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Electric Energy Management System in a Building with Energy Storage

***Abstract**. The following article presents the idea for electric energy management system with energy storage realized using basic programmable controllers of building automation. System under development will save electric energy while taking into consideration user criteria for comfort and safety.*

***Streszczenie.** W artykule przedstawiono koncepcję zasobnikowego systemu zarządzania energią elektryczną w budynku realizowanego za pomocą podstawowych sterowników programowalnych automatyki budynkowej. Opracowywany system pozwoli na oszczędność energii elektrycznej przy uwzględnieniu kryteriów komfortu i bezpieczeństwa użytkowników. (**Zasobnikowy system zarządzania energią elektryczną w budynku**).*

Keywords: energy management system, energy storage, energy efficiency.
Słowa kluczowe: system zarządzania energią, zasobnik energii, efektywność energetyczna.

Introduction

Civilization advancement entails economic development. It has been the fastest in the history for last 100 years. Consequence of this is drastic increase in energy demands, which is processed in over 80% from nonrenewable sources (oil, gas, coal, uranium) [1]. In summary of total energy usage, buildings use, depending on country, from 20 to 40% of energy, placing them most often as third, after industry and transportation [2]. It is estimated, that improving buildings' energy efficiency can bring decrease in energy usage in European Union in existing buildings by 20%, which means 60 billion Euro of savings p.a. [3].

The following article discusses energy resources management systems in buildings, with particular emphasis on electric energy. Issues of existing building management system solutions have been raised. New idea for electric energy management system with energy storage has been presented.

Building Management Systems

Developed energy-efficient and passive construction is possible only by using modern building management systems (HMS/BMS). Home/building management systems form the commonly called "intelligent installations". Control-measurement and implementation devices network creates building automation system, that reacts in designer-specified manner. Thus, it is apparent intelligence that depends on experience and imagination of designers [4]. Building management systems are developed and evaluated in three most important categories: comfort, safety and energy-efficiency.

The development of renewable energetics along with distributed generation technology causes individual consumer is not only a mere energy consumer, but also a producer. As of today, despite of buying energy in the UE by power companies from renewable sources, this type of activity is unlikely across individual consumers, for whom own sources are of few kW power. The biggest issue in this case is control over such sources, that has to remain under power companies, that in case of power failure would be able to disconnect all potential sources, ensuring service safety during power outage. Therefore, small and renewable energy systems are implemented as selected-load-only. One of the biggest problems in such solution can be the surplus of energy acquired. Ill-fitted sources, too small a energy storage and load off can lead to system damage. Due to stochastic nature of renewable sources work characteristics, system designers are able only to estimate sizes of the energy production, storage and transformation components. One can expect, that HMS/BMS systems will have to develop also towards management of energy produced in their own surroundings. This outlines a new vision of the HMS/BMS systems as support solutions for renewable energetics on the level of municipal consumers.

Energy Management Systems

Narasimhan and others [5] presented a draft of energy management system suitable for any applications requiring management: by acquiring energy from different sources, providing energy for different types of users and storing the energy surplus in one or more energy storages. If energy from unpredictable renewable sources is available (photovoltaic panels or wind turbines) it should be used first and conventional sources turned off. Only in case of energy shortage from renewable sources, other energy sources will be activated. Energy management system controls energy usage by all consumers. In case of lower than demanded energy production, the system, based on provided priorities, qualifies which receptions are necessary and must be connected and which ones to disconnect from power. This way the complete power outage is avoided. Additionally in the case of power shortage, consumers should switch to power-saving modes of work. The role of energy management system is to define energy distribution from each source individually to each consumer. Two basic elements of the proposed energy management system are control unit (CU) and switching unit (SU). Connecting those two, along with sensors, creates energy management system platform (fig.1).

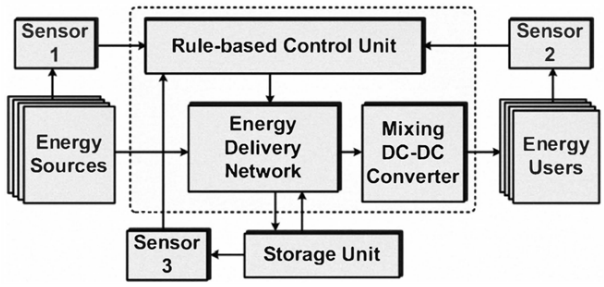

Fig.1. Energy management system flowchart, according to [5]

Energy Management System with Energy Storage

For individual consumers the article's authors propose the simplification of the above system by the use of energy storage and thus overcoming tracking of energy usage or production by each reception or source. New, under development, electric energy management system will firstly and automatically bypass energy loses connected to typical user “negligence” e.g. lights left on, TV left in stand-by mode (the results of own research [6] indicate, that depending on the number of electronics in home, energy usage by those devices left in stand-by mode accounts for 5-10% of total usage) etc. The second goal for the system being developed is the analysis of energy costs. Depending on user preference, having a choice of comfortable mode, or economical mode, the system will decide on the use of energy or not.

The assumptions of energy management system with energy storage:

1. The system monitors the energy management in building (energy production and consumption) based on the state of charge (SOC) of energy storage.
2. Energy produced from renewable sources is not sold to the power grid due to their low power and the difficulties arising from the need to access and control over them by the power utilities in the event of power system failure.
3. Minimalization of the cost of purchasing electricity from the power grid while maintaining the comfort criterion specified by the user of building.
4. Minimalization of the cost of replacement of the energy storage by reducing the level of discharge.
5. Control signals are:
   a) the state of charge of energy storage,
   b) the price for electricity purchased from the power grid,
   c) criteria of comfort specified by the user of building.

It should be emphasized, that the authors first draw attention to the comfort and ease of the users. Saving activities result from more precise control of energy resources, or from conscious decisions about energy consumption reduction. This type of activities may be currently realized by building management systems. Therefore, the system’s algorithms will be realized by basic programmable controllers dedicated for building automation. It will allow for costs reduction associated with purchase of new apparatus and for efficient implementation of the system and its compatibility with other components of the building’s electric wiring.

Due to very dynamic changes in load profile P(t) of municipal consumer, in the solution proposed by authors the system does not track individual energy usage by each reception. In the case of energy storage-equipped instalments, it provides as a buffer for energy used and produced in the given timeframe within the facility. Thus, control signals are states of charge (SOC). This way issues resulting from rapid changes in power demands and from unconventional sources’ diversified energy production have been avoided. The use of modern energy storage will directly contribute to improving the reliability and quality of powering the receptions. From the power companies’ point of view, consumers using energy storage of the storage capacity similar to daily energy demands, become the consumers with almost constant power demands from the electricity grid. It would be a comfortable situation for the power company, reducing the problem of uneven power load during the day.

Additionally, the system analyzes actual electric energy costs. As of today, available methods of settlements for electric energy are based on tariffs, that in defined timeframes determine constant electric energy rates.

Electric energy management system of a building with energy storage idea flowchart was presented on figure 2, where:

P_C – consumer’s power demands;

P_C_NEW – consumer’s power demands as a result of electric energy management system with energy storage;

P_DUMP – additional demands available in the case of produced energy surplus during storage’s full storage capacity;

P_LIMIT – power value disconnected for reduced usage;

P_ES – power absorbed or expended to/from the energy storage;

P_RES - input power from the renewable energy sources;

P_G – input power from the electricity grid.

For the variant of object powered by the grid and equipped with energy storage and renewable energy sources, the system analyzes state of charge. If the energy storage is charged (SOC > 90%) additional load is turned on for protection against overloading. Aggregated load equals then (1):

$$P\_C\_NEW = P\_C + P\_DUMP \quad (1)$$

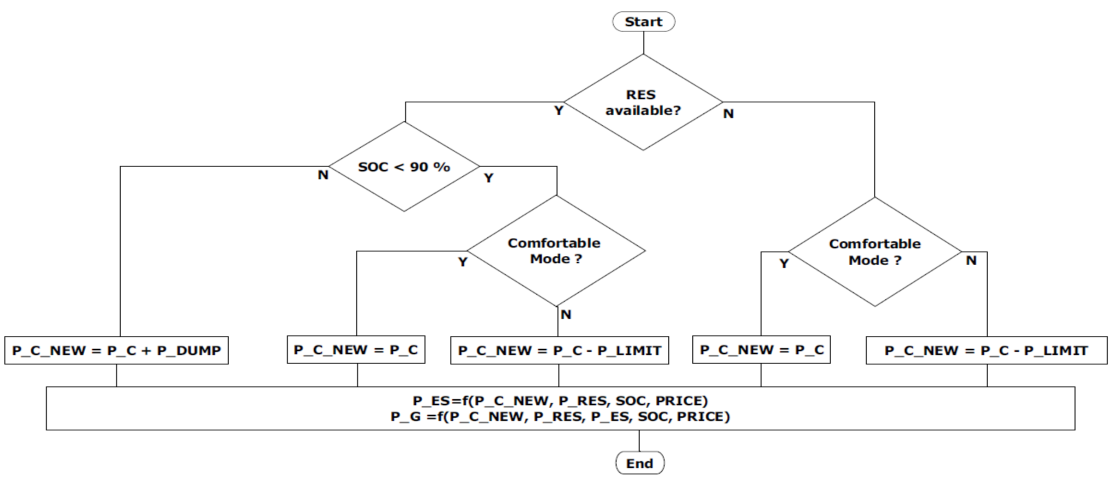

Fig.2. Electric energy management system of a building with energy storage conceptional flowchart

If SOC < 90 %, the system analyzes whether or not it works in comfortable or economical mode. For the first mode the load is not switched (2).

(2) $$P\_C\_NEW = P\_C$$

In economical mode load limit may happen (3), which is a function of current SOC value and standing electric energy price (4).

(3) $$P\_C\_NEW = P\_C - P\_LIMIT$$

(4) $$P\_LIMIT = f(SOC, PRICE)$$

Based on the balance of power the system analyzes consumer's power demands, renewable energy availability and storage's energy availability. While the energy storage is fully charged, the system does not limit the usage even in economical mode. The system analyzes currently standing electric energy price. This means, that thanks to proper energy policy, such energy circulation is possible (favourable purchase), that financial savings are available with no simultaneous resignation from used loads. It may also be the case, that economically better solution will be the purchase of "cheap" grid energy than storage's energy consumption along with the loses, which occur in the energy storage itself and in inverters. Example of discontinuity in function *P_LIMIT* is expressed by (5).

(5)

$$P\_LIMIT = \begin{cases} 0 \;\; for \;\; (LP \;\; or \;\; SOC > SOC_{\min 1}) \\ P\_LIMIT1 \;\; for \; (HP \;\; and \;\; SOC_{\min 2} < SOC < SOC_{\min 1}) \\ P\_LIMIT2 \;\; for \; (HP \;\; and \;\; SOC_{\min 3} < SOC < SOC_{\min 2}) \\ P\_LIMIT3 \;\; for \; (HP \;\; and \;\; SOC < SOC_{\min 3}) \end{cases}$$

for:
$SOC_{min1} > SOC_{min2} > SOC_{min3}$;
LP – Low Price;
HP – High Price.

It needs to be emphasized, that value of limited power P_LIMIT depends on user's preferences. First, decorative lighting may be turned off, internal and external. Other way to limit power is reducing lighting power by 10%, for what modern building management systems allow. In the literature [7] one may encounter a way to limit power by increasing temperature in range 0,5–1,5oC in the air-conditioning systems. In the presented conception the authors presume, that P_LIMIT value will not be higher than 5–20% of temporary consumer's power demands P_C. For the energy storage-only variant, depending on work mode, power load will have value equal to equation (2) or (3).

Using the energy storage allows for storing both the renewable energy and the grid-purchased energy in periods when it is cheap. Proposed electric energy management system with energy storage analyzes consumer's energy demands, the amount of energy provided by renewable sources, state of charge of the energy storage and the energy price. The value of collected or expended power from/to the energy storage is a function of the above parameters (6).

(6) $$P\_ES = f(P\_C\_NEW, P\_RES, SOC, PRICE)$$

The same parameters influence the power collected from the electric grid. Additionally, power collected by the energy storage is included, which may be charged by "cheap" energy (7).

(7) $$P\_G = f(P\_C\_NEW, P\_RES, P\_ES, SOC, PRICE)$$

It must be considered, that using the energy storage alone does not reduce energy usage by the individual consumer. Quite the contrary, for the systems w/o renewable sources, more grid energy is collected in connection with storage's and inverters' efficiency. However the time, in which the energy is collected, is changed and that has direct transition on the price. Actual reduction in energy usage may happen as a result of working building management system. The presented system connects the two above benefits into one electric energy management system in the building with energy storage.

Conclusion

The idea for energy management system with energy storage relies on two base parameters analysis. The first being charge level of the energy storage, the second – energy price. Thanks to such simplification, it is possible to implement the system with the use of basic programmable controllers used in building automation systems without added investment costs. The implementation of energy storage allows avoiding issues derived from rapid changes in power demands and from diversified energy production by unconventional sources. Depending on user preferences, the presented system may bring, according to the authors, from a few to several percent gain in electric energy savings.

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