ANALYSIS OF *SMART* SOLUTIONS IN MODERN EFFICIENCY DISTRIBUTION SYSTEMS FOR BUILDINGS

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Greenhouse gas emissions and climate changes are currently major international problems. This makes it important to increase energy efficiency. The implementation of energy efficiency improvement measures has reduced the energy demand for buildings, so that the power plans designed before adopting these measures are no longer appropriate to current tasks. The present study analyzes the current-supply systems of office buildings and proposes a new energy scheme to reduce the energy demand, while enhancing the "intelligence" of buildings equipment. An important role in intelligent control of energy needs is the computer platform of the buildings energy sector, which includes modern systems for measuring electricity, heat and water used. The platform operates on many specialized sensors and provides bidirectional communications with utility operators.

Keywords: Greenhouse gas emissions, intelligent platforms, Advanced Metering Infrastructure (AMI), intelligent networks

1. Introduction

Greenhouse gas emissions and climatic changes have become major problems worldwide. Renewable energy sources and electrical vehicles are considered potential solutions, but integrating them in electrical networks brings about new challenges. The unpredictable and uncontrollable character of generation makes necessary the development of advanced power analysis platforms and new control algorithms, to administrate the electricity consumption. Consequently, the adaptive control systems will become necessary, and a critical component will constitute the inclusion of energy consumers in the control loop.

On July 2014, the European Commission published a material concerning energy efficiency [1], proposing a goal of improving it by 30%, compared to 1995 (1.5% per year). That is why, a significant production of electricity from renewable sources can be counted among these measures for increasing the energy. Thus, a series of initiatives for passive houses, or even with positive energy has been observed nowadays. This type of house combines a very high level of comfort with energy savings and with security; in such a house, the temperature is adjusted as function of its residents' presence, the lights are automatically turned on as it is occupied, and turned off when they are not necessary, and the security systems are

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automatically managed. These intelligent solutions can make houses more secure, more comfortable, self-sufficient, offering a lower cost as well in the daily life of its residential consumers [2].

2. Intelligent applications that make life easier

In Romania, the electricity consumption is predominant in the industrial and business environment. That is why, proactive systems of energy efficiency monitoring are necessary to be implemented on a large scale. In industrial units and business environment, a major desideratum is for the control and automation systems, together with the industrial equipment, to furnish the largest production with the lowest energy consumption. It is known that, in industries such as refineries, auto, steel, paper, glass etc., energy constitutes the biggest part of their operation expenses.

Modern solutions available at present or under development for smart residential homes (Fig.1), which monitor and control the power performance of buildings, can offer facilities of complete map-drawing, to offer their beneficiaries a clear image and a better understanding of their power consumption.

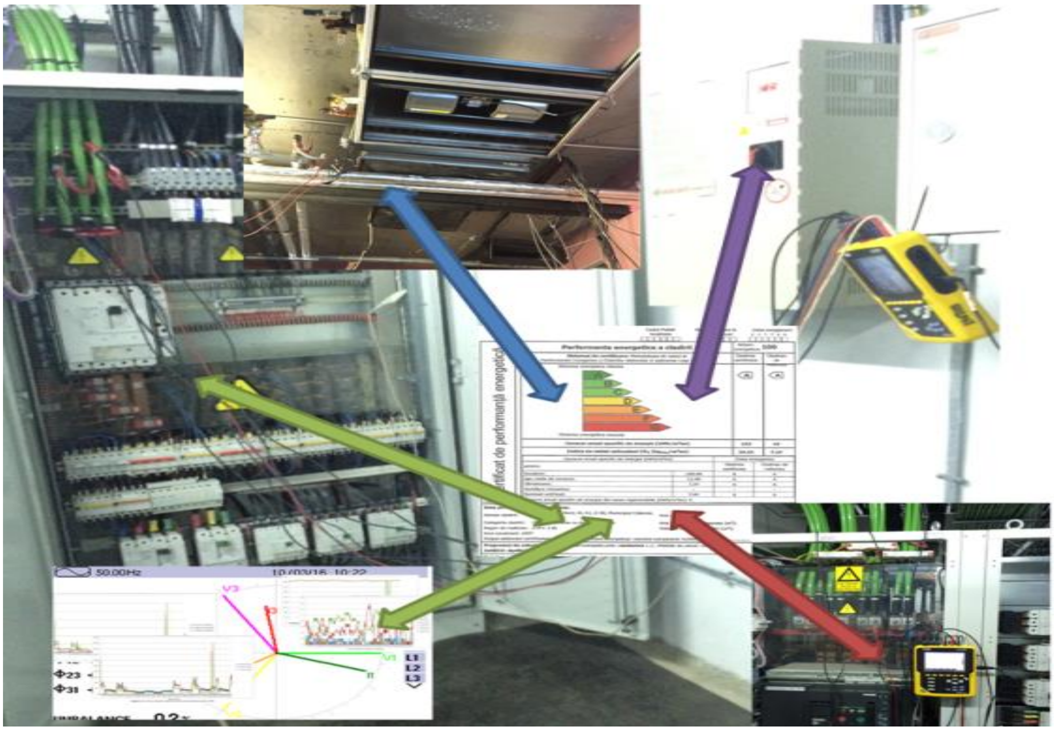


Fig.1. Example of intelligent power platform corresponding to *Smart Residential Home* – data acquisition and decision making.

This fact can be achieved because data analysis is easy to be used for monitoring energy efficiency and elaborating optimization measures, to improve power performance. Precise monitoring of energy consumption enables a better adjustment to the norms of thermal insulation, fitting the consumption as function of needs and the control of real energy invoices. These systems are based on data acquisition integrated for different types of energy, making power balances much easier to obtain and with more precision.

Based on the monitored information, the owners, building managers and industrial power managers can take more intelligent decisions to manage energy. Besides, they can optimize operations, increase energy efficiency, reduce risks, and improve the residents' comfort [3].

There are different characteristics of the communications network for control layer in a hierarchic al system. Network topologies in various implementations vary as function of integrating strategies. The control networks have merged with the corporative networks, so that the control engineers can achieve the monitoring from outside the control system network. Such abilities enable switching loads to remotely control devices that consume more energy, like water heaters, so that they would consume electricity when it is cheaper.

Energy Performance Certificates, based on data from the IT platform, can provide a realistic, accurate, easy-to-understand image at a given time (timing) on a concrete situation, from the perspective of the energy system which belongs the that respective building. But above all, the performance of electrical and thermal installations can be attentively monitored. Moreover, the information obtained can measure the real energy efficiency improvement impact over the facilities, starting from the initial data for their financial analysis.

These types of technical platforms use robust bidirectional communications and advanced sensors, and the distributed computing technology improves the operating efficiency, reliability, and security of the industrial and business units. Thus, by collecting data regarding the power consumption on a regular basis, the dedicated technical platforms enable an efficient management of the energy consumptions [2,3]. These intelligent platforms are appreciated as a modern solution [4], adequate and very friendly, both for industrial users (including office buildings), and for common people.

At the site level, the devices are capable of connectivity both wired and wireless, for monitoring HVAC (Heating, Ventilation and Air Conditioning) devices, lighting devices, and metering devices, offering a local complete integrated power control, as well as a remote control. The advanced intelligent systems of HVAC type are adapted for the cases in which there are sub-consumers that must be separately invoiced, as they are very easily measured. In this case, all the necessary data are securely acquired, and then used to automatically generate the respective invoices. Thus, these typologies of systems can be both implemented for an intelligent house or a block of flats/ group of blocks at an industrial/ business level in plants, production units, or offices. This characteristic is enabled because these intelligent systems rely on a series of analytical software, which can be used in common, associated with various power or utilities meters, as well as with temperature and pressure transducers, by means of the communications system.

3. Case study

A simple but quite suggestive case will be displayed as exemplification. It analyses the expected effects compared to those obtained, as a consequence of several intelligent *(smart)* solutions (both conceptual, algorithmically, and with actual practical implementations). Thus, a housing/ office complex is considered [5]. At the client's request, the builder had to achieve maximum energy efficiency, with a self-adaptive capacity to modern solutions (at present and in future), both for the present legislation, and anticipating various legal stages by different instruction procedures. The permanent goal is to reduce the consumption of any type of energy (electricity/ thermal) or other utilities (water).

The analysis of an operation period specific for a certain time of the year is presented (the data being monitored, analyzed, and then computed for a period of seven consecutive days). The 5 transformers have the powers ***T1,T2,T3,T4 -1250 kVA and T5 - 250 kVA***, according to the single line diagram below.

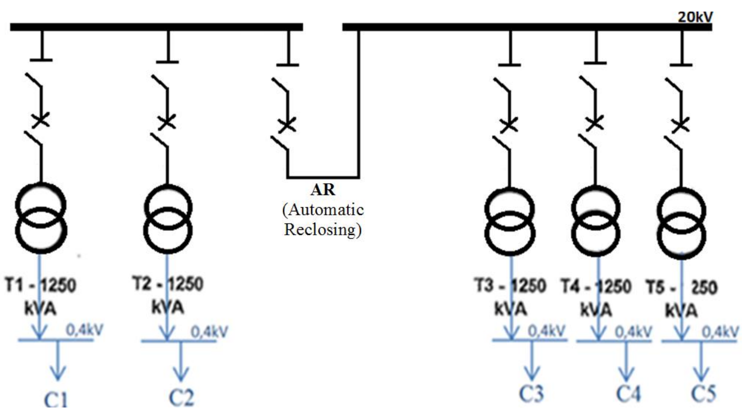
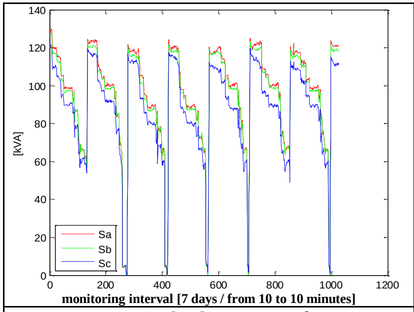
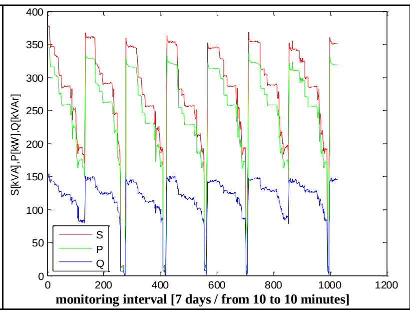
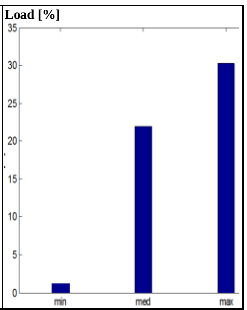
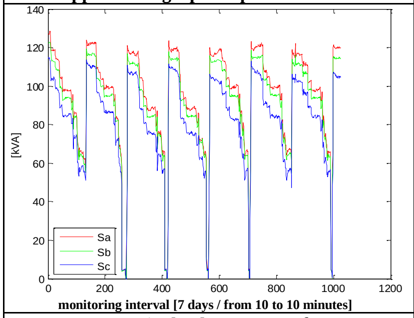
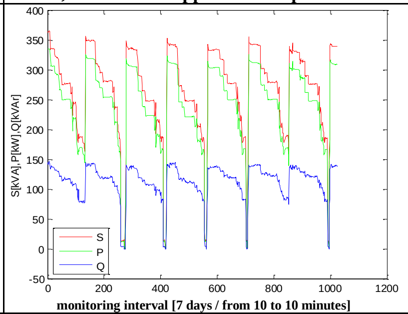
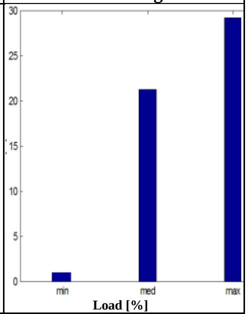


Fig. 2. Simplified single line diagram with the 5 transformers analysed *T1,T2,T3,T4* -1250 kVA and *T5* - 250 kVA.

Based on the measurements achieved in real time and control devices, the following characteristic curves have been extracted for the five transformers of 1250 kVA and 250 kVA, respectively. They are presented in Figs. 3*a*, 3*b*, and 3*c*.

		
Apparent single phase powers for T1	**Active, reactive and apparent total power for T1**	**T1 loading**
		
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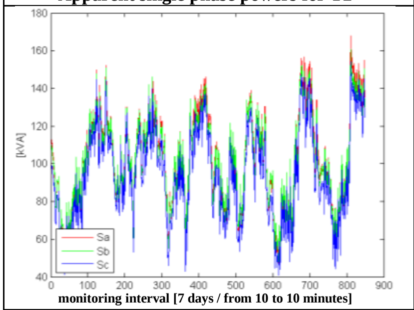
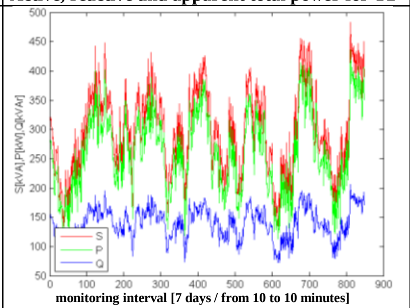
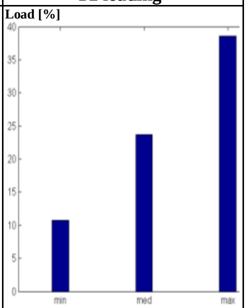
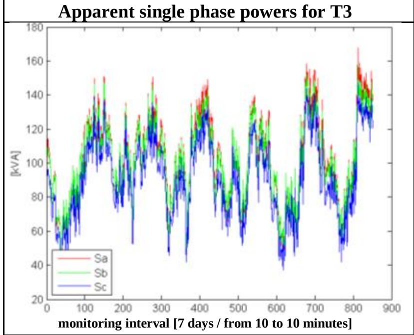
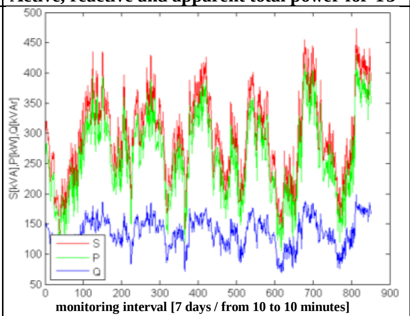
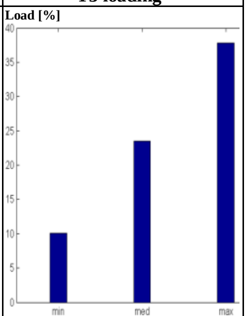
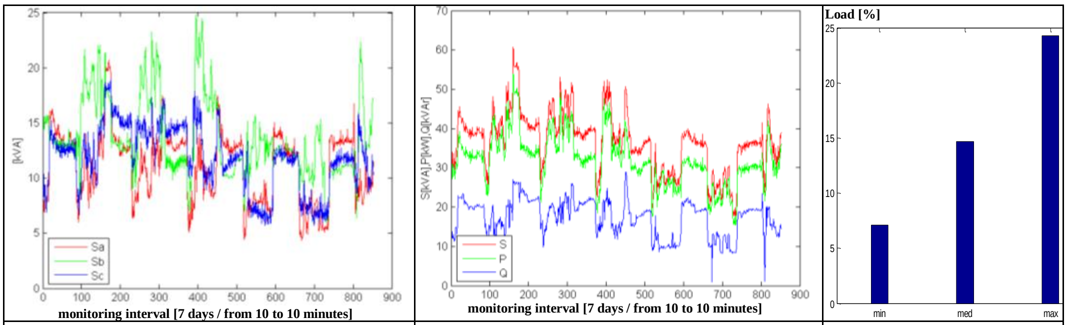
		
Apparent single phase powers for T3	**Active, reactive and apparent total power for T3**	**T3 loading**
		
Apparent single phase powers for T4	**Active, reactive and apparent total power for T4**	**T4 loading**



Apparent single phase powers for T5	Active, reactive and apparent total power for T5	T5 loading
a.	***b.***	***c.***

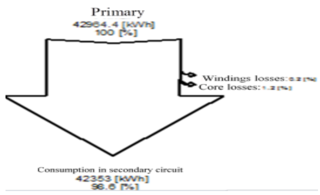
Fig. 3. The operation regimes of the 5 transformers T1, T2, T3, T4, T5: a. apparent single phase powers, b. active, reactive, and apparent total power, c. The 5 transformers loading (minimum, average and maximum) during the monitoring period.

The analysis of the curves shows that the shape of the power graphs is almost the same on working days, and on weekends, although the maximum power remains the same, the minimum powers show another shape. In the three phases, the powers are different, fact which determines the need for future analysis of the unbalance. The curve analysis in Fig. 3b shows that the reactive power *Q* follows the shape of the active power curve *P*, fact which leads to a practical power factor of 0.9. Fig. 3.c indicates the minimum, average and maximum power values for the monitored period.

The energy balance analysis of the 5 transformers is showed in Fig. 4. The mathematical formulas that formed the basis of the calculations are found in the bibliography [7].

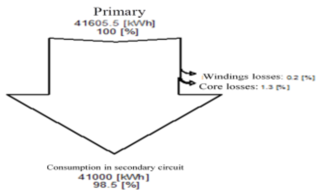
T1

Parameter		**Monitoring period**		**Total / year**
		kWh	**%**	**MWh**
MV (medium voltage) bars		42964.36	100	-
Transformer losses	Windings losses	80.404	0.187	4.115
	Core losses	530.617	1.235	27.156
	Total	611.020	1.422	31.271
LV (low voltage) – Consumption		42353.34	98.577	-



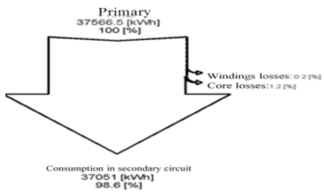
T2

Parameter		**Monitoring period**		**Total / year**
		kWh	**%**	**MWh**
MV (medium voltage) bars		41605.51	100	-
Transformer losses	Windings losses	75.043	0.180	3.844
	Core losses	530.100	1.274	27.156
	Total	605.143	1.454	31.000
LV (low voltage) – Consumption		41000.37	98.545	-



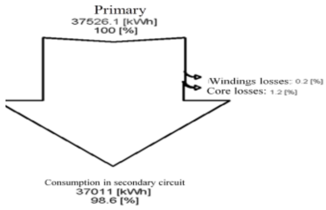
T3

Parameter		**Monitoring period**		**Total / year**
		kWh	**%**	**MWh**
MV (medium voltage) bars		37566.5	100	-
Transformer losses	Windings losses	75.926	0.202	4.695
	Core losses	439.167	1.169	27.156
	Total	515.094	1.371	31.851
LV (low voltage) – Consumption		37051.41	98.629	-



T4

Parameter		Monitoring period		Total / year
		kWh	%	MWh
MV (medium voltage) bars		37526.14	100	-
Transformer losses	Windings losses	74.652	0.199	4.605
	Core losses	440.200	1.173	27.156
	Total	514.853	1.372	31.761
LV (low voltage) – Consumption		37011.29	98.628	-



T5

Parameter		Monitoring period		Total / year
		kWh	%	MWh
MV (medium voltage) bars		4845.494	100	-
Transformer losses	Windings losses	18.699	0.386	1.152
	Core losses	298.550	6.161	18.396
	Total	317.249	6.547	19.548
LV (low voltage) – Consumption		4528.245	93.453	-

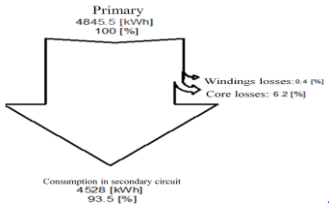


Fig. 4. Real balance analysis for T1,T2,T3,T4 and T5

One can notice that the losses in Transformer T5 are significant, compared to the ones in the other transformers. These losses must be considered; as one can observe in Fig. 3c, the maximum loading is of 25%. Considering the very reduced loading of T5, the measure proposed and analyzed in this article is to eliminate this transformer from the operational diagram, and to switch the electrical power consumption on another transformer. Consequently, the solution of passing the total consumption from T5 on T4 is further analyzed. In this case, the loadings of T1, T2, T3 remain unchanged, while the loading of T4 do not increase too much, and T5 is not connected. So, the load of T4 would have the minimal, medium and maximal values presented in Fig. 5.

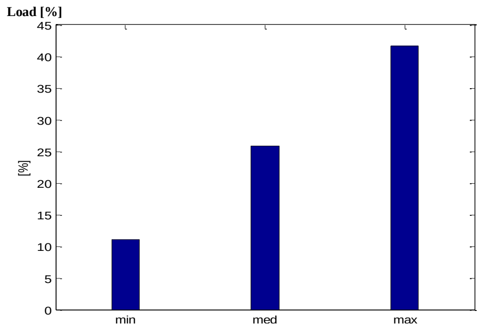


Fig. 5. Loading of T4 after reconfiguration of the network (after elimination of T5)

Because the loading of T4 increases, a small increase of its energetic efficiency can be noticed (cca. 3 - 4%) (Fig. 6). By disconnecting T5, a decrease of the active energy losses is accomplished, from 5428 kWh (T5) +37011 kWh (T4) per year to 40712 kWh per year, so an annual saving of 1727 kWh. This is equivalent with saving 102 euro/year, which is a relatively small saving, if one considers only the actual electric power. However, costs for maintenance, depreciation, various certifications, and others are also avoided.

Parameter		Monitoring period		Total / year
		kWh	**%**	**MWh**
MV busbar		41242.94	100	-
Transformer losses	Windings losses	90.329	0.219	5.572439
	Core losses	440.200	1.067	27.156
	Total	530.529	1.286	32.72844
LV Consumption		40712.42	98.714	-

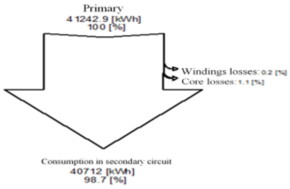


Fig. 6. Analysis of the active power balance – T4 after reconfiguration.

The system with 5 transformers was intended for an estimated consumption, but the measures and the solutions adopted for energy efficiency determined the reduced load found. These reductions of power consumption in this building assembly are obtained as a result of measures like:

- changing the older lighting system (even an older generation LED type) with a modern one, which has a consumption reduced to a half;
- changing classical motors of an older generation with modern motor of HEM type (High Efficiency Motor), possibly tooled up with modern starting devices;
- switching from computers with power values that can range till 350 – 450W to laptops, minicomputers, or tablets of maximum 90W;

Considering the present legislation as well, the intelligent devices proposed in this case should increase the energy efficiency without any help, by eliminating T5 from the operational diagram.

4. Analysis regarding the intelligent solutions implementation

It is further recommended to analyze the power scheme, considering the beneficiaries' program of switching to the adoption of intelligent solutions in buildings. Some of the solutions expected from the energy analysis that could lead to modifications to the power scheme are presented below.

Saving energy and energy efficiency are the main objectives in designing intelligent networks, ensuring a better reliability in them. Moreover, costs are reduced, because the efforts to reduce the consumption are less than building new units of energy generation. An advantageous way to reach this objective is designing an intelligent system for metering, command, and control of the systems for supplying electric energy, thermal energy, natural gases, water and other utilities at the consumers' level. At an international level, this system is named Advanced Metering Infrastructure (AMI) [1,8,10]. AMI represents the totality of the systems for metering, acquisition, and bidirectional communications, including the users' meters, the communications networks, the services suppliers (electrical energy, water, gas, etc.), and the system of data processing. Thus, specialized literature developed the supply concept idea [1], some partial-idea given by experts [8], many desires to follow [9], as well as some ideas that can lead to pricing/tariffs problems [10]. A scheme of the basic components of AMI is described in Fig. 7.

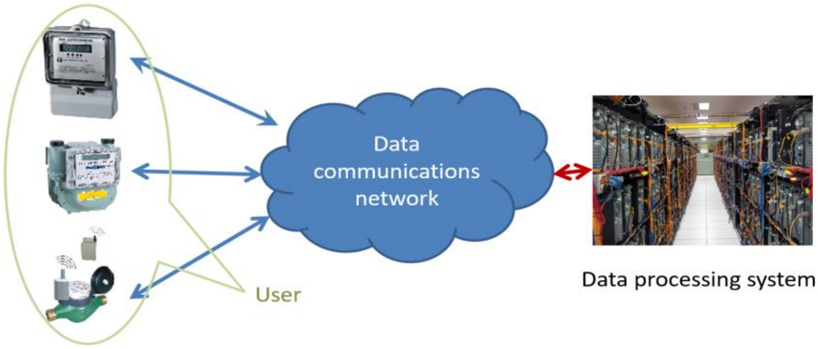


Fig. 7. AMI basic components

The intelligent meters use passwords associated with the individual users, the same as the IED (Intelligent Electronic Device) in electric stations. These passwords are common for several groups, which are usually known to all those involved in the metering systems. That is why, it would be necessary an authentication system based on secure and confidential passwords (not associated to the groups of users). A system of control and management of these passwords would be also necessary, to ensure that only the right users have access. Besides, authentication must be achieved depending on the user's activities: a user who supplies power in the network must have a different access level, compared to a simple user. Even the communications between meters and the AMI central point should be authenticated.

The certification of the remote meters represents another important aspect of the AMI security. This certification involves checking that an equipment in the field has the expected behavior and functions in the approved configuration. In the case of meters, this means checking the firmware version and if it has been deteriorated. One checks if it functions with the right settings, and if it had always functioned with a firmware version that was not deteriorated. An intelligent electric network implements the policies of energy efficiency on the whole chain that starts with power generation and ends with users. In the case considered here, this efficiency consists in reducing the losses in the lines of transport and distribution, the efficient control of tension voltage, as well as *reducing the users' consumption*. The connection between the financial investments and energy efficiency is shown in Fig. 8 [1,8].

Energy efficiency policies develop quite rapidly, being initiated both by governmental bodies and by the companies of utilities. Buildings will not be only "green", but also "intelligent", since the users would be able both to buy, and to sell this energy, by controlling it.

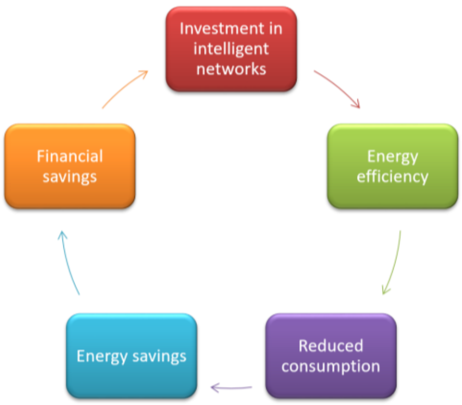


Fig. 8. Role of energy efficiency in intelligent electrical networks.

Thus, the users' intelligence will consist exactly in their capacity to manipulate the energy flow and the incomes obtained, by closely working with the intelligent networks they are connected to.

It is also important for the consumers to integrate sources of distributed generation, either as co-generation or as renewable energy sources, so that the whole network would benefit from them. One of the major challenges of the intelligent electric networks and of the control systems at the consumer's level is interoperability [9,10,11]. The systems of control connected to buildings are generally endowed with their own programming language. The first step to the communications interoperability is implementing standard protocols.

Besides, the appliances should "feel" the network from which they are supplied energy. For instance, a washing machine may "receive" the energy cost from the electric network and may autonomously "decide" starting to function only if it uses communications protocols compatible both with those in the network, and with those in the energy monitoring system.

When consumers are considered as energy suppliers, their control systems should communicate with the companies of utilities, and even with the energy market, in order to have dispatching assured.

Even if intelligent equipment is used [12], improving the *interaction between network and consumer* should be achieved, to have a proper response of the consumers at the network requirements.

The strengths in choosing to build an intelligent house/ building can be structured like this [8,9]:

- stimulating the clients'/ users' wish for comfort;
- stimulating the client's/ users' wish for security;
- the popularity of IT and web portals;
- extended and secure internet connection;

- the more and more expensive energy cost, fact which request new methods of optimization the electrical and thermal energy consumption;

Yet, there are also weaknesses, such as [10]:

- the expensive cost of implementation;
- the lack of clients'/ users' specialty knowledge – sometimes the problems caused by these buildings are too technically specialized and very complex, increasing the difficulties of usage, even for experienced persons;
- complicated installation combined with the clients'/ users' confusion (regarding their wishes and expectations);
- users' worries for the security of the data monitored/ transmitted/ stored;
- not always a low energy cost in some areas is beneficial; in many cases, it can cause diminishing the clients'/ users' motivation to automatize the house/ building;

5. Conclusions

The power supply of buildings in the future will have important changes in energy efficiency, both due to increased energy efficiency of the equipment and the beneficiaries' concern for the implementation of *SMART BUILDINGS*.

The intelligent system of each residence should be able to achieve and use a power label that can offer at any time an estimation of the average energy consumption, of the operation cost for the specific type of the device used (for various settings), the analysis of chronological archive of events, as well as the estimation on a short, medium, and long term of certain values considered as necessary (recommended – kWh, kVArh, money, etc.).

Moreover, the intelligent system of the building should access (and upgrade whenever necessary) a guide of energy with information regarding tariff (by hours, day-night, etc.), but also a part of up-to-date legislation with all the changes and modifications in this domain. In this way, the system would be able to quickly show any information in this sense at the user' request, so that he can take the right decision.

The automation of houses/ buildings has become more popular for users, since it increases the degree of comfort and security, while lowering the energy cost (electricity/ thermal), owing to some intelligent systems of managing / information.

The analysis carried out in the paper particularly highlighted that the energy supply system of the buildings, designed before the adoption of the energy efficiency measures and the increase of the intelligence level of the energy structure, needs to be periodically reviewed in view of the continuous concerns of the owner to increase energy efficiency and preoccupations for switching to *SMART BUILDINGS*.

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