



ACTUAL PROBLEMS
OF MODERN SCIENCE

2017

ACTUAL PROBLEMS OF MODERN SCIENCE

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Bydgoszcz – 2017

Actual problems of modern science. Monograph: edited by Musial Janusz, Polishchuk Oleh, Sorokatji Ruslan – 2017. – 921 p.

Monograph is prepared at the Khmelnytskyi National University in cooperation with UTP University of Science and Technology, Bydgoszcz, Poland. Article in monograph are presented in the author's original version. Authors are responsible for materials and interpretation.

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ISBN 978-83-938655-3-6

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ENHANCING ENERGY EFFICIENCY OF KHMELNYTSKYI NATIONAL UNIVERSITY

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Introduction

Photovoltaic systems (PVSs) [1] require an energy storage buffer to supply the loads also when the solar energy is not enough. Lead acid batteries are typically used for this purpose. High and fast energy (current) demands from the load can degrade the performances and lifetime of such batteries. Because of the output dependence on weather conditions, PVSs produce incomplete charge/discharge cycles, resulting in a low State of Charge (SoC). In these conditions, batteries cannot cope with fast and sudden energy demands from the load, as necessary for the applications (as motors and water pumps) characterized by transients or start-ups with current requirements for few seconds up to 6-8 times the rated current. For this reason, PVSs are not the best energy source to charge batteries.

In some cases, it can be advantageous to store energy from the electrical power grid and to use it at a different time (load time-shifting), even, depending on the energy cost and availability, to give it back to the grid itself. The feasibility of this option is affected by problems similar to PVSs [2].

The synergic use of battery and supercapacitor (SC) [3] banks could improve the ESS global efficiency by combining the advantages of both technologies: due to the low self-discharge, low manufacturing costs and high energy density, batteries are suitable for permanent and almost constant loads; on the other hand, due to the high charge efficiency, high power density and fast charge/discharge, SCs are able to quickly answer to fast load variations [4].

The base research

The main problem of Khmelnytskyi National University is high expenditures on gas heating system resulting from the high price on gas in Ukraine. It leads to considerable decrease in financing for education, science and cultural development of the University.

To solve this problem, we suggest partial replacement of gas heating system with the electric heating system. Ukraine is one of the biggest producers of nuclear energy in Europe. The quantity of electric energy produced by nuclear power stations is the same at night and during the daytime. But at night energy consumption is much less and, consequently, the price of electric energy at night is twice less than during the daytime.

Nowadays, solar energy production is rapidly developing in Ukraine. To use cheaper nuclear energy at night and solar electric energy during the daytime it is necessary to have electric energy storage system. Traditional electric energy storage systems use batteries which have limited number of charge/discharge cycles. Combined electric energy storage systems consist of conventional batteries and supercapacitors. Such systems are characterized by better efficiency, have longer lifetime and are more environment friendly.

The introduction of a system that could manage the electric energy in Khmelnytskyi National University in a more efficient way may considerably reduce the costs on heating and other needs.

Such a system will provide electric energy for universities and municipal organizations during faults and black-outs for a short term because its efficiency depends on the intensity of sun rays in the daytime. At night consumption of electric energy is not considerable and the energy stored by the system in the daytime is sufficient to supply fire alarms and security systems.

An Advanced Hybrid Battery-Supercapacitor Management System (AHB-SMS) is developing in Khmelnytskyi National University. This system should be a cost-effective device able to manage dynamically the (dis)charge profiles of energy storage systems (ESSs) through a smart control strategy. The AHB-SMS can assess in-real time which ESS (batteries or SCs) is more suitable to match the energy scenario, mainly by monitoring the load demand and the power available from the PVS or grid sources.

Therefore, an Hybrid ESS (HESS) can:

- Support simultaneously different types of batteries (lead acid, lithium and so on) or SCs, based on their properties.
- Optimizing the performances of ESS.

- Cope with the fluctuations both from load side (local load or grid) and from the power supply side (PVS or grid).
- Avoid the need of oversizing the battery banks.
- Keep an high SoC of batteries.

The goal of research is the development and the hardware implementation of AHB-SMS through an intelligent energy storage control strategy that controls dynamically the charge and discharge profiles of different energy storages, monitors the energy demand of load and energy supply of photovoltaic source and in-real time decides which energy storage (batteries/supercapacitors) to use for matching energy demand of load, optimizing the performance of each of them. Here the supercapacitor banks operate as high power storage or peak shaving, able to cover peaks of demand and power fast fluctuations. This helps batteries avoiding a high stress, increasing lifecycle of batteries. Input data required for the design of the AHB-SMS include load demand and photovoltaic supply profiles over time collected by measurement campaigns and survey.

The AHB-SMS controls the flows of energy from the photovoltaic panels to the hybrid energy storage (batteries and supercapacitor banks) and to estimate load demand. It is responsible to calculate the SOC for both batteries and supercapacitor banks and to implement the correct charging strategy. Sensors and measurement circuits have the task to recognize the conditions of each (photovoltaic panels, of batteries, of supercapacitor banks and load) in order to adopt the correct strategy to improve the efficiency of overall system.

Another task of research is the hardware implementation of the AHB-SMS that once setup will allow to carry out the on-site experimentation in order to validate it in a Hybrid Energy Storage Systems (HESS) and to appraise real benefits on the overall efficiency.

As further for a future development (not included in this project), partners are thinking to implement on AHB-SMS to recognize two different battery technologies (e.g. lead acid and lithium-ion batteries) to provide customized charge-discharge profiles for each battery monitoring the SOC and the mutual influence of different operating regimes on batteries lifetime.

The use of the AHB-SMS in Khmelnytskyi National University will considerably reduce the energy costs (for heating and other needs).

The main results expected at end of the research are the realization, the validation, the marketing and the deployment of the AHB-SMS setup.

The availability of a AHB-SMS will have several valuable impacts, as those listed in the following:

- Reduction of total investment costs compared to a single storage system.
- Increase of global system efficiency.
- Increase of storable energy.
- Increase of lifecycle of batteries.

These results are relevant both from a technical and from an economic point of views.

The developed AHB-SMS solution could be introduced in the Khmelnytskyi National University to reduce the energy costs and for a better exploitation of the available energy. The Khmelnytskyi National University could move from the acquired knowledge to integrate new features and to develop new products. The use of photovoltaic energy is still limited in the Khmelnytskyi National University Campus but there are several buildings and spaces that could be covered by photovoltaic panels if this will appear advantageous. The Khmelnytskyi National University laboratories are able to produce every element of the AHB-SMS, as demonstrated by the manufactured batteries, SCs and MPPTs.

The AHB-SMS approach could be spread on a large scale in Ukraine, also thanks to the partnership of Khmelnytskoblenenergo company. A broad use of such technologies could lead to a distributed energy production and storage with a smart power flow that could be regulated by a central market, as already explored in other countries.

On the other hand, the success of this research could be important for the future of the SC technology. The SC technological development and cost reduction opened new scenarios in electrical and electronic systems, offering extraordinary opportunities for applied research and industry. In fact, the number of manufacturers is constantly growing (also in Ukraine) as the estimated business turnover. However, SC technologies are relatively new on the market. Thanks to the new business opportunities provided by the AHB-

SMS, the achievable performances are expected to be higher and higher at lower and lower costs.

The research foresees the following phases:

1. Analysis and estimation of the load and PVS profiles over the time (daily, weekly, monthly). This activity requires the collection of input data required for the design of the AHB-SMS by measurement campaigns and surveys, including data on load demand and PVS average performances. The first case study will be the Khmelnytskyi National University Campus that can be considered as a large residential and office load.

2. Definition the best control strategy and algorithm, by the identification of the power/energy flows optimal for each storage type, load profile and PVS condition. The obtained algorithm will be able to decide, based on the recognized scenario, which energy storage type (batteries/SCs) should be employed to match the energy demand and availability.

3. Hardware implementation of the AHB-SMS prototype.

4. On-site experiments (in Ukraine) in order to setup the AHB-SMS and to validate it in a HESS and to appraise the actual benefits on the overall efficiency.

5. Exploitation of the AHB-SMS through marketing, publications on scientific journals and patents.

In parallel with these activities, Khmelnytskyi National University, whose mission includes the promotion of energy efficiency, will support the optimization or time-shifting of its energy loads. In particular, a specific audit will be performed in order to assess the efficiency of the heating systems and the possibility to move to more efficient systems based on electrical power.

Summary

Increase in the efficiency of the electric heating system with the combined electric energy storage system is realized by the automatic control system. The automatic control system provides maximum power of solar panels which allows increasing their efficiency. It is suggested to use smart grid technology to provide efficient work of the combined electric energy system. Such a system allows selecting the optimal charge/discharge modes using mathematical models

of supercapacitor cells and supercapacitor modules developed in Khmelnytskyi National University. The use of such novel mathematical models enables to reduce energy losses in this system, control its operation abilities and find possible failures. A new technology of Maximum Power Point Tracking for solar panels has been developed in Khmelnytskyi National University. It enables taking maximum power from each separate solar panel, not a string of solar panels, in contrast to the existing MPPT technologies. Our technology enables to control each panel separately, find solar panels with failures and increase the efficiency of solar panels in general. A special software capable of monitoring the work of batteries, supercapacitors and solar panels and providing effective management of the system as a whole has also been developed in Khmelnytskyi National University.

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