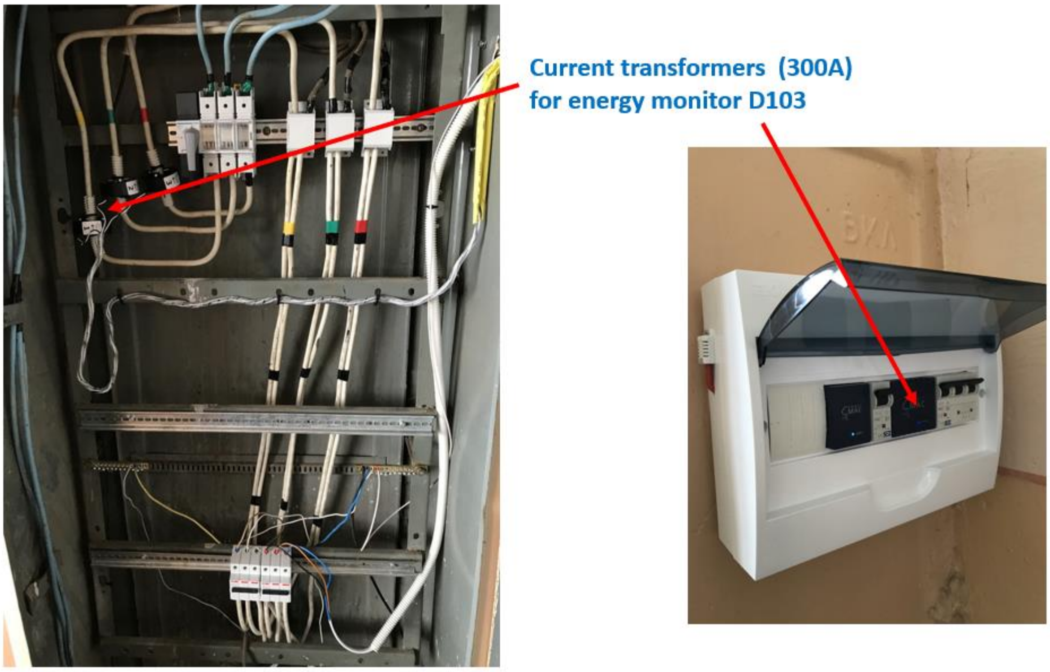
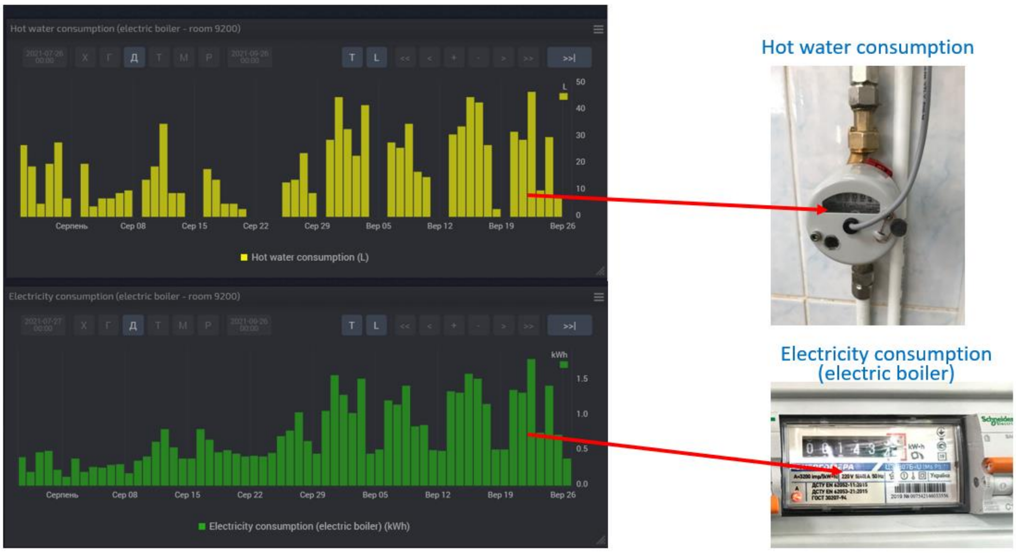


Figure 6 An example of installing a segment of an energy monitoring system to determine the electricity consumption of a part of a building

For the integrated solutions of the energy monitoring tasks, third-party devices are also integrated with smart-MAIC devices - water, heat, fuel meters, sensors for gas meters, and other flow meters with pulse outputs. This approach allows you to use the energy monitoring system meters that are already available in the building. In this case, the equipped with two pulse inputs universal monitor smart-MAIC D105 is used. Figure 7 shows an example of monitoring the hot water consumption in the building and the cost of electricity for its preparation. In this case, a hot water meter with a pulse view, which is mounted on the output of the electric boiler, and a classic electronic meter with a mechanical metering device (through which the boiler is powered), which has a telemetric pulse output. Accordingly, these meters are connected to the universal monitor smart-MAIC D105 to transmit data to the energy monitoring system of the building.



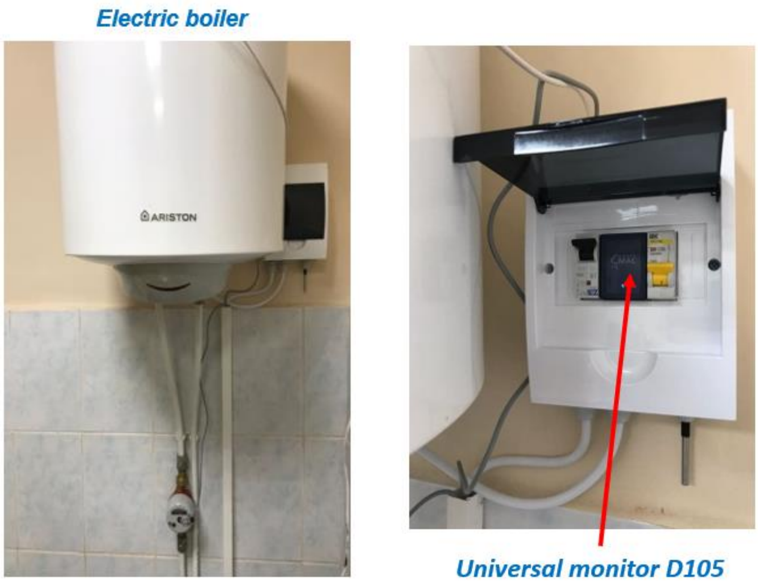


Figure 7 An example of the hot water consumption monitoring in the building and the cost of electricity for its preparation counting

The building's energy monitoring system must have a meteorological module to obtain local meteorological data. Indeed, to assess the energy efficiency of the building, it is necessary to obtain information on the thermal energy consumption or the consumption of natural gas or electricity used for heating the building, depending on the outside air temperature. Figure 8 shows the implementation of part of the meteorological module of the energy monitoring system of the building, which is designed to record the temperature and humidity of the outside air and the value of atmospheric pressure. The temperature, humidity, and atmospheric pressure sensor BMP280, connected to the universal smart-MAIC D105 monitor, is used as the primary converter. To ensure correct meteorological data, the sensor is protected against solar radiation – it is located on the north side of the building in the shade. Also, the energy monitoring system allows you to integrate other devices, as an example related to security systems. Figure 8 shows how a dosimeter radiometer is attached to the building's energy monitoring system to monitor the state of the radiation background.

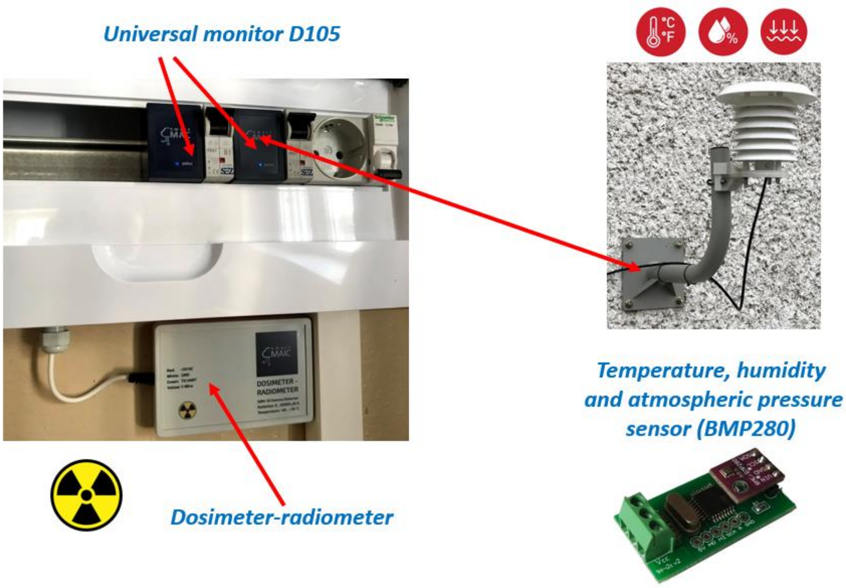


Figure 8 Implementation of parts of the meteorological module of building energy monitoring systems, which are designed for registration of temperatures and humidity of outdoor air and atmospheric pressure values

3. Conclusion

The obtained data on actual energy consumption, after the deployment of the pilot monitoring system, during the calendar year will allow to assess the specific thermal characteristics of the building, determine the actual energy consumption to ensure regulatory microclimate in the building, assess the rationality and trends of energy consumption. Also, such data will help to assess the real effect after the implementation of energy efficiency measures to reduce energy consumption in university buildings.

Acknowledgements

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Roadmap for building an energy management system at university as public institution

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Abstract

ISO 50001 purpose of enable an organization to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy security, energy use, and consumption. Ivano-Frankivsk National Technical University of Oil and Gas has been dealing with energy efficiency and rational use of energy resources for more than 10 years. Based on the experience gained, the university scientists have developed and prepared an energy management system for certification. According to the order has been created a working group on energy management has. It is consisting of management representatives and employees, responsible for the functioning of the energy management system. Ivano-Frankivsk National Technical University of Oil and Gas establishes an energy baseline on the results of the initial energy analysis and takes into account the data for the relevant period of consumption of fuel and energy resources.

Keywords: energy management system, standard, energy efficiency, audit, building, approach.

1. Introduction

The standard ISO 50001 Energy Management System (EnMS), created by the International Organization for Standardization (ISO), specifies the requirements for establishing, implementing, maintaining, and improving an Energy Management System. ISO 50001 purpose of enable an organization to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy security, energy use, and consumption.

The ISO 50001 standard is a powerful tool for organizations to improve their energy performance. It has been estimated that the ISO 50001 Energy Management Standard could have a positive impact on some 60% of the world's energy use by providing public and private sector organizations with management strategies to increase energy efficiency, reduce costs and improve energy performance. Effective energy management is a priority focus because of the significant potential to save energy and reduce greenhouse gas (GHG) emissions (ISO (International Organization for Standardization). Win the Energy Challenge with ISO 50001).

The structure of ISO 50001 is designed according to other ISO management system standards, ISO 9001 (Quality Management Systems) and ISO 14001 (Environmental Management Systems) in particular. Since all three management systems are based on the Plan-Do-Check-Act (PDCA) cycle (Figure 1), ISO 50001 can be integrated easily into these systems (ISO (International Organization for Standardization). The ISO Survey-2012).

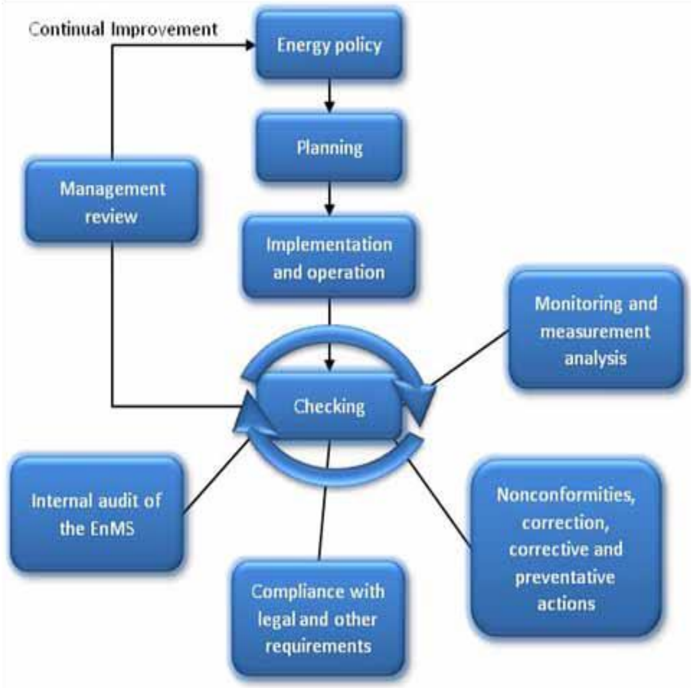

Figure 1 Plan-Do-Check-Act (PDCA) Cycle of ISO 50001

In the context of energy management, the PDCA cycle can be summarized as follows (ISO (International Organization for Standardization). ISO 50001 Energy Management Systems—Requirements with Guidance for Use):

- Plan: conduct the energy review and establish the baseline, energy performance indicators (EnPIs), objectives, targets, and action plans necessary to deliver results in accordance with opportunities to improve energy performance and the organization's energy policy;
- Do: implement the energy management action plans;
- Check: monitor and measure processes and the key characteristics of operations that determine energy performance against the energy policy and objectives and report the results;
- Act: take actions to continually improve energy performance and the EnMS.

ISO 50001 provides a framework of requirements for organizations to develop a policy for more efficient use of energy; fix targets and objectives to meet the policy; use data to better understand and make decisions about energy use; measure the results; review how well the policy works; continually improve energy management (Dobes, V.).

2. Energy Management System Documentation

Ivano-Frankivsk National Technical University of Oil and Gas (IFNTUOG) has been dealing with energy efficiency and rational use of energy resources for more than 10 years. During the last years, it was established an energy audit laboratory and an energy management center. Also, it was purchased special equipment and was provided staff training. During the last time, it was conducted energy audits not only for all university buildings but also for more than 50 private, public buildings and enterprises. Also, it has been set up an attestation commission to train people who will deal with energy management and energy audits of buildings and energy systems.

Based on the experience gained, the university scientists have developed and prepared for certification an energy management system. List of documents for energy management system consists of Implementation order of EnMS; Regulation on the working group on the EnMS; Energy Policy; Questionnaire - Management system certification body; Documentation management; Internal Audit; Corrective and Preventive Actions; Record Management; General Guidelines; Methodology for calculating the basic level of consumption of fuel and energy resources, and analysis of energy consumption (Figure 2).

Figure 2 Documents for energy management system

On the basis of the developed documents, which concern the implementation of the energy management system, was signed an order to approve the developed regulatory documentation in accordance with the ISO 50001 requirements in the conditions of IFNTUOG, including Energy Policy. According to the order has been created a working group on energy management has. It is consisting of management representatives and employees, responsible for the functioning of the energy management system.

The working group has:

- at least once a year to hold meetings to review the implementation of organizational and technical measures to save energy resources, control over the approval and implementation of plans for the use of energy resources and the functioning of the energy management system;
- approve the annual plan for analyzing the use of energy resources and the functioning of the energy management system.

The working group on EnMS is an advisory and consultative body on the effective implementation of EnMS, use of fuel and energy resources (FER), implementation of energy-saving measures and technologies. Its activities are guided by the requirements of ISO 50001, legislative and other requirements related to energy efficiency and rational use of energy resources, orders, and regulations of the IFNTUOG, as well.

The main task of the working group on EnMS is to organize work on continuous improvement of energy management and energy efficiency. In accordance with the task it performs the following functions:

- conducts energy analysis of energy consumption based on measurements and other data;
- establishes and documents the baseline of energy consumption;
- sets energy efficiency indicators for monitoring and control;
- sets goals in the field of energy management for the current year;
- develops proposals for energy objectives and work plans (measures) (a program of measures to save and prevent overruns of energy resources, etc.);
- monitors the implementation of work plans (measures, programs) in the field of energy management;
- identifies the need to increase the competence of personnel involved in significant energy consumption;
- ensures staff awareness on energy saving and the operation of the EnMS;
- determines the need to develop the necessary documentation on the functioning of the EnMS, changes, and additions to it, and measures for its implementation;
- identifies ways to increase energy efficiency and improve the EnMS;
- reviews the results of internal audits of EnMS and participates in the development of adjustments, corrective and preventive actions;

- considers the results of audits of IFNTUOG on the effective use of energy resources and the implementation of energy-saving programs;
- monitors the compliance of structural units with energy-saving legislation;
- considers proposals for the introduction of new energy-saving measures, technologies, and methods for calculating saving of fuel and energy resources;
- considers the submitted proposals for the improvement of EnMS, increase of energy efficiency and rational use of energy resources and makes decisions on the expediency of their adoption for implementation or on justified rejection;
- considers materials on incentives for employees at the management level, which relate to the effective use of energy resources.

The staff of the working group on EnMS is approved by the order of the rector. The work of the EnMS working group is organized by the representative of the management in EnMS, and he/she carries out:

- management of the work of the working group on EnMS;
- if necessary, submits operational issues, calls for an extraordinary meeting for consideration by the working group on EnMS;
- approves the minutes of meetings of the working group on EnMS.

A responsible EnMS employee:

- prepares draft work plans and decisions, recommendations on issues under consideration;
- draws up minutes of meetings;
- exercises current control over the implementation of decisions made and reports on the status of their implementation to the representative of the EnMS management;
- maintains and stores the documentation of the working group.

The EnMS working group, within its competence, has the right to receive information on the functioning of EnMS, energy conservation, and the rational use of fuel and energy resources, consider materials on the savings received from the introduction of energy-saving measures, and submit proposals to the rector of university to promote (penalize) individual employees for the rational (irrational) use of fuel and energy resources.

Responsible for the work of the working group on EnMS is the Management Representative in EnMS. Employees are responsible for failure to perform or improper performance of the tasks assigned to them in accordance with applicable law. IFNTUOG directs its efforts to reduce the consumption of fuel and energy resources and constantly improve the energy efficiency of its processes according to the Energy Policy includes obligations regarding:

- reducing the consumption of fuel and energy resources and the unreasonable costs of fuel and energy resources;
- improving energy efficiency through the implementation of energy-saving measures and the rational use of fuel and energy resources;
- compliance with the requirements of the current legislation of Ukraine, international agreements, standards, methodologies, and instructions in the field of energy resources use, energy conservation, and energy efficiency;
- setting and continuous analysis of energy goals, objectives, and programs for their implementation;
- monitoring, continuous analysis, and improvement of energy efficiency indicators;
- ensuring the availability of information on activities in the area of energy efficiency and providing the necessary resources to achieve the goals and objectives;
- raising awareness, information, and motivation of staff on energy efficiency and the functioning of the energy management system.

The management of IFNTUOG takes responsibility for the implementation of the Energy Policy, including the provision of the necessary information, material, and technical resources. Compliance with the provisions of the Energy Policy is the basis for continuous improvement of the image of IFNTUOG as an institution focused on reducing fuel and energy resources consumption and increasing the energy efficiency level. Documentation related to the functioning of the EnMS belongs to the category of standards of the organization, it is developed in accordance with the approved plans and is subject to development, design, analysis, approval, implementation, accounting, use, verification, modification, updating, re-approval, withdrawal, and cancellation. All these actions are documented by quality protocols. Documentation related to the operation of the EnMS is developed taking into account the requirements of ISO 50001.

Job descriptions are personalized and identified by names, serial numbers, and dates of approval, while regulations on departments are identified by names and dates of approval. Documentation directly related to the EnMS, and falling under the category of work plans, is developed by a designated leader or a working group and approved. The works provided for in the plans are included in the monthly plans, approved, and monitored on a general basis. Internal documents are subject to routine verification to confirm their compliance with existing requirements and needs. The frequency of inspections is set during the development of the document, and in the absence of such instructions, the inspection is carried out every 3 years.

Internal documents on paper and in electronic versions are used as official documents. Computer files with the ultimate electronic versions of documents are protected from unauthorized use and password corruption, and all intermediate versions are destroyed. Internal documents that have expired or are subject to replacement are removed from all users, identified by the inscription "Canceled" (or "Canceled and replaced ..."), and, except for the control copy, they are destroyed. The control copy of the canceled document is transferred to the archive, registered, completed (by content, by category of documents, by areas of activity, etc.) with other documents, and stored for at least 5 years. Changes to documents are analyzed and approved by the same person or working group that approved the document and conducted the initial analysis. Making changes is carried out by changes pasting, replacing, deleting, and adding individual sheets; replacing (reissuing) the document as a whole (a new version). It is allowed to make changes to the document by hand with the person's signature, authorized to make changes (quality officer, management representative).

The content of previously approved changes to the document is not included in the following changes. Each change acts independently. During the next change of section, subsection, item, sub-item, paragraph, table, graphic material, an annex to the document, their new full edition is submitted for a change instead of the initial edition and the previous change. In this case, the last change to the document applies. In case of supplementing the text of the document with new sections, paragraphs, subparagraphs, tables, graphics, annexes, or in the case of removing them from the text, the numbering of sections, subsections, paragraphs, subparagraphs, tables, graphics, annexes isn’t usually changed. If possible, new sections are placed before annexes, and new subsections, paragraphs, subparagraphs - at the end of the relevant sections, subsections, paragraphs in the ascending order of their numbering. To maintain a logical sequence of presentation, new paragraphs (in the absence of paragraphs), subparagraphs, tables, graphics can be entered between the existing ones. In this case, the entered paragraph (subparagraph, table, figure) is denoted in the same way as the previous paragraph (subparagraph, table, figure) with the addition of a lowercase letter of the alphabet.

The document planned for development is registered in the Journal of registration and accounting of internal normative documents and changes to them, marking it with a pencil as "project". After approval, the mark "project" is deleted. A copy (usually one) is made from the approved copy of the document (original). After that, the original is identified as a "control copy" and the copy – as a "copy № 2". The purpose of the internal audit is to establish compliance of the EnMS with the requirements of ISO 50001, as well as to verify the effectiveness of the implementation and maintenance of EnMS. The essence of the audit is to inspect the facility and obtain objective information (audit evidence) necessary to determine the degree of compliance with the regulated requirements. The audit object may be a type of activity, a process, an element of an energy management system, etc. Conducting an internal audit allows you to get an objective assessment of the effectiveness of the functioning of all components of the EnMS and to determine ways and means of activities improvement.

The main objectives of the internal audit of EnMS are:

- confirmation of the conformity of activities and results in the management system with the planned activities;
- analysis and elimination of the causes of identified non-conformities;
- confirmation of the implementation and effectiveness of corrective actions;
- assessment of the functioning effectiveness of EnMS;
- assessment of the understanding by the staff of energy goals, objectives, and requirements established by the EnMS documents;
- determination of areas for further improvement of EnMS and its elements.

The internal audit is based on the following organizational principles:

- uniformity – each audit is carried out according to one officially established procedure, ensuring its orderliness, unambiguity, and independence;
- consistency – planning and conducting an audit of various processes of the system is carried out taking into account their established structural relationship;
- documentation – each audit is documented in a certain way, which ensures storage and comparison of information about the actual condition of the object;
- warning – each audit is planned, and the personnel to be audited are warned in advance about the purpose, scope, timing and methods of the audit in order to provide auditors with the necessary level of trust and exclude the possibility of staff evading the provision and demonstration of all required data;
- regularity – audits are carried out with a certain periodicity so that all areas of the EMS functioning are the subject of constant analysis and evaluation by the management;
- openness – the results of each audit are available for review by any employee;
- independence – the persons who conduct the audit do not bear direct conformity for the activities of the auditee in order to exclude the possibility of biased and impartial conclusions of the audits.

Internal audit is divided into planned and unscheduled. A scheduled audit is carried out in accordance with the approved audit program, an unscheduled audit is carried out directly on the instructions included in the monthly plan. The reasons for an unscheduled audit may be the following:

- ongoing verification of the effectiveness of the functioning of the EMS or its individual elements and functions;
- claims or the identification of non-conformities;
- making significant changes to the EnMS;
- verification of the elimination of discrepancies and assessment of the effectiveness of corrective actions;
- other justified cases.

At the beginning of the year, a management representative and/or an employee responsible for the operation of the EnMS compiles an audit program per year. The internal audit planning is carried out in such a way that all EnMS processes are checked during the year. The plan/program fixes the objects of verification and the timing of its implementation, as well as notes the heads of the verification work. The audit is carried out clearly at the time planned in the program. The personnel involved in conducting internal audits should be sufficiently competent in the specifics of the activity; they are subject to verification. They are administratively independent of the officials whose activities are subject to verification and are not involved in the performance of audited work. The working records of the audit results, current findings, and recommendations made during the audit process are documented in any acceptable way, but the fact that the audit evidence is based only on such information that can be verified is taken into account. Upon completion of the audit, all the results obtained should be summarized and it should be determined which ones should be considered as inconsistencies. Nonconformities should be justified by the specific requirements of standards or other regulatory documents for compliance with which audits were carried out.

Corrective and preventive actions are carried out in order to continuously improve the functioning of the EnMS. The purpose of corrective action is to eliminate the causes of identified nonconformities in order to prevent their recurrence. Corrective actions should be determined according to the consequences of the identified nonconformities. Implemented corrective actions (if effective) should be applied to other similar processes and services. The purpose of preventive actions is to eliminate the causes of potential nonconformities (which have not yet occurred but may occur), in order to prevent their occurrence. Preventive actions should be appropriate to the potential consequences. The choice of corrective and preventive actions is made taking into account the significance of the detected nonconformities or potential problems and their possible consequences. The results of the implementation of corrective and preventive actions must be provided for analysis by management.

The analysis of information in order to identify problems that may lead to nonconformities, and assess the need for action to prevent nonconformities are carried out by the executors of the process at least once a quarter. The analysis is organized by a management representative. Conclusions based on the results of the analysis, including identified potential nonconformities and their causes, assessment of the need for action to prevent nonconformities, the proposed preventive actions are considered at meetings. When making decisions on preventive actions, it is necessary to ensure their relevance to the significance of the problems, as well as to take into account their possible impact on other areas of activity. As a result of the discussion, the planned preventive actions are reflected in the minutes of the meeting in any form. The results of the implementation of preventive actions are considered in the analysis by management in accordance with the deadlines and reflected in the minutes of the meeting. In case of negative results and ineffectiveness of preventive actions the repeated analysis of the reasons for nonconformities and search of new decisions are carried out. In case of a positive assessment of the results of the implementation of preventive actions, if necessary, the representative of the management makes changes to the relevant documentation of the EMS (procedures, provisions of the instructions, etc.).

Management of the IFNTUOG in the person of the rector undertakes to implement, ensure the effective functioning and continuous improvement of the EnMS by:

- formulation, approval, and periodic review of the Energy Policy;
- appointment of a management representative in the EnMS and creation of an energy management group;
- providing the resources needed to develop, implement, maintain and improve EnMS and energy efficiency;
- determination of the scope and limits of EnMS;
- bringing to the staff the importance and significance of EnMS;
- setting goals and objectives in the field of energy efficiency;
- ensuring long-term planning of energy efficiency;
- providing measurements and registration of results at set intervals;
- periodic analysis of the functioning of the EnMS by management.

IFNTUOG has developed, implemented, and brought to the attention of the staff “Energy Policy”. It defines strategic directions of activities in the field of energy management and the improvement of energy efficiency in accordance with ISO 50001. The Energy Policy of IFNTUOG is issued as a separate document and approved by rector. The process of energy analysis is performed in accordance with the methodology and includes:

a) analysis of the use of fuel and energy resources on the basis of measurements and other data, existing energy sources are identified and energy use at this time and in the past is assessed;

b) based on the analysis of energy use and consumption, determine:

- - areas of significant energy consumption, ie processes that significantly affect the use and consumption of energy; other relevant variables that affect significant energy consumption;
- - assessment of future energy use and consumption;

c) setting priorities and documenting opportunities to improve energy efficiency.

Analysis of energy efficiency is one of the important steps in determining the energy-saving potential and the formation of an economically sound and feasible energy-saving program. IFNTUOG establishes an energy baseline based on the results of the initial energy analysis and takes into account the data for the relevant period of fuel and energy resources consumption. Changes in energy efficiency are measured relative to energy baselines. As an energy basis for the items of energy consumption: water, heat, and electricity for own needs, the current values of the generalized characteristics of consumption of fuel and energy resources are used, determined by calculation and analytical methods, taking into account the statistics. Adjustment of the energy base occurs in the following cases:

- when energy efficiency indicators no longer reflect the real state of energy consumption;
- significant changes have taken place in the processes related to energy saving and rational use of fuel and energy resources (modernization, maintenance, and repair of equipment).

Energy Policy of IFNTUOG includes obligations concerning:

- reduction of consumption of fuel and energy resources and reduction of unreasonable costs of fuel and energy resources;
- increasing energy efficiency through the implementation of energy-saving measures and rational use of fuel and energy resources;
- compliance with the requirements of the current legislation of Ukraine, international agreements, standards, methods, and instructions in the field of energy resources, energy conservation, and energy efficiency;

- establishment and constant analysis of energy goals, objectives, and programs for their implementation;
- monitoring, continuous analysis, and improvement of energy efficiency indicators;
- ensuring the availability of information on activities in the direction of energy efficiency and providing the necessary resources to achieve the set goals and objectives;
- raising awareness, awareness, and motivation of staff on energy efficiency and functioning of the energy management system.

The management of the IFNTUOG assumes responsibility for the implementation of the Energy Policy, including the provision of the necessary information and material resources. The determination of an objective and reasonable basic level of consumption is a key task for the effective functioning of energy management. Basic indicators of energy consumption are determined in accordance with the methods, in the presence of objective data on energy consumption for previous periods. The basic levels (energy characteristics) should be reviewed at least 1 time per year or after the introduction of measures affecting energy consumption or changes in the operating mode IFNTUOG, and in case of errors in the initial data that were used to calculate energy consumption indicators. The generalized analysis on the efficiency of energy resources consumption is carried out by working group 1 time a year. Based on the results of the analysis, a section of the annual report “On the functioning of the EnMS of IFNTUOG is drawn up and recommendations are provided on:

- - increasing energy efficiency;
- - improvement of microclimate parameters;
- - application of stimulating energy saving.

Based on the results of the analysis, a list of measures to improve energy efficiency is formed.

3. Conclusion

The ISO 50001 standard is a powerful tool for organizations to improve their energy performance. Ivano-Frankivsk National Technical University of Oil and Gas has been dealing with energy efficiency and rational use of energy resources for more than 10 years. Based on the gained experience, an energy management system has been developed and prepared for certification by university scientists.

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Practices of the penta-helix approach in the European leading smart cities

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Abstract

The enhancing globalisation raises new challenges for the cities, such as rapid population growth, growing environmental problems and overcrowding in some cities, to which smart cities can give adequate solutions. Nowadays, with the widespread adoption of smart technologies and Industry 4.0 solutions, more and more cities are preparing strategies to be more innovative. The penta-helix model besides the classical stakeholders and civic society also integrates the participation of the social entrepreneurs and activists in its proactive model. The aim of the research is to analyse the penta-helix initiatives in the European smart cities, how it is applied in the different best practices. The analyses underlie that the leading European smart cities regarding the penta-helix approach are Aarhus, Berlin, Copenhagen, Helsinki, London, Oslo, Stockholm and Zurich, which emphasize the citizens' participation in the smart solutions. The case studies verify this group of cities, where there is a strong people-centric approach along the project generation and implementation.

Keywords: smart city, penta-helix, European Union, case studies, comparison of rankings.

JEL Classification: R12

1. Introduction

In the global economy, rapidly changing conditions (globalisation, industry 4.0, artificial intelligence or the current pandemic situation) are setting new challenges for cities. Today, 55% of the world's population lives in cities, which is expected to increase to 65% by 2050 (Worldbank, 2018). The cities are the most important hubs of economic activity around the world (concentration of population, enterprises, trade, stock exchanges). As an example, „the ten most innovative cities in the United States account for 23% of the national population, but for 48% of its patents and 33% of its gross domestic product" (Balland et al. 2020, p. 248). The biggest cities are somehow the steering centres of the countries' economies. "By 2025, the 600 biggest cities in the world are projected to account for 60% of global GDP." (Debnath et al. 2020, p. 5). These challenges require new and innovative solutions from cities. Smart cities may be the winners in the process, as the smart solutions they adopt can make a major contribution to their resilience and competitiveness (Arafah and Winarso, 2017).

The term "smart city" has appeared in the literature since the late 1980s and early 1990s, but nowadays, in these times of pandemic, it is becoming even more relevant with the use of IoT technologies, open data solutions, e-government tools or digital education methods. The development of a successful smart city strategy is a critical issue for most city governments, but the strategies for stakeholder engagement vary from city to city. Some use top-down approaches, while others emphasise bottom-up and co-creation methods. The aim of this research is to examine the success of smart cities from the perspective of penta-helix models, which, in addition to classical stakeholder involvement, also stress public participation (social entrepreneurs, civic society) in the design and implementation of smart strategies.

The main research question is whether cities that involve stakeholders more intensively in smart solutions can achieve better positions in the European ranking of smart cities? In the analysis, I will examine the ranking of the European smart cities, with a particular focus on factors that include stakeholder involvement, and then I will also overview/check some best practice solutions for the top performing cities.

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2. Theoretical background

The term 'smart city' became popular in the early 1990s and has changed its interpretation several times since then. Today, there is no single agreed-on definition of smart cities in all parts of the world. Initially, the vast majority of the definitions focused on the technological aspect of smart city development. One of the most frequently cited concepts in technocratic approaches is that of Harrison et al. (2010), emphasising that smart and appropriate use of ICT technologies can lead to intelligent, institutionalised and interconnected cities. Related to this ICT-based approach, Caragliu et al. (2009) have argued also that dimension of cities. Later on, more and more researchers integrated soft elements such as knowledge, innovation, creativity and human capital into the definitions, creating complex concepts. An example is related to Komninos (2011), who argues that a smart city is an area with a very high share of knowledge and innovation. Based on the above-mentioned dimensions and other empirical studies, the synthesis can be the following: A smart city is an area that adopts innovative strategies and solutions to improve the quality of life of the citizens, while effectively using the citizens' creativity and knowledge base (Szendi, 2019).

The concepts have a common feature of aiming to improve the quality of life of residents and emphasise the role of sustainability, innovation and knowledge. The different concepts attempt to define smart city performance based on several components (e.g. Giffinger et al. (2007): economy, people, governance, mobility, environment and living conditions) and a number of indicators, using both qualitative and quantitative ones. The role of stakeholders in smart city processes is rarely reflected in the definitions, as different cities may adopt different approaches based on their initial conditions, capabilities and governance methods. Lim et al. (2018, p. 44) argue that citizen-participation is an important aspect of today’s smart cities, as the citizens are the possible source of the complexities, they are beneficiaries of the values which smart cities can deliver and they are also responsible for the development of smart cities. In the model of Simonofski et al. (2017) citizen-participation can be realized in three different forms: citizens as democratic participants (participation in governance, decisions), citizens as co-creators (direct interaction, living labs, online platforms), or citizens as ICT users (infrastructure, open data). The closest to the topic of this recent research is the role of citizens as co-creators, hence the penta-helix approach (proactive) integrates the participation of social entrepreneurs and activists alongside classical stakeholders and civil society.

Until the end of the first decade in the 2000s, the main idea of partnerships relied mainly on the approach of the triple-helix framework. This builds on the cooperation of three different stakeholder groups (public, private and academic fields - practically governments, enterprises and universities or research institutes). It is basically a top-down model where the role of civic engagement is relatively low (Calzada and Cowie, 2017).

Compared to this the quadruple-helix, coming from the 2010s, also integrates the participation of the civic society in the model, as “triple-helix is not really sensitive enough for democratic additionality” (European Union, 2016, p. 14). This model gives a reactive solution for the emerging problems, and can react more flexibly to the changes happening in the city’s environment. So it is an institutionalized bottom-up framework, where also the civic society can contribute to build smarter solutions (Szendi, 2021).

The penta-helix approach goes one step further, as it integrates the social entrepreneurs and the social activists in a proactive model, where the project ideas are generated in a bottom-up manner (Calzada, 2020). It is important to mention that two interpretations of the penta-helix approach are prevalent parallel in the literature. The approach described above interprets the model in terms of the number of stakeholders and their contribution, based more on the emerging needs of local communities. However, there is another interpretation, which includes besides the elements of triple helix (industry, government, academia) the society as a fourth helix pillar, and the environment as the fifth helix dimension (e.g. Cabrera-Flores et al. 2020). Regarding smart cities, I thought that the first version (which integrates citizen-participation and social entrepreneurs) is closer to the research topic, as smart cities have in the majority of concepts their own pillar dedicated to environmental issues, and the different types of project generation processes are more interesting.

Based on the above, my main focus area is on the examination of smart city solutions in Europe from the aspect of penta-helix approach. In most cases, the governance or people pillar includes information regarding citizen-engagement.

3. Methodology and data

The aim of the research is to examine the success of smart cities from the aspect of the penta-helix approach, which also emphasises the participation of residents in the design of smart strategies. The first step of the research was to compare different smart city rankings in order to see the best performing cities in different dimensions and find the common points of the rankings. The analysis covered the following six models: 1. Giffinger et al. (2007) ranking of European medium-sized cities; 2. Giffinger (smart-cities.eu) ranking of larger European cities (2015); 3. IMD Smart City Index (2020); 4. Eden Strategy Institute Top 50 Smart City Governments (2018); 5. IESE Cities in Motion Index (2020); 6. Szendi et al. (2020) smart index ranking of EU28 capitals. In each model I examine the role of the citizen-participation component in the global smart city ranking mostly based on the governance and people pillars.

For each method, I have defined a threshold value which indicates the success of cities in each pillar. Table 1 below summarises these critical points of the analysis.

Table 1 Selected methods and their threshold values

Method	Threshold	Notes
Giffinger et al. 2007 for medium-sized European cities	both people and governance pillar top 10 position, complex index top 10 position	-
Giffinger et al. 2015 for larger European cities	both people and governance pillar top 10 position, complex index top 10 position	-
IMD Smart city index (2020)	minimum 2 significant components from the total 3	Components: 1. minimum 30% of respondents have thought the citizens engagement as the most important priority axis (from the analysed 15), 2. minimum 65% of respondents contributes in decision-making, 3. minimum 65% of respondents provides feedback on local government projects
Eden Strategy Institute Top 50 smart city governments	top 25 places in people-centricity pillar	people-centricity component means a “sincere, people-first design of the future city”
IESE Cities in Motion index	governance pillar top 25 places	-
Szendi et al. 2020. smart performance of EU28 capitals	top cities in governance pillar	-

Source: own compilation

The original model by Giffinger et al. (2007) analyses the best performing European medium-sized cities along six dimensions: economy, people, governance, mobility, environment and living conditions. The criteria for cities are: a population of between 100 000 and 500 000, at least 1 university in the area and a catchment area with a population of up to 1 500 000. The same components and indicators were subsequently used to assess the larger European cities (population between 300 000 and 1 million; included in the Urban Audit database). The IMD Smart city index was most recently published in 2020, and ranks the 109 smartest cities in the world. The list measures residents' opinions on the structures and technological applications available in their cities (IMD, 2020). The Eden Strategy Institute evaluates the Top 50 smart city governments based on 10 factors: vision, leadership, budget, financial incentives, support programs, talent-readiness, people-centricity, innovation ecosystems, smart policies and track record. The IESE Cities in Motion index is produced annually by the University of Navarra Business School and is also a well-known example of smart city ranking. The current (2020) version of the index ranks the 174 analysed cities on the basis of 9 dimensions and 101 indicators. The main dimensions are: human capital, social cohesion, economy, governance, environment, mobility and transport, urban planning, technology and international relations. Szendi et al. 2020 analysed the smart performance of the EU28 capitals based on the methodology of Giffinger et al. (2007) with an extended and modified indicator structure.

4. Results

The ranking of cities based on the penta-helix approach can be compiled from those cities that are indicated in a favourable position in the above-mentioned rankings. The different methods have resulted in the following number of cities (Table 2): Giffinger et al. (2007) model: 5 significant cities, Giffinger et al. (2015) model: 6, IMD smart city index: 3, Eden Strategy Institute: 7, IESE Cities in Motion index: 7 and Szendi et al. (2020): 5 cities.

Table 2 Significant cities by the different components

Giffinger et al. 2007 medium-sized	Giffinger et al. 2015 larger	IMD Smart city index	Eden Strategy Institute	IESE Cities in Motion	Szendi et al. 2020.
both people and governance pillar top 10, complex top 10	*both people and governance pillar top 10, complex top 10*	*minimum 2 significant components*	*top 25 people-centricity*	*governance top 25*	*top governance pillar*
Aarhus	Stockholm	Zurich	London	London	Copenhagen
Umeaa	Copenhagen	Oslo	Barcelona	Reykjavik	Stockholm
Eskilstuna	Göteborg	Geneva	Vienna	Copenhagen	Luxemburg
Odense	Helsinki		Amsterdam	Berlin	Helsinki
Jyväskylä	Aarhus		Tallinn	Zurich	Valletta
	Malmö		Berlin	Oslo	
			Dublin	Stockholm	

Source: own compilation

Two main clusters can be distinguished from the results: leading cities regarding the penta-helix approach, whose significant position is supported by 2 or 3 methods, and strong cities regarding the penta-helix approach, which are supported by 1 method. I have examined the cities' performance based on the different indices and have created clusters among them. The intersection of the created clusters has resulted in two groups of cities with different characters. The synthesis of the rankings can be transformed to the following hierarchy (Figure 1).

The penta-helix approach, involving social entrepreneurs and activists, helps to better respond to the challenges of a changing environment and can increase the resilience of cities. The vast majority of the world's leading smart cities are using this model to shape their smart vision; however, the geographical intensity of this model's application varies considerably. In Europe, it is mainly Scandinavia where the adoption is the highest. It is also remarkable that these citizen-centred components are not always a guarantee for overall success, but can be a major contributor to a good overall position (and a traditionally top-down driven city can be similarly successful, like Vienna). Europe's leading smart cities according to the penta-helix approach are Aarhus, Berlin, Copenhagen, Helsinki, London, Oslo, Stockholm and Zurich, where community participation plays a strong role in the creation of smart city projects.

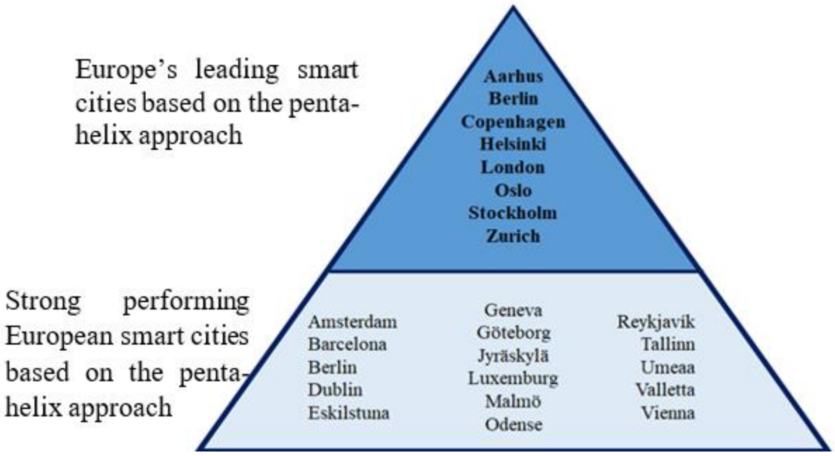

Figure 1 Hierarchy of smart cities regarding the penta-helix approach

Source: own edition

4.1 Case studies

In the last part of the study, I have examined some examples of the above-mentioned leading smart cities to see what kind of co-creating projects exist in the practice which support their good position.

Aarhus

In the case of the Danish Aarhus, the smart city idea is based on the Smart Aarhus project, which uses digital solutions to make Aarhus greener, better and generally smarter. The project is implemented by the collaboration between the municipality, companies, citizens and knowledge institutions (smartaarhuseu.aarhus.dk, 2021). So it is a working penta-helix. Regarding the projects, there are a lot of different solutions in the city, like the center for telehealthcare, LED street lights, IoT Forum, traffic control center, or open data portal. The mostly participation-centered solution may be probably the Aarhus City lab (a digital test center for smart city solutions and a showroom for smart initiatives), where the citizens can actively contribute to project generation (smartaarhuseu.aarhus.dk, 2021).

Berlin

The main aim of the Smart Berlin project is threefold: 1. expanding the international competitiveness of the Berlin-Brandenburg metropolitan region, 2. increasing the resource efficiency and climate neutrality of Berlin by 2050, and 3. creating a pilot market for innovative applications (Senate Department for Urban Development and the Environment, 2015). The implementation model follows basically rather a quadruple-helix framework, and involves the following stakeholders: economic actors, alliances, science field, NGOs, representatives, government. But the city also has a CityLAB where the different stakeholders can participate in the project generation processes. Here also the social activists, NGOs can suggest new solutions, but the participation of inhabitants is weaker. The main ways of creating projects are various co-working, discussion events, hackathons, think tanks, experimental labo-ratories and exhibition areas (smart-city-berlin, 2021).

Copenhagen

In the smart strategy of the Danish capital there is a clearly declared citizens-come-first mindset, which means that regarding a lot of projects there is a strong co-creating process with the inhabitants. There are IoT living labs and voting platforms where "developers can submit a request for testing their smart city solution to the city's Street Lab. Once accepted, Copenhagen Street Lab offers full assistance to install and connect the solution to the existing infrastructure" (cities-today.com, 2021). There is also a Smart City Academy in the city, where there is an active cooperation among Anchor Cities, Corporate Partners, National Partners, and Academic Partners (stateofgreen.com, 2021).

Helsinki

The Finnish capital creates a regional smart specialisation strategy together with its broader region Helsinki-Uusimaa as they think that the whole region is considered together as a knowledge and innovation hub. Here the citizens are also "active, creating together with companies and cities agile, user-focused services and solutions" (helsinkismart.fi, 2021). Besides that the whole city is an entire city-lab, to test the operability of creative businesses (myhelsinki.fi, 2021). Here the citizen-engagement is very strong, which can be verified by the fact that over 800 of Kalasatama's 3000 residents (a district of Helsinki) have already participated in developing new smart solutions (myhelsinki.fi, 2021).

London
The city has launched the Smarter London Together project in 2018, and aims to transform the city into the most innovative/smart in the world. There are numerous priority axes connected to the idea of penta-helix, like the "more user-designed services" axis (they seek to realize Civic Innovation Challenges, or new civic platforms to engage citizens and communities), or the "improve city-wide collaboration" axis (collaboration of different systems). The innovation challenge for example creates good opportunities to test solutions together with the business leaders, science sphere, and government (Greater London Authority, 2018).

Oslo
The Smart Oslo Strategy aims to create a smarter, greener, more inclusive, and creative city for all citizens and besides that a living-lab is working in the city. Oslo has created a framework for innovation, tech and knowledge hubs. The citizen-participation appears in almost all projects generated in the city (grafill.no, 2018).

Stockholm
Stockholm would like to be a smart and connected city, and that is why the common goal is to achieve "A Stockholm for all". The smart city strategy is developed together with residents, academia, business through direct dialogues, social media, and work meetings (City of Stockholm, 2020). A good example of citizen-engagement projects can be the Maptionnaire online platform of urban planning which gives an opportunity for presenting the residents' ideas and opinions about public place designs (maptionnaire.com, 2021).

Zurich
The grounding principles of Smart Zurich are the people-centric approach, connectedness and collaboration, openness and sovereignty, agileness (Stadtentwicklung Zurich, 2018). There is a working city lab in Zurich, which means a smart participation among the stakeholders; the specific urban projects are used to test innovative forms of participation and the involvement of various stakeholders. The main focus area is to connect people, organisations or infrastructures in such a way as to create social, ecological or economic added value (stadt-zurich.ch, 2021).

5. Conclusion

This recent article analysed the role of penta-helix approach in the case of the top performing smart cities in Europe. I have checked the role of citizen-engagement in the smart cities with the help of six ranking methods and have created homogenous clusters from the leading ones. As a synthesis of the results, I can conclude that the vast majority of top smart cities in Europe apply the penta-helix approach to some extent. Usually the Scandinavian cities use this approach more often, but there are also other regions among the best performing ones. The Top cities in Europe are the following (leading cities based on the penta-helix approach): Aarhus, Berlin, Copenhagen, Helsinki, London, Oslo, Stockholm and Zurich. However, these elements are not always a guarantee of success (top-down models can be also successful, e.g. Vienna), but can contribute strongly to a good overall position. It is also important to mention that this model of analysis has some limitations, and the list of ranking methods can be extended further, as for example Amsterdam or Barcelona are well-known practices of people-first thinking, living labs or innovation, but these 6 models don't verify their leading role. The analysed case studies of the best performing smart cities underlie the strong role of penta-helix approach by these entities, and the importance of people-centric thinking by the project generation of intelligent solutions.

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Protection system with energy management for smart building

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Abstract

The problem of constructing intelligent buildings is very extensive, for this reason in the article we focus only on the issue of power and protection. Powering a smart building or house is currently the biggest challenge in securing enough electricity, especially by renewable energy sources, despite their very low power requirements for operation. The article describes the most used power and protection system for these buildings.

Keywords: smart building, solar power, solar panels, protection system, renewable energy sources, nanogrid, microgrid.

1. Introduction

The development and construction of smart buildings have advanced significantly in recent years, which has led to the simplification of smart grid research. Despite its constant evolution, the term "smart building" includes the interconnection of several functional parts that are interrelated and interconnected. For this reason, only buildings that satisfy this definition of interconnectedness should use name "smart". Next, we are explaining this connection of functional parts. Figure shows the benefits and the main parts.

Figure 1 Benefits of smart buildings.

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Smart building parts:

- **Security:** This part ensures the security of the whole building or house by means of camera systems (CCTV), sensors for motion detection, sensors for breaking windows, alarm system, system simulating movement by using the lights.
- **Wireless Control:** This part provides wireless control from a mobile phone, tablet, or computer to the following parts: security, temperature control, power supply control and monitor switched on devices.
- **Temperature Control:** This part provides temperature control to maintain the set temperature in the building and manages the water heating, cooling, and ventilation.
- **Energy Saving:** This part ensures energy savings by adjusting heating and ventilation appropriately, switching off lights or equipment when leaving the room, and using A^{+++} appliances.
- **Automatization:** This part ensures automation of all set functions to be performed and thus provide increased comfort. The unit compares the set parameters with those measured by sensors. Automation also includes lighting control and regulates it using blinds and lights.
- **Own Power Supply:** This part provides continuous power supply, which is most often provided by solar panels with battery storage energy or only solar panels without battery storage energy, diesel generator with battery storage energy. One of the most important parts is the power supply to provide enough power for all the other parts.

Smart buildings can be classified as nanogrids from the point of the distribution system operator. Studies on intelligent buildings and energy management based on a monitoring system using the SCADA (Supervisory Control and Acquisition) system to balance consumption are needed for use in microgrid systems. From the perspective of the main grid, these buildings can act as a load or as a power source, as these smart buildings are still dependent on grid power. While several articles point to the possibility of using these smart buildings for the development of microgrid systems, which would be composed of these nanogrids [2,3,4,9].

Another view on the issue of energy management in smart buildings is the use of artificial intelligence to predict energy consumption, which, using deep learning, should be able to predict consumption appropriately, while such a smart solution still needs to be developed and currently does not achieve satisfactory results for large-scale use [5].

To increase the reliability of photovoltaic (PV) systems, the concept of continuous monitoring has been proposed to maintain adequate performance. In addition, monitoring of each panel increases the speed of fault detection and aging prediction capabilities. Using such a monitoring system for PV system will contribute to the improvement of energy management system. Smart monitoring systems simultaneously consider both energy consumption and local generation to optimise and streamline the use of electricity in the building [6,7].

Smart Grid context, it is expected that the traditional consumer will become a simultaneously producer and consumer and tariffs will be dynamic. Energy efficiency improvements and renewable energy increase are seen as the critical priorities to reach the goals of smart building are development of microgrid [8,9]. The issue of battery systems is quite complex when it comes to conventional battery plants, which is why the idea of replacing traditional battery plants with electric vehicles has been developed. The idea is feasible, but energy storage systems still need to be developed, not only with battery systems but also in non-traditional ways such as flywheels.

2. Smart building

In this chapter we look at the power supply options and describe the most used protection principle for such buildings and review examples from practice.

2.1 Supply for smart buildings

Power supply is one of the most important parts as mentioned in the introduction, so we will explain all the ways.

Power supply options for smart buildings [10]:

- **On-grid system** obtains a battery-free system that is connected to the public power grid. Any excess solar energy they produce is provided in the power grid. The primary disadvantage of this structure is that they fail to operate during a blackout.

- **Off-grid system** typically provide power for remote villages, industrial operations, and military bases. We use PV panels with battery systems, but in this case, we have certain performance limitations, and a diesel generator is needed for backup.
- **Hybrid system** can be disconnected from the grid to operate autonomously, ensuring continuity of power supply in the case of an outage. This approach is common in locations where the grid can be unreliable, such as storm-prone or mountainous areas, but this option is also used in smart building. As shown in Figure system takes advantage of both previous systems.

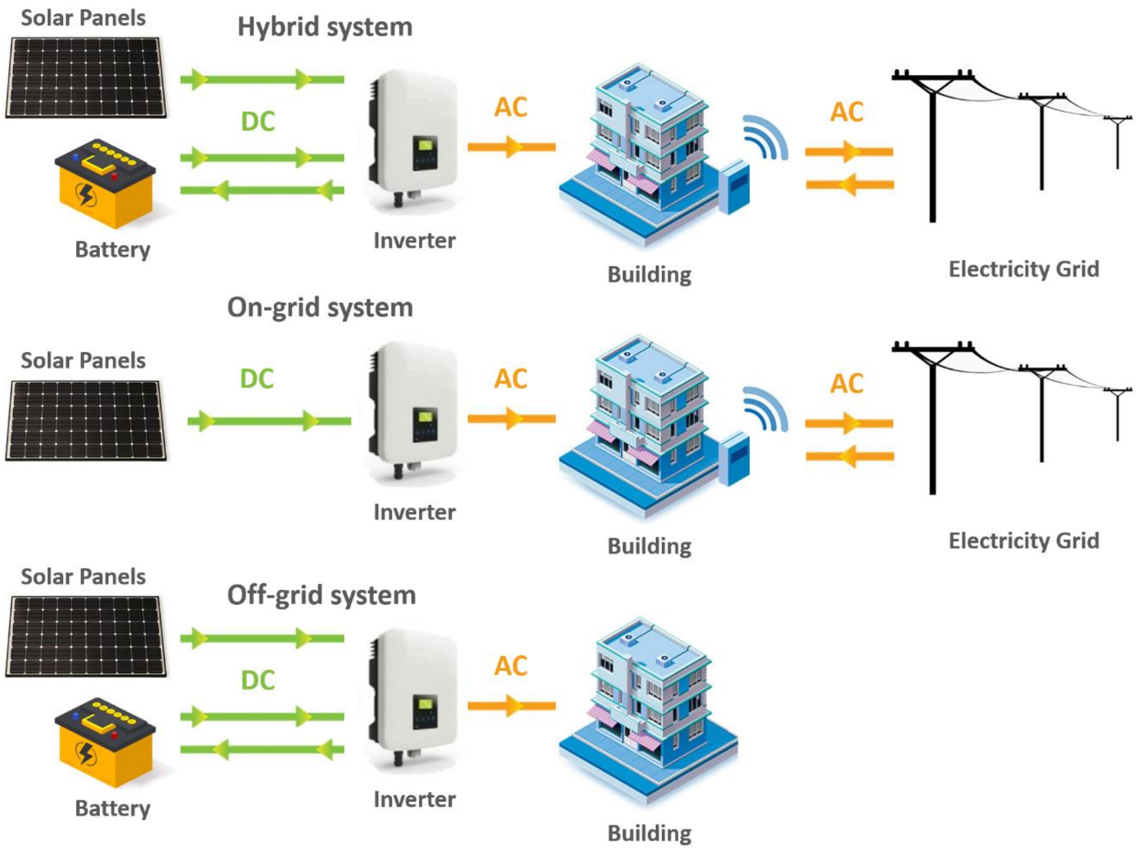

Figure 2 Power supply options for smart buildings

2.2 The system wiring connection

Figure describes the basic most used wiring hybrid system that is plugged into smart buildings. The diagram shows the wiring of three switchboards, where the switchboard DC - AC contains control and protection devices for both the DC and AC system and protects the inverter and the battery system together with the PV array. This switchboard is found in all options of power supply buildings. The only difference to on-grid, hybrid or off-grid is the addition of a battery system. The main switchboard of the electrical installation contains two busbars for supply to the mains in the right side and a busbar for supplying power to the building in the left side. On-grid with hybrid systems have the same remaining two switchboards for meter and electrical installation, but the off-grid system does not include a meter switchboard and parts of the busbar for the mains are removed from the electrical installation switchboard. The meter switchboard contains a four-square meter and protective devices, which are already managed by the electricity distributor if the building is connected to the grid. The meter switchboard will not be used only in the off-grid system and parts of the busbar for the mains are removed from the electrical installation switchboard.

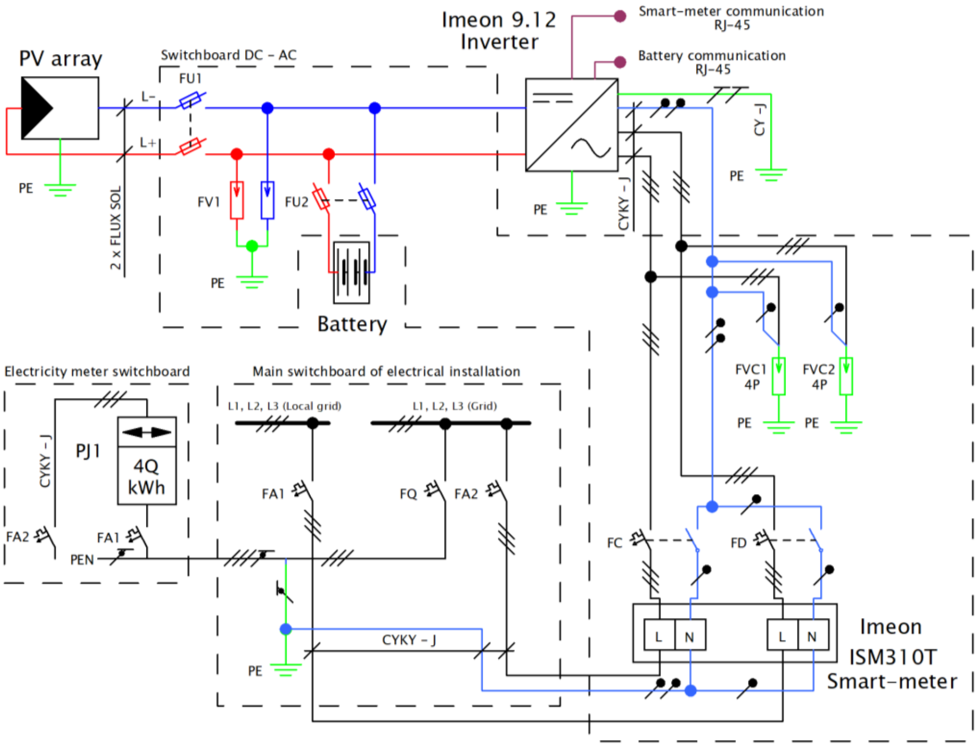

Figure 3 Wiring connection of smart building.

FLUX SOL wires are used for DC circuits systems, a CYKY-J and a CY-J wires are used for AC circuits systems. As protection systems are used for overvoltage Surge Protection Device for both systems and for overcurrent and control for DC system are used fuse-switch disconnectors and for AC systems are used circuit breakers. The inverter used also contains a frequency and voltage control device. The smart meter provides power metering for the inverter so that the renewable energy sources work as efficiently as possible and the energy drawn from the grid is as low as possible, thus approximating the self-consumption to 100%.

2.3 Examples of smart buildings

The ranch shown in Figure , located in Vernon, British Columbia, Canada, contains a multi-purpose building that is equipped with a 28.35 kW PV system, which would provide 100% of the electricity needs for the entire ranch. The ridgeline of the barn roof was oriented exactly due east/west, to afford maximum solar gain for the 90 solar panel systems mounted on the south-facing upper roof and lower roof surfaces [11].

Figure 4 Canadian ranch with PV system [11]

Another somewhat unconventional building is the eco capsule shown in Figure 9. It is a low-energy mobile home that is a versatile dwelling, also in terms of energy consumption. The Eco capsule is powered by two sources, an 880W solar panel and a 750W wind turbine. Rainwater is collected on the surface, where it is collected to water tank and filtered [12].

Figure 9 Eco capsule - the concept of mobile housing [12].

3. Conclusion

The development of intelligent buildings is progressing rapidly, which can be helped by research into microgrid systems. Currently, such technology is becoming affordable, which can lead to a reduction in the peak load on the distribution system during the day. The development of battery systems is still needed for their durability and capacity, and the issue of recycling needs to be addressed as well.

Acknowledgements

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Virtual Reality in architecture

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Abstract

My contribution to this paper is in the implementation part. We created the control and the way the character moves through the virtual space. When the user of the application wants to move in the virtual plane, he uses the touchpad of the controller by moving his finger on its surface. Motion control is based on the two-dimensional plane. For each of the axes of the plan, we have created a function in C ++ that calculates the new position of the character in the plan. The movement in the three-dimensional plane is made with the help of the movement in the two-dimensional plane, and on the vertical axis, the movement is made with the help of the collisions with the objects.

Keywords: Virtual Reality, architecture, Unreal Engine, software implementation, HTC Vive Pro

1. Introduction

"The term 'virtual reality' was coined by Lanier in the late 1980s, but the origins of VR technology can be traced back to Ivan Sutherland's work on interactive computing and head-mounted displays in the mid-1960s". Sutherland's research at MIT and University Harvard was partially funded by the US Department of Defense's Advanced Research Agency. In a paper, he contributed to the 1965 International Congress on Information Processing, entitled

"The final display" presented the model for a human-computer interface that continued to inspire thinking about computer-generated virtual environments since then. 'Sutherland's idea was that a computer display could create a simulation of the physical world with which the operator could interact directly through the senses. Such a display would provide new possibilities for displaying information. In a subsequent paper presented at the 1968 Fall Joint Computer Conference, "A Three-Dimensional Head-mounted Display", he explained how this happens. The device could be built using a position sensor and computer graphics to generate a world. three-dimensional. [1 - 3]

By January 1, 1970, Sutherland, then at the University of Utah, and a team of researchers had developed the first interactive head-mounted interactive display system? From now on, several threads can be identified that would eventually lead to the take-off of VR technology in the late 1980s. These are broadly in three areas: art, flight simulation and robotics, military research, and spatial.

In art, the first person to explore the potential of interactive VR computing devices was Myron Krueger, although he prefers the label "an official reality". In the early 197O, Krueger created a gallery installation that allowed users to interact with a two-dimensional computer-generated environment. The difference between Krueger's "artificial reality" and immersive VR systems is that he does not try to create a simulation that gives the user the impression of bodily "presence" in a virtual world. Instead, the Krueger system projects silhouette images onto a walled screen that users can interact with as they move in front of these "worlds". Interactivity is achieved in this case by recording the user's loves with a video camera so that the silhouette image of the

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user can interact with the designed "world". This system also allows several users to interact with each other in the "world" of the projected screen. [3 -4]

Virtual reality (VR) is an advanced, human-computer interface that simulates a realistic environment. The participants can move around in the virtual world. They can see it from different angles, reach into it, grab it and reshape it. Cyberspace is thought of as the ultimate virtual reality environment. It is an alternative computer universe where data exists like cities of light. Information workers use a special virtual reality system to enter cyberspace and to travel its data highways. The paper discusses the latest developments in virtual reality. It considers applications in engineering and medical fields.

Traveling to visit tourist attractions around the world can sometimes be very difficult or even impossible. Due to the many obstacles that arise when you want to make a certain visit, for this reason, there is the possibility of losing interest in a certain objective.

To prevent the disinterest that may occur in tourists, and to help them decide on the ideal vacation, the concept of virtual reality comes to the rescue. This concept is quite new, it can help both tourism, by transposing the user to a certain tourist location to increase his interest, and other areas such as architecture, medicine, and others.

In architecture, virtual reality has a lot of uses for both architects and designers. With the help of virtual reality (VR) architects can present to their clients the plans on a real scale, even allowing them to walk and interact with the chosen project before it is physically ready. This technology, from my point of view, can reduce the time of choosing a project, but also the execution time because the client being inside the desired building will be able to see his requirements and will be able to modify the project until he reaches what he wanted. From the designers' point of view, virtual reality reduces the costs of arranging a building. Just like the facilities presented for architects, and in design, customers can see in advance what is to be done physically and can change their options during the design. [4 - 7]

2. Description of the implementation method

In this chapter, I will describe step by step how the code for architecture was implemented. The user will be able to explore and interact with this architecture.

2.1 Creating a character for user interaction with the application

When the project is opened in the Unreal Engine editor, Microsoft Visual Studio will also open, where the C ++ code will be edited.

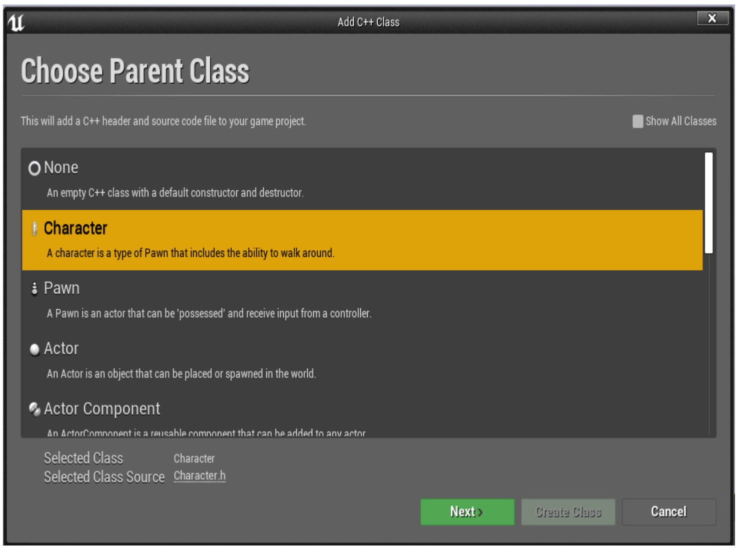

Figure 1 Choosing the parent class

To create a new character we need to create a new C ++ class, this is done from File -> New C ++ Class, a window will appear (figure 1) in which it will select the parent class, the class from which it is derived the new class we want to create, it will inherit the methods of the parent class. The parent class for a new character must be of type Character because with the help of this class it will be possible to implement the movement part of the character in the application.

After choosing the parent class, we will give it Next, then a window appears in which you can edit the name of the class, the place of that class in the project, when to call, but also the location where it is saved and the type of class (private or public).

When the class is finished creating, the Microsoft Visual Studio development environment will open if it was not already started. The first tab will be the class header, and the second will be the compiled file. The code changes and what we are going to add will be done both in the header and in the compilation file (.cpp file).

In addition to creating the class in C ++, you also need to create the application settings mode and integrate the newly created character with the settings mode.

The creation of the settings mode is done from Unreal Engine -> Blueprints -> Project settings (GameMode) -> Create -> GameModeBase, figure 2 is presented more explicitly this way of creating the settings.

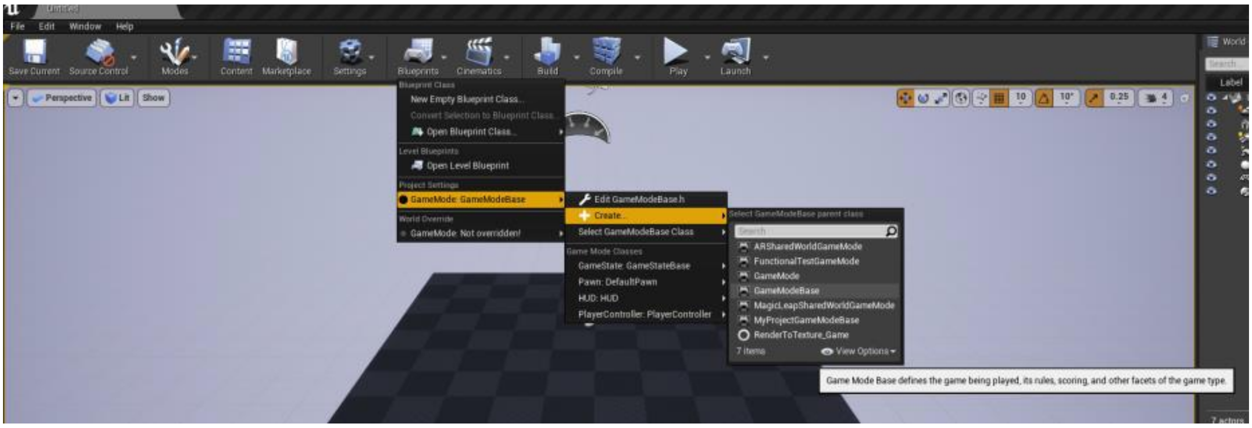

Figure 2 Creating the settings module

2.2 Creating motion controls

To be able to create the movement of the character through the camera, it is first necessary to take over the characteristics of the camera and to make the connection between the C ++ code and the Blueprint in which the character was created.

The camera features are taken over by the following UCameraComponent command (this command takes over the camera components) because it does not need to be visible in the entire application source, it will be private. The syntax to declare this feature of the application is as follows:

private: UPROPERTY (VisibleAnywhere)

class UCameraComponent * Camera;

That * Camera creates a reference of the application components. The reference will be used in the program file, where the data processing will be done so that the motion effect can be created.

"UPROPERTY (VisibleAnywhere)" is the method by which the component is assigned the visibility property throughout the program file, after inclusion. This property is only required for the latest versions of Unreal Engine (versions of Unreal Engine 4.15 and later). It must be put before each function that we implement in the header.

In the program file, we must first set the attachment, and the parent class will take its basic components.

To make it possible to move the character in the application workspace, we need to think of that plane as a two-dimensional (2D) axis system (figure 3). Suppose we want to make a forward-backward movement, this involves the movement on one of the axes of the plane, preferably the "Y" axis is chosen. To be able to perform the movement, in C ++, we need a function derived from the parent class, which takes data from the forwarding vector (forwardVector) and transmits them to the class defined in the header. For the front-back movement, we can do it by incrementing or decrementing by one or more pixels depending on the speed with which we want to make the move. Incrementing or decrementing can only be done with an integer, it cannot be done in half pixels.

For the right-left movement or vice versa, the procedure is quite similar. It involves the movement on one of the axes of the plane, different from the axis we chose for the front-back movement, preferably the "X" axis is chosen. To be able to perform the movement, in C ++, we need a function derived from the parent class, which takes data from the targeting vector (rightVector) and transmits them to the class defined in the header. As with the previous function, you cannot increment or decrement by half a pixel.

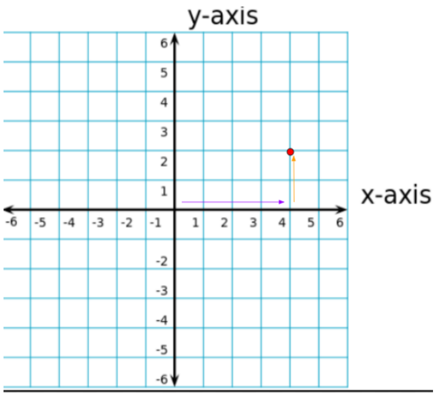

Figure *3* 2D plan

Figure 4 HTC Vive Pro controller

For the physical controllers part, we will use the levers included in the HTC VIVE PRO virtual reality package. Setting them and setting the specific buttons for movement is done from Unreal Engine: Settings -> Project settings -> Input -> Bindings. More accurately you can see how the settings in the following set of figures are made: figure 5 and figure 6.

Figure 5 Movement setting

To be able to add functions (axes) we click on "+" next to "axis mappings" and a place will appear where we can enter the name of the axis, this name must be identical to the reference we gave- o in C ++ code.

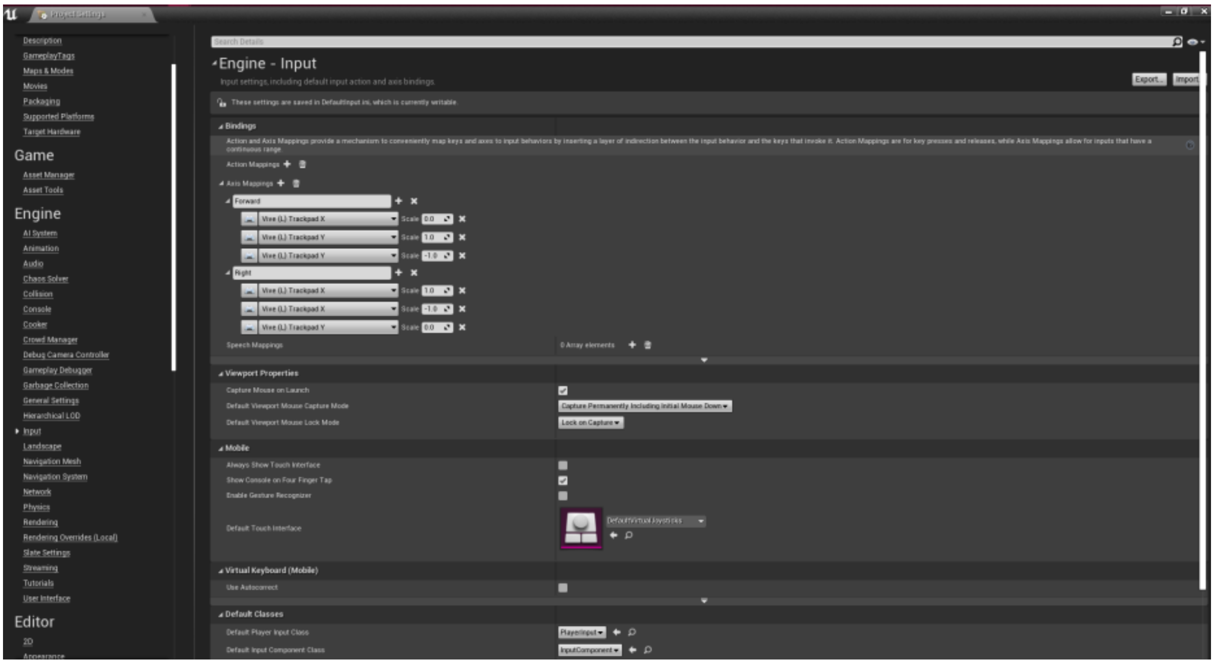

Figure 6 Movement setting

From figure 7 it can be seen that we named the axes "forward" and "right". For the "forward" axis I set the "Y" axis of the trackpad on the left joystick, and for the "right" I set the "X" axis of the same trackpad.

```
AVRCharacter::AVRCharacter()
{
    // Set this character to call Tick() every frame.  You can turn this off to improve performance if you don't need it.
    PrimaryActorTick.bCanEverTick = true;
    //Camera =CreateDefaultSubobject<UCameraComponent>(TEXT('Camera'));
    VRRoot = CreateDefaultSubobject<USceneComponent>(TEXT("VRRoot"));
    VRRoot->SetupAttachment(VRRoot);

    Camera = CreateDefaultSubobject<UCameraComponent>(TEXT("Camera"));
    Camera->SetupAttachment(GetRootComponent());

    DestinationMarker = CreateDefaultSubobject<UStaticMeshComponent>(TEXT("DestinationMarker"));
    //DestinationMarker = CreateDefaultSubobject<UStaticMeshComponent>(TEXT("DestinationMarker"));
    //DestinationMarker->SetupAttachment(GetRootComponent());
}
```

Figure 7 Program file

Because after several tests the movement was diagonal, I noticed that for each "forward" or "right" axis, the "X" or "Y" axis that is not used for movement, must be set to 0.

```
// Called to bind functionality to input
void AVRCharacter::SetupPlayerInputComponent(UInputComponent* PlayerInputComponent)
{
    Super::SetupPlayerInputComponent(PlayerInputComponent);
    PlayerInputComponent->BindAxis(TEXT("Forward"), this, &AVRCharacter::MoveForward);
    PlayerInputComponent->BindAxis(TEXT("Right"), this, &AVRCharacter::MoveRight);
}
void AVRCharacter::MoveForward(float throttler) {
    AddMovementInput(throttler * Camera->GetForwardVector());
}
void AVRCharacter::MoveRight(float throttler) {
    AddMovementInput(throttler * Camera->GetRightVector());

}
```

Figure 8 Program file

The following set of figures exemplifies some of the code in C ++ for capturing controls on levers.

```
    // Called to bind functionality to input
    virtual void SetupPlayerInputComponent(class UInputComponent* PlayerInputComponent) override;
private:
    void UpdateDestinationMarker();
    void MoveForward(float throttle);
    void MoveRight(float throttle);
private:
    UPROPERTY(VisibleAnywhere)
    class UCameraComponent* Camera;
```

Figure 9 Header file

To see all the methods, which are already implemented in the parent classes of the C ++ code for the development of VR applications by those from Unreal Engine, on the publisher's website you can find the documentation, and from the C ++ API, you can see all the methods.

3. Conclusion

From my point of view, virtual reality is a concept that will be implemented in almost all areas of work around the world.

To develop an application that serves the field of architecture you need a team of people who can create textures and objects, to be able to assemble them to come up with a useful application.

What we did in the application is the part of motion control, adjustment of collisions, introduction, and modification of already existing objects, and the part of user interaction with objects in the application. This is done by bringing the user closer to an object and based on collisions that object moves around the room.

The application you need me for further developments to be fully functional in architecture, but it is a starting point for a much more complex application. What should be introduced are more textures, to create more objects, but also to introduce a catalog through which the user can choose the objects he wants to put in a certain room. Objects entered in the application are entered manually. From my point of view, the most important further development should be the introduction of hand controls, but also their physical display in the application. With this feature, the user will be able to move their objects around the room at will.

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Optimization of calculation of parameters for a small hydroelectric power plant

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Abstract

In the mountain regions of Ukraine, there is a problem with the power supply for remote facilities, which are located in the gorges near the channels of small rivers. The use of solar energy and diesel generators for such facilities is unfeasible. It is also inexpedient to use dam and derivation small hydropower plants due to the inconsistency of runoff of small rivers. Gravity-rotating small hydropower plants, which can operate at minimum water pressures, are considered as the best suited for such conditions. The existing method of calculating parameters of gravitational-rotating small hydropower plants provides series of multiple procedures for recalculating parameters to obtain optimal values of its characteristics. To eliminate this drawback, a web application has been developed that optimizes and automates the calculation process. Optimization is carried out by selecting the dynamic characteristics of the vortex to organize the work of the impeller of a certain type of turbine with the maximum possible efficiency for it. The web application is written in JavaScript using the React library and the MongoDB database. The web application contains 12 blocks with algorithms and a common navigation dashboard. The navigation block indicates the symbols of all parameters that are calculated by the program. When clicking the designation of any of the parameters is an automatic transition to the block with the formula for its calculation. To optimize the choice of a small hydropower turbine, a scale with a movable slider is used, which sets the desired efficiency. According to the set efficiency, the recommended type of turbine and its image appear in the program window. Separately, the web application has a unit for selecting a model of a small hydropower plant from its own database and a unit for outputting and recording the results of the calculation. The selection of the model of a small hydropower plant is carried out according to the values of water consumption at optimal productivity, the diameter of the impeller and the capacity of the turbine and the generator. The results of the calculation are displayed in a table and can be written in text format. The web application allows you to enter data to calculate the parameters of a small hydropower plant or use data with optimization of the dynamic characteristics of the vortex. To facilitate the work with the application, it implements a system of contextual hints. The developed web application is easy to use, uses a small amount of computer memory and can be easily supplemented with new settings and data. The use of the developed web application will simplify the process of designing gravitational-rotating HPPs, reduce the time for its implementation and optimally select the equipment for the dynamic characteristics of the vortex created by the flow of a small river. This will reduce the cost and develop the process of electrification of remote mountain facilities.

Keywords: gravitation water vortex power plant, method of calculation, generation of electricity, small hydroelectric power stations, web application.

1. Introduction

In the mountain regions of Ukraine, there are problems with electricity supply to remote facilities, especially those located in mountain gorges near small riverbeds. Due to the significant shading from the mountains and tall trees, the use of solar panels to power such facilities is impractical. Autonomous electric generators on liquid fuel create a significant level of noise, harm the environment and require constant provision of fuel reserves, which is economically unfeasible. It is also impractical to use dam and derivation hydropower plants (HPPs), which require powerful water flows and significant height differences in short sections of the river. The problem can be solved by gravitational-rotating small hydropower plants, which operate on the principle of vortex formation (Mini-HES po pryntsypu vodovorotu, 2008). Part of the river runoff is used for the operation of such small hydropower plants, and the hydraulic working pressure can be minimal. Gravitational-rotating small HPPs begin to generate electricity at a pressure of 0.7 m. The method of calculating the parameters of gravitational-rotating HPPs is given in (Vashchyshak, I. R., 2021). The essence of this technique is an iterative procedure for calculating the electrical and hydraulic parameters of a small hydropower plant with sequential change of some of them to achieve optimal characteristics of the turbine and generator at a given river hydropower potential.

The aim of the work is to create a web application to optimize the calculation of the parameters of a small hydropower plant, the choice of the type of impeller of the turbine and the selection of the optimal model of the hydraulic generator from the database. The developed web application will allow to develop small hydropower projects for mountain rivers with insignificant hydro potential in a short time, which will promote electrification of objects remote from the infrastructure.

2. Body of Paper

A significant part of the hydropower potential of small rivers of Ukraine (about 28%) is concentrated in its western regions (Derzhenerhoefektyvnosti Ukrainy, 2020). However, due to the complexity of the terrain, remoteness from infrastructure and lack of logistics, this potential for electricity generation is used extremely inefficiently. In addition, the annual runoff of mountain rivers during the year is much more unstable than the plains. These rivers then quickly fill with water and flood the surrounding areas, then dry up badly, leaving runoff minimal. This complicates the use of hydropower structures on mountain rivers due to environmental and technical problems with the organization of dams and diversion aqueducts. In addition, the use of dams reduces the speed of water, its significant warming and intense evaporation, which negatively affects the overall flow of the river. The gravitational-rotating hydroelectric power station, which constantly mixes water, increases its speed and prevents freezing, is free from these shortcomings. If air-filled opaque rubber balls are placed on the water surface of the supply channel and in the place where the vortex is formed, the water temperature will drop and evaporation will decrease significantly, which will turn the gravitational-rotating HPP into a natural cooler. This is especially important to prevent the negative impact of global warming on the country's water resources.

The paper (Vashchyshak, I. R., 2021) considers the methods of placing the hydroturbine in the vortex of the gravitational-rotating HPP and indicates that to ensure its minimum size and obtain high efficiency, the impeller of the hydroturbine should be placed in the lower part of the vortex. The process of vortex formation and the way to improve its dynamic characteristics are described. In accordance with this, a method of calculating the hydraulic parameters of the fluid jet, turbine and vortex, which are associated with the electrical power of the AC generator.

Table 1 shows the formulas for calculating the parameters of the gravitational-rotating HPP. The water flow through the cross section of the bottom hole Q for the calculation is selected not more than 25% of the average annual runoff of the river, and the hydraulic pressure H is selected from the height difference along the riverbed at the installation site of a small hydropower plant. The optimization of the calculation is to select the dynamic characteristics of the vortex to obtain the maximum efficiency of the turbine with an impeller of a specific size within the specified limits of pressure change (**Figure 1**). Optimization is also carried out in order to reduce the size of the impellers of hydraulic turbines while obtaining maximum power generation. In both cases, you need to constantly list most of the parameters of a small hydropower plant in **Table 1** to achieve the desired result.

To automate this process, better understand the impact of parameters on each other, automatic selection of the type of hydro turbine, selection of a small hydroelectric power plant model and ease of use, a web application was created in the JavaScript programming language. The web application uses the React library and the MongoDB database. The database of the web application includes the main types of impellers of hydraulic turbines (with visual images) and their efficiency, some constants, as well as models of ready-made small hydropower plants that are offered on the market. In general, the web application consists of 12 blocks of formulas and a navigation block common to them all, a block of turbine model selection and a block of calculation results for all parameters. In the navigation block there are symbols of the parameters that are calculated. In the first block of formulas at the top is the name of the web application "Online power calculator of hydropower plants" (**Figure 2**). Below it is the name of the parameter that is calculated "Coefficient of compression of the liquid jet". The calculation formula and the variables included in it are given below. The web application provides two ways to enter variables: manually and with the arrows located on the right side of the field to enter a variable. Arrows appear when you hover over them. In the left part of the formula blocks there is a navigation block, selecting the variable from which the automatic transition to the block with the desired formula is performed. Below the input fields of the variables is the inscription "Result", under which the calculated value of the variable appears after clicking on the "Calculate" button.

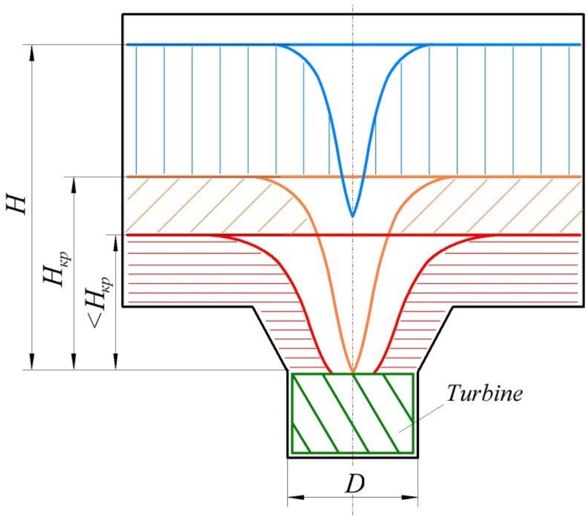

Figure 1 Formation of a vortex in an open vessel

All formula blocks, starting with the second, have fields with a check box (Checkbox), in which you can use either the recommended values to optimize the parameters of the vortex, or entered manually (**Figure 3**). In the lower right part of the block of formulas "Power developed by the hydroturbine" there is a scale, moving the slider of which it is possible to change efficiency of the hydroturbine. To the right of the scale appears an image of a hydroturbine for a small hydropower plant (Francis, Kaplan, Auger, Thomson, Turgot, Pelton), which best corresponds to the selected efficiency (**Figure 4**). The turbine model selection unit "Characteristics of the recommended turbine" optimizes the parameters of a small hydropower plant according to the following calculation results: water flow (*Q*), turbine power (*Pt*), diameter (*D*), generator power (*Re*), weight. When you click on any of the buttons on the right, a parameter scale will appear, from which the closest to the calculated value is selected. After that, the program recalculates the data to optimize the dynamic characteristics of the vortex for the selected efficiency of the turbine and offers a model of a small hydropower plant, which is best suited for the calculated parameters. The table "Characteristics of the recommended turbine" provides the main technical data of the proposed model (**Figure 5**). The table "Calculations" of the block of calculation results displays the values that the user enters and calculates, which are automatically updated when you click "Update". After clicking the "Download calculation results" button, all calculations and data of the selected small HPP model will be saved on the computer in text format. The effect when the mouse cursor is within certain limits of the variable or the "Hover" effect is used to implement the prompts. If you hover over a variable, a field will appear indicating what that variable means. The colors of the text and the background, however, differ for visual selection on the background of the main page.

Table 1 Formulas for calculation of the parameters of the gravitational-rotating HPP

Parameter to be calculated	Calculation formula
Power to be produced by hydro-turbine, W	$P_T = m_в \cdot Q \cdot (H/\omega) \cdot \eta_T,$ $P_T = \rho \cdot g \cdot Q \cdot H \cdot \eta_T$
Units of measurements used	
$m_в$ – mass per unit volume of water, kg; *Q* – water flowrate, l/s; *H* – hydrostatic pressure, m; ω – cyclic rotational speed of the turbine, rad/s; η_T – turbine efficiency; ρ – water density, kg/m^3; *g* – acceleration of the free fall, m/s^2	

<table>
<tr><th>Parameter to be calculated</th><th>Calculation formula</th></tr>
<tr><td>Electric power of the generator, W</td><td>$P_E = \rho \cdot g \cdot Q \cdot [H - (h_г + h_i)] \cdot e_t \cdot e_g \cdot (1 - f_t) \cdot (1 - f_i)$</td></tr>
<tr><td colspan="2">Units of measurements used</td></tr>
<tr><td colspan="2">$h_г$ – hydraulic losses; h_i – other losses; e_t – utilization factor at the average water runoff in long-term Q; e_g – generator efficiency; f_t – transformer losses; f_i – other losses of electricity.</td></tr>
<tr><td colspan="2">In order to calculate the optimal values of P_E it is advisable to use the following values: $h_г$ – 0,07; h_i – 0,01; e_t – 0,85; e_g – 0,9; f_t – 0,1; f_i – 0,01.</td></tr>
<tr><td>The compression ration of the liquid jet</td><td>$\varepsilon = S_c / S$</td></tr>
<tr><td colspan="2">Units of measurements used</td></tr>
<tr><td colspan="2">S_c – compressed cross section of the jet, m^2; S – cross section of the bottom hole, m^2</td></tr>
<tr><td>Flow rate factor</td><td>$\mu_H = \varepsilon \cdot \varphi_H$</td></tr>
<tr><td>Speed factor</td><td>$\varphi_H = \sqrt{1/\alpha + \zeta_{TC}}$</td></tr>
<tr><td colspan="2">Units of measurements used</td></tr>
<tr><td colspan="2">α – coefficient of losses in the area from the entrance to the hole to the compressed section; ζ_{TC} – coefficient of hydraulic losses of the hole (for the condition of vortex formation $\zeta_{TC} = 0{,}09$, α = 1).</td></tr>
<tr><td>Critical hydrostatic pressure, m</td><td>$H_{кр} = 0{,}5 \cdot D \cdot \left(V / \sqrt{g \cdot D}\right)^{0{,}55}$</td></tr>
<tr><td colspan="2">Units of measurements used</td></tr>
<tr><td colspan="2">D – diameter of the bottom hole, m; V – speed of the liquid spilling out of the hole with the diameter D with the flowrate Q, m/s.</td></tr>
<tr><td>Speed of the liquid spilling out of the hole with the diameter D, m/s</td><td>$V = Q / S_{д.о.} = 4 \cdot Q / \varepsilon \cdot \pi \cdot D^2$</td></tr>
<tr><td>The cross-sectional area of the bottom hole from which the liquid flows, m^2</td><td>$S_{д.о.} = 4\pi \cdot D^2 / 4$</td></tr>
<tr><td>Required hydrostatic pressure to pass through the hole diameter D at the given flowrate Q, m</td><td>$H = Q^2 / \mu_H^{\,2} \cdot S_{д.о.}^2 \cdot 2 \cdot g$</td></tr>
<tr><td></td><td>To optimize the dynamic characteristics of the vortex, the condition must be satisfied: $H > H_{кр}$</td></tr>
<tr><td>Propeller turbine speed, rad/s</td><td>$\omega = Z \cdot \sqrt{\rho} \cdot (g \cdot H)^{5/4} / \sqrt{P_T}$</td></tr>
<tr><td colspan="2">Units of measurements used</td></tr>
<tr><td colspan="2">Z – turbine speed factor</td></tr>
<tr><td>Rotational speed of turbine, Hz</td><td>$f = \omega / 2 \cdot \pi$</td></tr>
<tr><td>Reduction of a reducer for the HPP generator (at working frequency of the generator N, Hz)</td><td>$\varsigma = N / f$</td></tr>
</table>

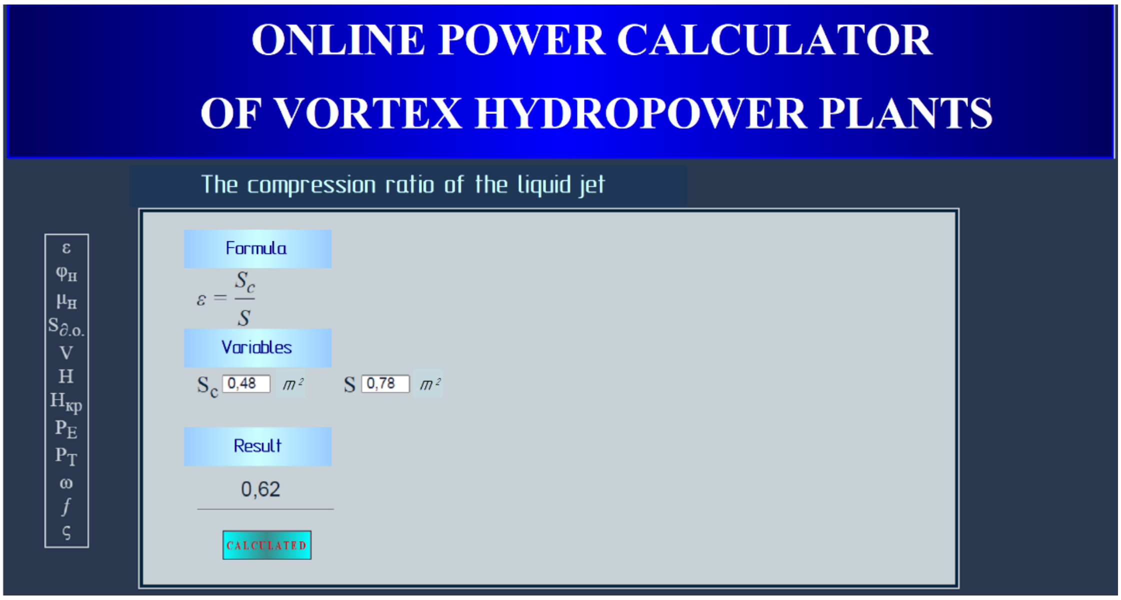

Figure 2 View of the first block of formulas

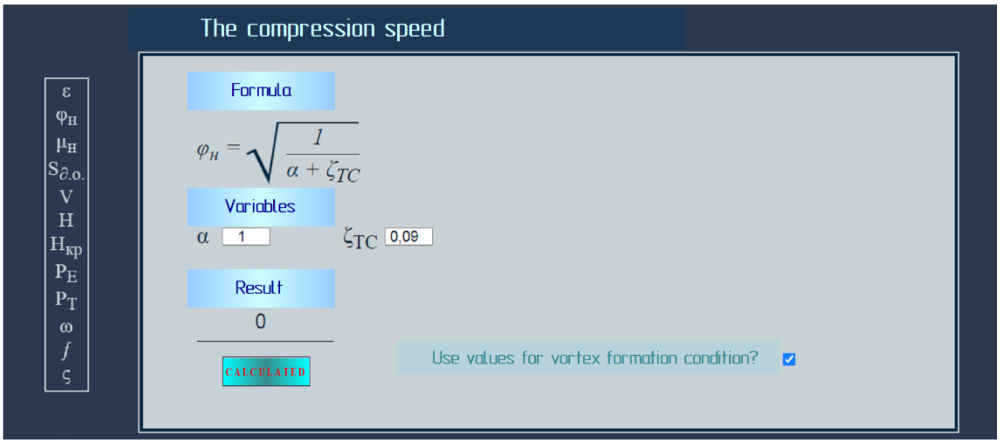

Figure 3 – View of a block of formulas with a flag for automatic entry of parameter values

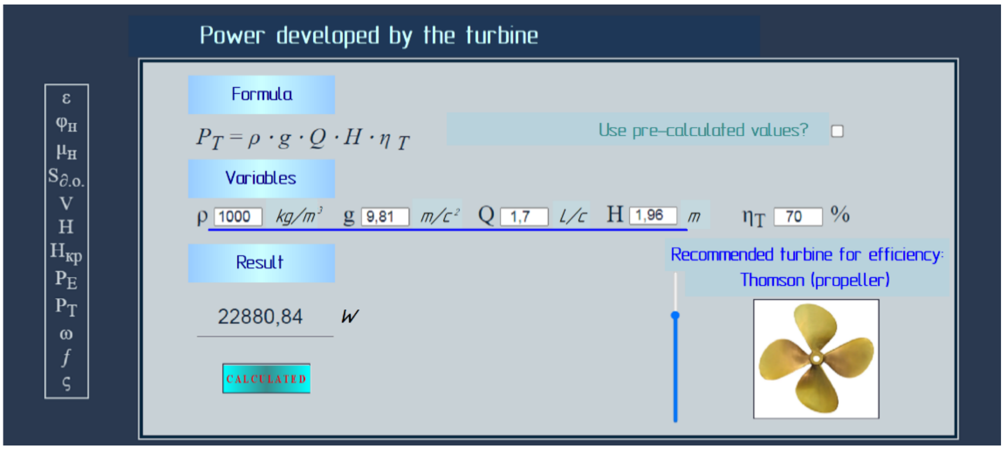

Figure 4 – View of the block of formulas with the choice of the type of turbine

Figure 5 – View of the turbine model selection unit

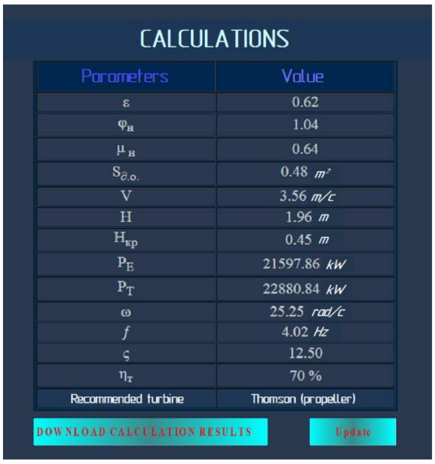

Figure 6 – View of the block of calculation results

3. Conclusion

A web application has been created that optimizes the calculation of the parameters of a small gravitational-rotating HPP for operation in a vortex with dynamic characteristics that provide maximum efficiency of the turbine. The web application has a user-friendly interface and offers a choice of ready-made models of small hydropower plants that are sold on the market and are the closest in parameters to the calculated ones. Selection of models of small hydropower plants is possible by water consumption, impeller diameter and power of the turbine and generator. Using the developed web application will allow you to automate the design process, carry it out in a short time with maximum efficiency and save money on equipment. This will speed up the electrification of remote mountain facilities.

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