MANAGEMENT OF MICROGRIDS ; ENSURING CONTINUITY IN ENERGY SUPPLY

MANAGEMENTUL MICROREȚELELOR ; ASIGURAREA CONTINUITĂȚII ÎN ALIMENTARE

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Abstract: *The study analyses the operating scenarios of the equipment that make up a designed microgrid system. The aim of the study is to highlight the resilience of the power supply to user receivers. The aim of the study is to highlight the resilience of the power supply to user receivers, of microgrid. Thus, a system was designed and configured to manage the equipment operating sequence according to the desired priority in order to enhance resilience. The equipment was interconnected and programmed so that different operating scenarios could be simulated depending on the state of the power sources.*

Key words: Microgrid, PLC (Programmable Logic Controller) Command and Control, Grid Analyzer.

Rezumat: *Scopul lucrării este de a pune în evidență rezilienţa alimentării cu energie electrică a receptoarelor utilizatorilor dintr-o microreţea. În cadrul lucrării sunt evidențiate scenariile de funcționare ale echipamentelor care alcătuiesc o microrețea având ca scop final creșterea rezilienței energetice . Astfel, a fost proiectat și configurat un sistem capabil să gestioneze ordinea de funcționare a echipamentelor în funcție de prioritatea dorită în scopul creşterii continuității în alimentare. A fost creat un stand de lucru, au fost interconectate/setate și programate echipamentele astfel încât să poată fi simulate diferite scenarii de funcționare în funcție de starea surselor de alimentare. Schema de alimentare a receptoarelor microreţelei ia în considerație condițiile specifice de funcționare pentru receptoarele critice, receptoarele prioritare și receptoarele uzuale (neprioritare). Managementul sistemului de alimentare al echipamentelor este realizat cu ajutorul unui PLC (controler logic programabil), iar măsurarea parametrilor microrețelei se va face cu Analizorul de Rețea și interfață HMI (human machine interface).*

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Cuvinte cheie: Microrețea, Decarbonare, PLC (controler logic programabil) Reziliență în alimentare.

1. Introduction

Decarbonizing the energy system is essential to overcome the global warming crisis. This study refers to "microgrids" as one of the energy system development solutions for achieving the decarbonation goals through an efficient use of local energy sources.The solution to this problem are smart (controllable) grids. They have huge potential to make our power systems more reliable and provide cleaner energy. The paper analyzes and proposes a solution for powering a telecommunications transmission station located in an area with an undeveloped energy infrastructure. A microgrid can be a small-scale power system that includes one or more generation sources that can operate independently of or connected to the national power system. Their main characteristics are [1- 4]:

Autonomy - Microgrids have autonomous generation, storage and consumption and can operate autonomously or connected to the grid. By developing microgrids, we can minimize CO_2 emissions, while maximizing the need for renewable energy and minimizing the need for fossil fuel, thus resulting in a reduction of carbon dioxide emissions in the area

Stability – a microgrid can be stable under nominal operating conditions and transient events in the public network;

Flexibility -microgrids are technology neutral and capable of incorporating various=energy sources using renewable sources. It also offers solutions in case of faults in the public network.

Remote control and monitoring – can ensure demand response, optimizing energy costs.

Efficiency – provides energy independence in case of events with the power grid.

The analysed microgrid consists of sources and users grouped around an isolated (site) high-frequency transmission facility. The conditions of power supply reliability imposed require the construction of a network fed from multiple power sources so that interruptions during operation are minimized. The proposed system is able to manage this principle through intelligent management of the energy sources. The microgrid includes transmission-reception facilities, auxiliary facilities, electric lighting, ventilation and heating.

2. System Architecture

The system is equipped with high-performance equipment and automation, so that it can automatically switch from the off-line state to the on-line state. [5-7]

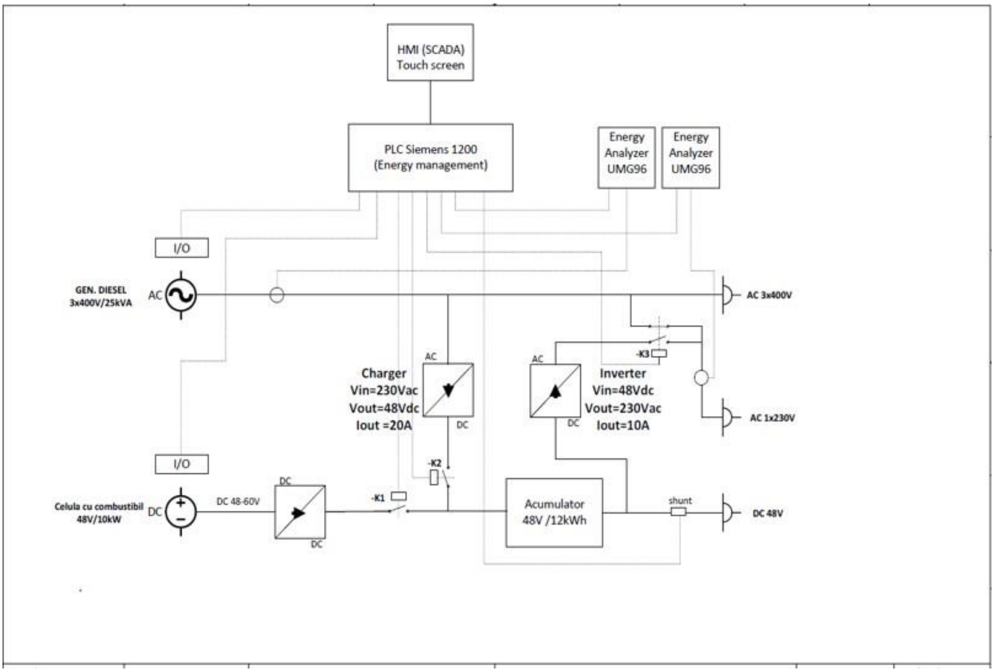

Fig.1. System Architecture of microgrid.

The designed system can be paralleled with the distributors' voltage network ensuring redundancy in case of voltage interruptions or failures. It is equipped with high-performance equipment and automation so that it can switch itself from off-line to on-line status. With the help of PLC-like command and control equipment, all the desired scenarios can be configured and set, so that the collected data can be stored or sent to the operators via various telecommunication routes (fibre optic network connected to LAN, Swich/Router) or GSM equipment [8- 11].

An appropriate choice of the user's power system scheme must allow for reliable power supply to critical receivers, appropriate use of the type of source depending on its response and ensure specific power quality conditions.

The main conditions required for a resilient power system are the following [12]:

– ensure reduction of critical receiver outage duration by at least 3 orders of magnitude compared to standard power supply, depending on the type of UPS, the characteristics of the powered receiver and the service level of the equipment;

– achieving a minimum 99.999 % probability of operation;

– ensuring virtually uninterruptible power supply (at most hundreds of milliseconds).

Achieving 99.999% performance leads to an accepted outage of no more than 4.8 minutes per year.

In the absence of mains voltage, the generator driven by the Diesel engine will start automatically by means of an automatic switch and the receivers in the telecommunications site will be powered in order of importance criteria:

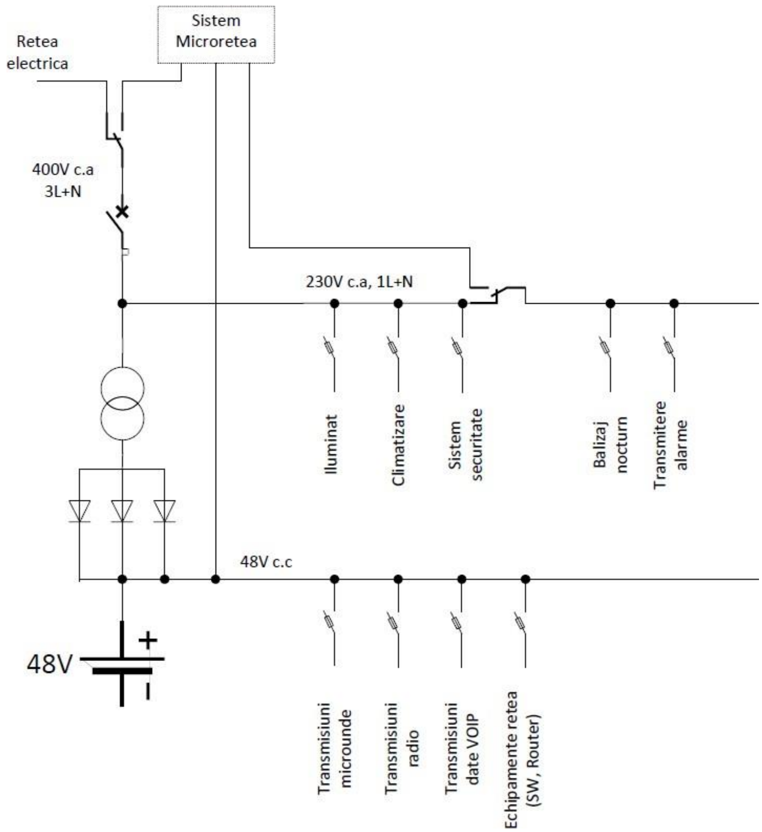

Fig. 2. Single-wire diagram of a redundantly powered telecommunications site.

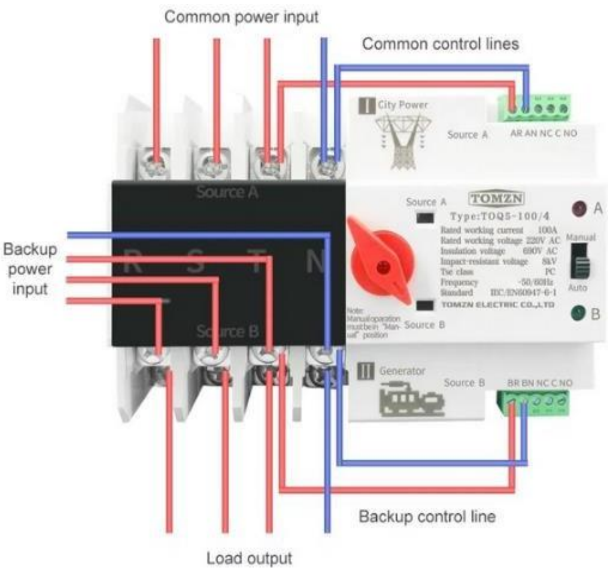

Fig. 3. Automatic switch network manager 4P

Table 1. **Consumer prioritization**

SYMBOL	NAME	INPUT/OUTPUT	ACTION	CONTACT
I0	Grid voltage present	Digital input	Signal from the network presence surveillance relay (1=voltage present, 0=no voltage)	Normally Open Contact
I1	Minimum diesel level	Digital input	Signal from the diesel fuel level probe (1=voltage present, 0=good level)	Normally Open Contact
I2	Minimum H2 level	Digital input	Signal from the hydrogen level probe (pressure sensor) (1=voltage present, 0=good level)	Normally Open Contact
I3	Diesel gen. alarm	Digital input	Alarm/failure signal from the Diesel generator (1=alarm, 0=operating state)	Normally Open Contact
I4	Fuel cell alarm	Digital input	Alarm/failure signal from the fuel cell (1=alarm, 0=operating state)	Normally Open Contact
I5	Presence of voltage in the Diesel gen.	Digital input	Signal from the voltage presence surveillance relay Diesel generator (1=voltage present, 0=no voltage)	Normally Open Contact
AI0	Battery voltage	Digital input	Battery voltage analogue signal (48V c.c.) Resistive voltage divider	0-10V
AI1	Battery current	Analogue input	Battery current analogue signal (48V c.c. output) Shunt +signal conditioner	0-10V
O0	Starting the diesel gen.	Digital output (relay)	Diesel generator start switch (1=on, 0=off)	Normally Open Contact
O1	Starting the fuel cel	Digital output (relay)	 (1=on, 0=off)	Normally Open Contact
O2	Starting the battery charging	Digital output (relay)	 (1=on, 0=off)	Normally Open Contact
O3	Starting the 230 invertor	Digital output (relay)	230V c.a. invertor start switch (1=on, 0=off)	Normally Open Contact

CRITICAL CONSUMERS:

– The MW (microwave) system, data transmissions that has the role of data transmission.

– The RBS radio system (Radio base Station).

– Network equipment (SW, Router, etc.).

PRIORITY CONSUMERS:

– Night beaconing

– Alarms

NON– PRIORITY CONSUMERS

– Lighting

– Air conditioning

– Security System

In the TIA-PORTAL program used for system management, the "I" inputs and "Q" outputs were defined.

In table no. 2 the inputs and outputs of the control system are indicated.

Table 2. **Defining inputs and outputs of the control systemSetup Experimental**

NR	DIGITAL INPUTS	ANALOG INPUTS	DIGITAL OUTPUTS
1	Mains voltage present	Level charge batery	Starting generator
2	Minimum level Diesel	Continuous voltage	Start fuel Cell
3	Minimum level H2		Starting Invertor
4	Generator alarm of diesel		
5	Alarm H2		
6	Present generator voltage-ok		

By programming the PLC (programmable logic controller) equipment, the sequence of operation of the equipment is defined according to the desired priority in order to achieve good resilience in terms of power supply.

The grid analyser Janitza UMG 604 was used for the experimental assembly, that measures the parameters of the grid (voltage, electricity, current) transmitted to PLC through the MODBUS TC protocol. The analyser is set up from the GRIDVIS application.

The data transfer and tag definition are done from the HMI (human machine interface) control panel. PLC is defined as MASTER and analyzer as SLAVE (fig. 4).

Using the GRIDVIS interface, Figures 4 and 5 show the recorded values of electric currents and power consumption as well as the related voltages and frequency (fig.5 si 6).

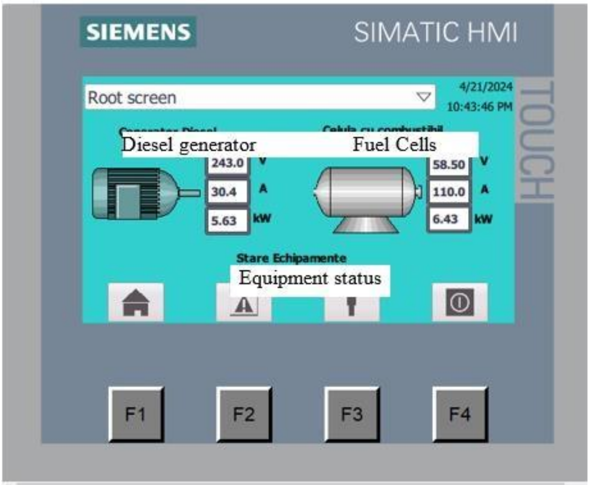

Fig. 4. Defining tags in the HMI control panel.

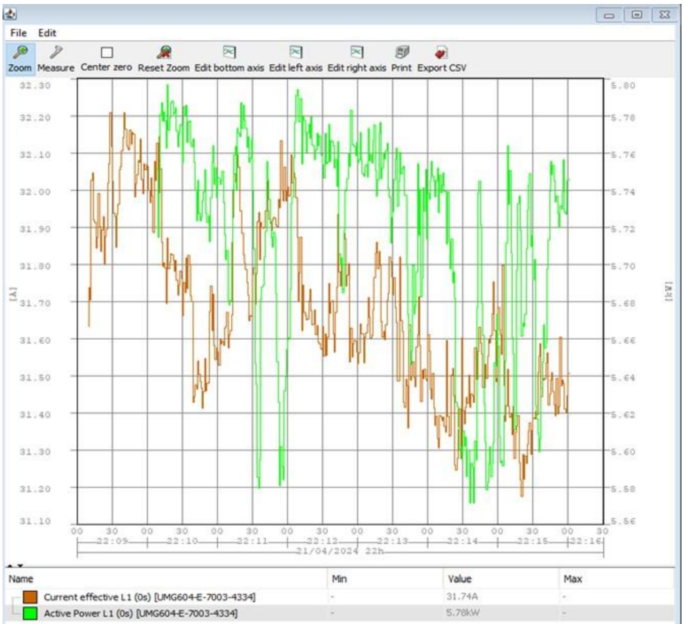

Fig. 5. Measured values of electric current and active power at the Diesel generator terminals

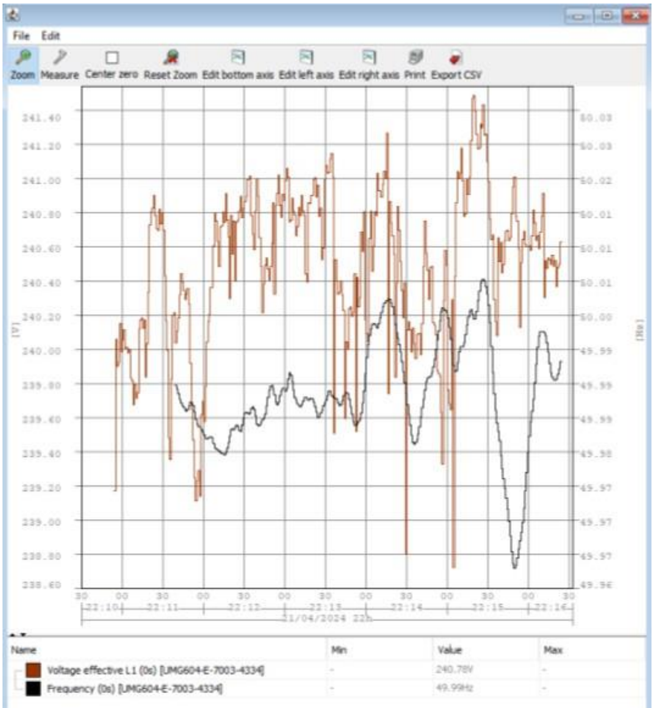

Fig. 6. Measuring the voltage and frequency at the Diesel generator terminals.

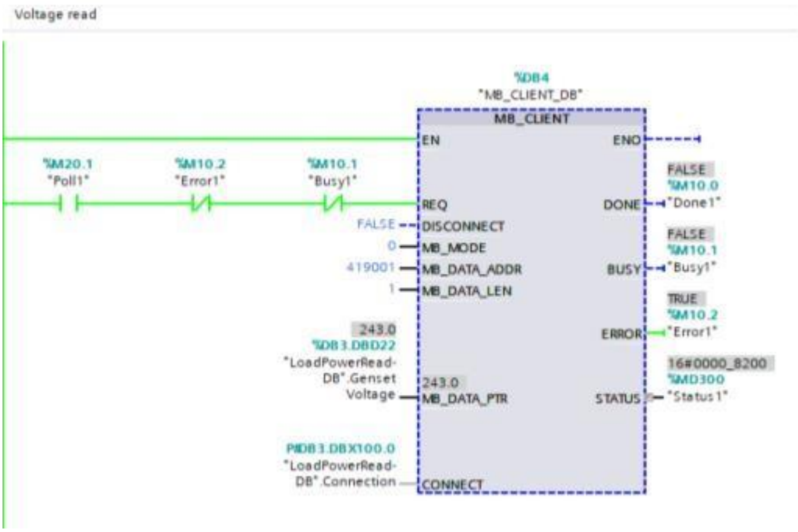

Fig. 7. Modbus communication software module illustrating the voltage value indicated by the analyzer and transmitted to the PLC.243 V.

For example, the logic diagram for setting the Diesel generator as the primary power source for the equipment is shown in Figure 8.[13-14].

Fig. 8. Simulated operation of the diesel generator as a primary energy source.

4. Microgrid management system; Mathematical modeling of the microgrid -Symulink Matlab

Matlab Cod:

```
demand_power = 2000;solar_power = 800;fuel_cell_power =
1000;battery_power = 1200;diesel_generator_power =
1500;excess_energy = 0;power_balance = 0;fuel_cell_active =
false;battery_active = false;diesel_generator_active =
false;power_available = solar_power + fuel_cell_power; % Power
availave ;power_balance = demand_power - power_available; % the
difference between power demand ;if power_balance <=
0;excess_energy = - power_balance;battery_active = true;fprintf('Exces
de putere: %.2f W. Charging baterie.\n',
excess_energy);fprintf('Demand power: %.2f W.\n', power_balance); if
battery_power >= power_balance;battery_active = true;fprintf;end
```

Rezultatele rularii codului:

– **Power deficit:** A power deficit of 200 W is displayed. The power required to supply the load (2000 W) exceeds the power available from the renewable sources (solar panels and fuel cell), which is 1800 W. Thus, a deficit of 200 W that must be covered from other sources.

– **The battery covers the necessary:** The system finds that the battery has the necessary capacity to cover the power deficit. Therefore, the battery is activated to provide the missing 200 W, while the other sources (fuel cell and diesel generator) remain inactive.Starea componentelor:

– **Fuel cell:** Inactive, because its maximum available power (1000 W) has already been used and there is no need to produce more current.Bateria: Activa, deoarece este capabila sa acopere deficitul de 200 W, furnizand putere suplimentara pentru a echilibra cererea si oferta de energie.

– **Diesel Generator:** Inactive, because the battery was able to cover the requirement without having to activate the Diesel generator, which is usually a reserve source activated only when other options are insufficient.

Symulink:

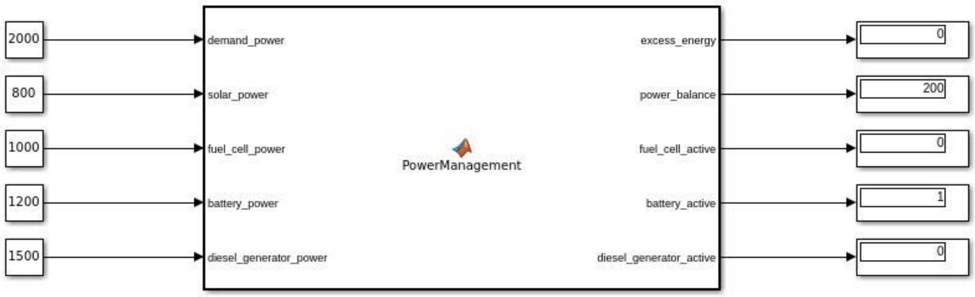

Fig. 9. Simulare Symulink.

- **excess_energy:** The value is 0, which indicates that there is no excess power, so no additional battery charging is needed.
- **power_balance:** The value is 200, which indicates a power deficit of 200 W.
- **fuel_cell_active:** The value is 0 (inactive), which means that the fuel cell is not activated, as no additional power is needed from this source.
- **battery_active:** The value is 1 (active), indicating that the battery is activated to cover the power deficit.
- **diesel_generator_active:** The value is 0 (inactive), indicating that the Diesel generator is not needed.

5. Tools Used

A series of experimental checks were carried out to validate the programs used. The set-up and measuring equipment used for this purpose are shown in Figure 10 : Analyzer Janitza UMG 604, PLC, HMI, PC.

Fig. 10. Tools used.

6. Conclusions

a. A proper prioritization of the power supply to the microgrid receivers was achieved through the management and control of the equipment, which ensured a good energy resilience

b. The proposed solution for the electricity supply corresponds to the conditions imposed for the microgrid receivers; the studied option of using hydrogen fuel cells turned out to be economically unjustified. Currently, the strict use of hydrogen to power the proposed system is extremely expensive compared to the use of other energy sources.

c. For critical receivers because they cannot accept the risk of power cuts, UPS and power storage systems will be used.

R E F E R E N C E S

[1] *** National Integrated Energy and Climate Change Plan 2021-2030 (April 2020).

[2] *** Regulation No 2018/842/EU of the European Parliament and of the Council on the binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet their commitments under the Paris Agreement and amending Regulation No 525/2013/EU

[3] Puianu M., Flangea R.O., Arghira N., Iliescu S.S., Microgrid control simulation and testing, Sci. Bull., U.P.B. Series C, Vol. 80, Iss. 2, 2018

[4] Cañizares C.A., Palma-Behnke R., Olivares D.E., Mehrizi-Sani A., Trends in microgrid control, IEEE Trans. Smart Grid 5 (4), 2020.
[5] Younesi A., Shayeghi H., Wang Z., Siano P., Mehrizi-Sani A., Safari A., Trends in modern power systems resilience: State-of-the-art review, Renewable and Sustainable Energy Reviews 162, 2022.
[6] Zabetian-Hosseini A., Sangsefidi Y., Mehrizi-Sani A., Model predictive control of a fuel cell- based power unit. IECON 2017-43rd Annual Conference of the IEEE Industrial Electronics
[7] Felseghi R.A., Carcadea E., Raboaca M.S., Trufin C.N., Filote C., Hydrogen fuel cell technology for the sustainable future of stationary applications, Energies, 2019,12 (23), hpps://doi. Org/10.3390/en 12234593
[8] Minea V.L., Minea M., Semenescu A., Efficiency of application monitoring in improving mobile communication networcs'rezilience □ a case study, U.P.B. Sci. Bull., Series C, Vol. 83, Iss. 4, 2021
[9] Scott N., *Microgrid. A Guide to Their Issues ans Value*, prepared or Highlands and Enterprise in partnership with Scottish Government, Issued 2016, Rep 1499/002/001B
[10] Golovanov N. ş.a.,Quality of electricity. Solutions for improving the continuity of electricity supply,AGIR,Bucharest 2013,ISBN 978-973-720-497-4
[11] ABB-IEE 2030.7 "https://new.abb.com/medium-voltage/packaging-and-solutions/digital- systems/microgrid---the-future-of-energy-management
[12] ***Improving reliability with standby power supply,https:// www.lpqi.com
[13] SIEMENS type 12XX DC/DC/RLY,https://ro.rsdelivers.com/product/siemens /6es7211-1be40- 0xb0/siemens-simatic-s7-1200-series-plc-cpu-for-use-s7/8624455",Siemens- 6ES7211-1BE40- 0XB0
[14] ***The 2021-2030 Integrated National Energy an Climate Plan. Deloitte calculations based on information provided by the Inter-institutional Working Group on the NICE and the COM recommendations;

Appendix 1. Diesel VS Hidrogen

In order to analyse the efficiency of the main powering from a fuel cell using hydrogen as fuel, we compared the costs of the diesel generator with the costs and problems of using the fuel cell.

For the operation of the hydrogen generator, we calculated the costs for continuous operation for one week (168 hours):

- Generator purchase cost: 6.000 € (RON 30.000);
- Price pe 1 Liter of diesel fuel: RON 8;
- Fuel consumption (diesel fuel)/hour: 4 litres;
- Fuel consumption /week: 4 litres * 24 h * 7 = 672 litres;
- Diesel cost/week: 672 litres * RON 8 = ***RON 5.376*** .

For independent operation of the hydrogen fuel cell for 7 days (one week, 168 hours):

– The power generated by 1 Nm^3 of hydrogen is of approx. 3.5 kWh.
– Estimated system power: 10 kW
– Operating time of the designed system: 7 days x 24 hours = 168 hours
– Required test power : 168 hours x 10 kWh = 1680 kWh
– Hydrogen generated power: approx. 3,5 kWh/Nm^3
– Capacity/no. of cylinders (12 cylinders of 50 l; filling pressure 20 MPa (200 bar): 106.80 Nm3.
– Necessary hydrogen : 1680 kWh : 3.5 kWh/Nm3 = about 480 Nm3.

In order to ensure continuity of hydrogen supply, these batteries should be connected in a pressure reduction system/station. In this case, from a technical point of view, the optimal solution is to use 3.8 hydrogen batteries (purity 99.98%). Approximate costs for running the system for one week using only hydrogen fuel cells: 480 mc H2 x 12 Euro/mc= 5.760 Euro; Approximately ***RON 28.512.***

Acknowledgements

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Authors biographies

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