Evolution of smart buildings. A Romanian case

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***Abstract*-The constant evolution of electricity grids towards smart grids is changing the paradigm. The intelligent layer which is added over the physical one is bringing a change in the mode in which the electricity is provided. Hence, the electricity providers are shifting their business from product-centered to service-centered ones, change that ensure a better use of their resources and a much wider acceptance from their customers.**

The wave of changes has reached the construction domain, and therefore the buildings have evolved into smart buildings, concept which offers a greater elasticity for both energy providers and end-users. Current paper deals with the Romanian framework for smart buildings, presenting comprehensively the drivers of change, as well as a very useful set of real-data simulations and smart solutions deployment, which will help complete the image of nowadays technological trends and future technical expectations for smart buildings.

***Index Terms*—Electric distribution systems, power quality, reliability, simulation, smart buildings, smart grids.**

I. INTRODUCTION

There are numerous definitions of the term "smart building". For increase their energy, economy and information efficiency, cities must undergo a change in their organization and infrastructure, while maintaining secure and continuous access to critical infrastructures.

Electric power systems are a critical infrastructure underlying all other infrastructure systems. Disruptions in the power system have severe economic and social consequences, even for short periods of time [1]. Therefore disruptions must be avoided if possible. Today, electric power infrastructure is using more and more information and communication technology elements. Renewable energy sources are accessible to an increasing number of people. Solar photovoltaic panels are falling steadily in price and size [2] so it is becoming a plausible possibility to create a cluster of distributed generation installation, so called virtual power plant, and using demand side management to enable near uninterruptible power supply. This would require an intelligent and advanced control system to take the full advantage.

The electrical energy system is a critical infrastructure underlying many other critical and non-critical infrastructures is the focus of this paper. The whole city must be upgraded to a so called "smart city".

II. SMART BUILDING

The concept "smart buildings" have been used for more than a two decades to introduce the concept of networking devices and equipment in the building, and energy efficiency.

Today, smart buildings use concept with additional subsystems for managing and controlling renewable energy sources, house appliances and energy consumption using most often a wireless communication technology. Furthermore, they can adapt to grid's conditions and communicate with other buildings, hence creating active micro grids or virtual power plants [3].

In general the smart building consists of:

- Sensors - monitoring and submitting messages in case of changes;
- Actuators - performing a physical action;
- Controllers – controlling units and devices based on programmed rules set by user;
- Central unit – enabling programming of units in the system;
- Interface - the user communication with the system;
- Network - allows communication between the units
- Smart meter - offers two-way, near or real-time communication between customer and utility company

Sensors, actuators, controllers, central unit, interface with network standard make a building automation. The smart energy building has in addition to mentioned components also energy storage and small renewable energy source.

III. POWER QUALITY

The impact analysis of the smart buildings on the distribution system requires indication of the type of network used (low voltage – LV or medium voltage – MV, in the urban, suburban or rural zone), depending on the location of the system and the voltage level. In terms of smart grid, power quality becomes an important issue and should not be ignored. Power quality is influenced by both, the activity of producers, transporters, distributors and suppliers as well as electricity users' activity. Generation, transmission and distribution systems, due to their characteristics and specific requirements are the source of disturbances in the form of disruptions, power failures, unbalance, overvoltage, voltage and frequency variations. Also, operation of industrial users

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and, lately, the operation of the interconnected electricity producers (wind and photoelectric) may be along with the introduction in power system disturbance of the form of voltage fluctuations, harmonics and voltage dips which may reduce the quality of delivered power users connected to the network.

Power quality is a major concern in the electric network, especially nowadays when the power converters producing harmonics are increasingly common in all industries and in the residential sector.

An important impact of distributed generation units on the grid is caused by higher short circuit current. Harmonic emissions may also constitute a particular concern when using converters based on power electronics as an interface between the DG and the network [4]. Although the interface based on power electronics can be seen as an opportunity to improve conditions for connection to the power grid (especially for renewable sources), it may also pose a problem for harmonic pollution. Increase or decrease the voltage to a certain level on distribution network can affect the voltage profile of the lower voltage network. DG units' stability and their ability to cope with the disturbance became also a problem increasingly important [5].

In normal operating conditions (steady state), for the safety and efficiency of energy supply and the functioning of the grid, the voltage must be maintained within the limits permitted in any part of the distribution network regardless of the point at which connects DG units.

IV. Study Case

The study case consists in analyzing the electrical network distribution in conformity with a real network. The study was conducted order to provide a concise picture on a large area of interesting aspects, from the primary analysis of the power flow all the way to the more sensible ones, such as harmonic analysis and finding solutions for the new challenges presented by technology embedded in smart grid.

The distribution network was modeled and simulated using ETAP program. This model focuses on three smart buildings. In the first case it is considered a smart building which comprises wind turbine, photoelectric panels and non-linear source. The second case focuses on the smart building which comprises linear source, batteries and photoelectric panels. The third case consists a smart building comprising: wind turbine, batteries and linear source. The grid is shown in Figure 1 analyzed.

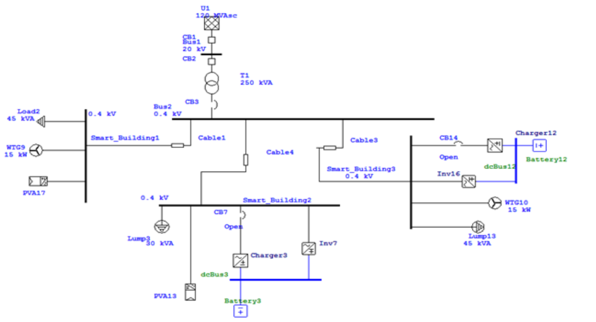


Fig. 1 Distribution Network

The system illustrated in Figure 1 it was designed with the aim to include all possible technical solutions for advanced smart building area. This analysis was made in several stages, including the evaluation of the voltage level, reactive power flow and harmonic distortion analysis.

In figure 2 it is illustrated the power flow in the distribution network.

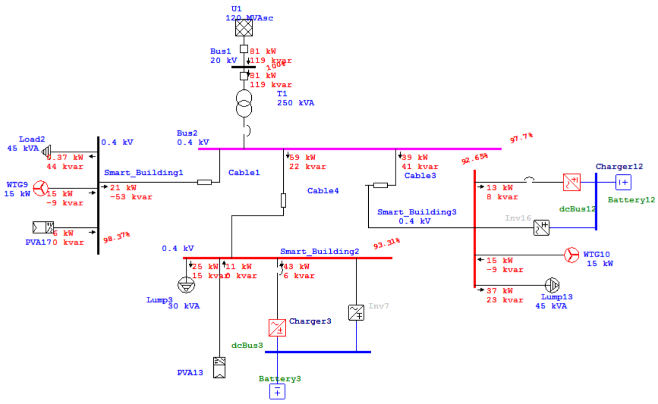


Fig. 2 Power Flow Analysis

After the power flow calculation in Table 1 and Table 2 (column), it can be seen that the voltage reaches the marginal values, even critical cases 2 and 3. Table 2 (column b) the improvement can be observed when the battery voltage is low, reaching a value of 100%. Because control is achieved local voltage can be seen and improvement of the voltage for case 3 and 2 bar.

Tabel 1. Battery Charging

Bus ID	Voltage [%]	*P* [kW]	*Q* [kVAr]
Bus 1	100	80.917	119
Bus 2	97.7	97.605	116
Smart_Building1	98.37	21.149	52.845
Smart_Building2	93.31	67.339	21.453
Smart_Building3	92.65	49.916	40.233

Tabel 2. Battery Discharge			
Bus ID	Voltage [%]	*P* [kW]	*Q* [kVAr]
Bus 1	100	22.699	38.946
Bus 2	99.69	22.879	55.014
House 1 (Caz 1)	100.32	21.148	54.584
House 2 (Caz 2)	100	28.292	25.872
House 3 (Caz 3)	100	39.995	39.294

In Figure 3 can be observed the voltage waveform for the three cases. It can be seen that the voltage pattern of the waveform is similar for all cases. This behavior shows that regardless of smart technology used differently in different cases, its impact upon the voltage is similar, which allows implementation of a wide range of technologies to improve power quality. These technologies reliable and scalable installations can reduce costs, improve energy efficiency, increase electricity supply safety of users.

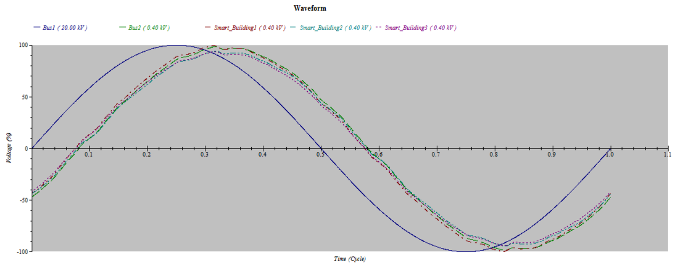
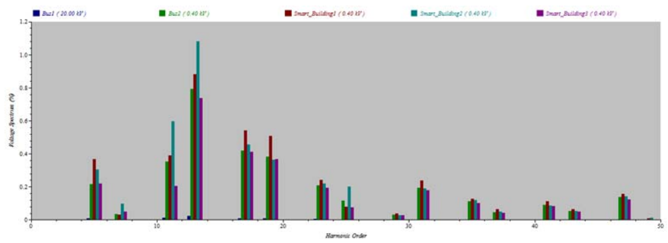


Fig. 3 The voltage waveform for the three cases

In Figure 4 shows the harmonic analysis of tensions on the bars of the analyzed system. It can be seen the presence with a share, harmonics characteristic dual-phase invertors bridge (6 pulses).



Frequency [Hz]

Fig. 4. Harmonic spectrum of network nodes

In Figure 5 presents current waveform. One can notice that the model of the current waveform differs from model voltage waveform in the case two.

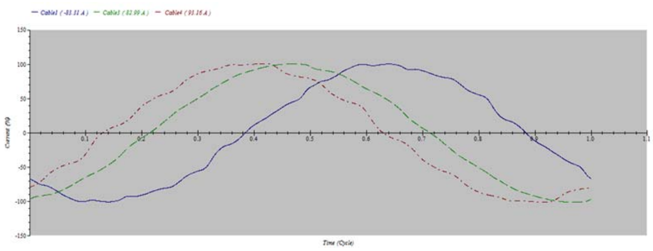


Fig. 5. The current waveform for the three cases

It is noted that current waveform case 3 (cable 3) is even closer sinusoidal as the linear load is higher, and the electric current waveform case 1 (cable 1) is deformed as linear load is much lower. Current waveform for the case 2 (cable 4) is in opposition to the voltage curve due to the fact that it is considered as a source, the other two cases, when viewed as tasks. Electrical energy storage system has a very important role in maintaining sinusoidal shape. The presence of the storage facility to house post two qualities enable a high voltage level (100% versus 91.88% in the absence of storage facility).

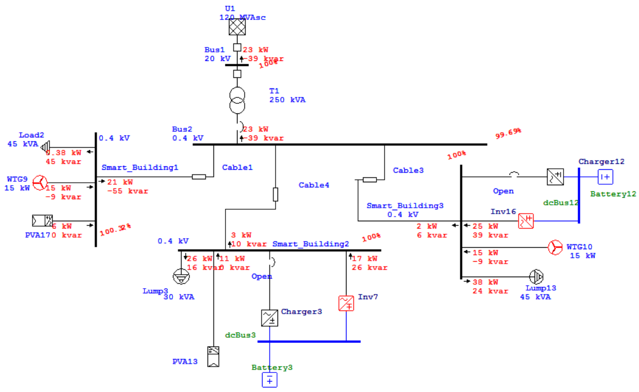


Fig. 6 Power Flow Analysis

In figure 6 is illustrated the power flow in the distribution network, batteries injects power in the network thus making charging and discharging cycle of the batteries.

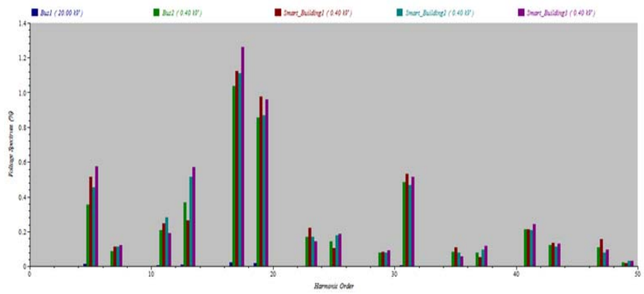


Fig. 7. Harmonic spectrum of network nodes

In Figure 7 shows the harmonic analysis of tensions, it can be seen the power electronic influence on the power quality.

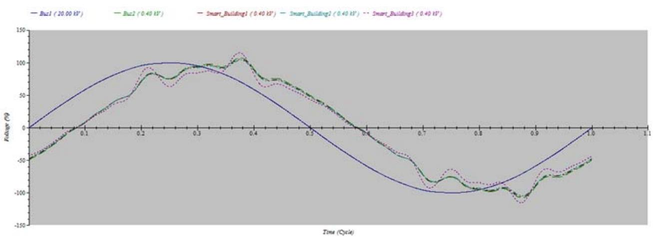


Fig. 8 The voltage waveform for the three cases

Figure 8 is showing that the voltage waveform is sinusoidal.

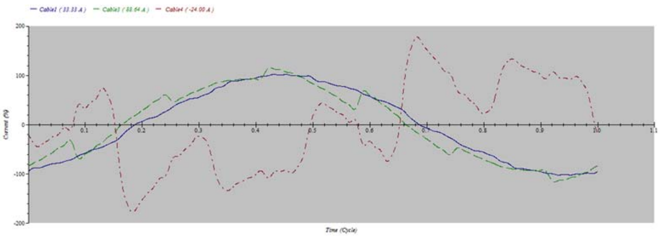


Fig. 9. The current waveform for the three case

The current waveform it is presented in figure 9, current waveform for smart building 2 represents different pattern according to the voltage pattern because the battery is on discharge mode. In this manner the battery injects power in the network, while the current pattern for smart building 1 and 3 is similar with the voltage pattern, because this are drawing out power form the network. It can be seen the harmonic influence on current waveform

V. CONCLUSION

The model examined in this paper consider the possible future development of smart grids. This work focused on three possible solutions for building intelligent environment to improve power quality for future smart grids.

The case study focused on the provision of smart technologies in various images - a power distribution system classic.

Main results of the work were to identify different possibilities to achieve results in accordance with a range of parameters of a real system of electricity distribution and assess the influence of storage on power quality. At this stage electricity was investigate through a small scale smart buildings consisting of 3 homes. The model acts in expected behavior, according to current and future features of smart grid, including utilization of renewables and storage.

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