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## MANAGEMENT IN DEVELOPING POWER SYSTEM

**Summary.** Development of power system influence on management information system is the main aim of the article. Starting from the general review of hierarchical information system in power, changes in its (and in management information) systems implied by injection of renewable energy sources are discussed.

**Keywords:** Management information system, renewable energy source. Smart Grid, microgrid.

## ZARZĄDZANIE W ROZWIJAJĄCYM SIĘ SYSTEMIE ELEKTROENERGETYCZNYM

**Streszczenie.** Celem artykułu jest przedstawienie wpływu rozwijającego się systemu elektroenergetycznego na system informatyczny zarządzania. Przedstawiono ogólne informacje o hierarchicznym systemie informacyjnym zarządzania i omówiono zmiany w systemie informatycznym zarządzania wywołane wprowadzeniem odnawialnych źródeł energii.

**Słowa kluczowe:** Informatyczny system zarządzania, odnawialne źródła energii, sieci inteligentne, mikrosieci.

### 1. Introduction

Fundamental inventions in electricity in eighteenth- and nineteenth centuries implied considerations on electricity application. In the end of nineteenth century as a result of discussion between Thomas Alva Edison (Alternating Current – AC which won because it could be transformed to proper voltage value necessary for transmission electric energy from generator to far end receiver) and Nikola Tesla (Direct Current – DC) was AC applied in PS.

In [3] we can find information, that The Edison Electric Illuminating Company of New York constructed the first generating station in 1881, and this day we assume as the Power System (PS) birthday.

Technological chain of an Electrical Energy (EE) generation and delivering system consists of following main subsystems:

- Generation: turbo generator (in steam power plant) or hydro generator (in hydro power plant) or Nuclear Power Plant. From the end of 20<sup>th</sup> century growing role in electricity generation play Renewable Energy Sources – RES (Wind, Photovoltaics, Geothermal, Biomass etc.)
- Step-up transformer changing generated voltage to higher voltage used in transmission power to receivers,
- Power line, mostly overhead or cable,
- Step-down transformer matching voltage to the level applied in distribution networks and used by receivers,
- Receivers.

It is important to remember that through that chain (with length of the line sometimes exceeding 400 km) flows the same EE with changing its parameters according to physical laws. This is very important because it is a platform for applying hierarchical organization system based on natural monopoly. New devices installation in result of technological progress does not change hierarchical organization of PS up to ninetens of the twentieth century what implied possibility of the same Management Information System (MIS) up and down levels of the hierarchical management system application. Complexity of electrical processes needs automation system (AS) support the growing PS and this technical system transmits to MIS some data necessary in management receiving a very few data from MIS only.

Growing EE utilization, pollution of an environment and decreasing fossil fuel resources as well as growing number of very expensive blackouts implied necessity to change mission from new power plants construction to delivering electrical energy for consumers resulting in development researches in new area called Smart Grid. According to Bush “The smart grid is an electric power grid that attempts to intelligently respond to all the components with which it is interconnected, including suppliers and consumers in order to deliver power services efficiently, reliably, economically and sustainably” [3]. One of fundamental decision was obligation to include each one of a Renewable Energy Source (RES) which in the beginning was part of the so called Microgrid [7]. It is possible to find different types of RES [8] and for that reason they are called Variable Generation (VG) but when “VG resources reach 30%, the current control systems will simply be inadequate and Transactive energy system provide a way to maintain the power system reliability and security” [2, 3, 8].

In [6] we can find definition and characteristics of Transactive Energy (TE). “TE is a system of economic and control mechanisms that allows the dynamic balance of supply and

demand across the entire electrical infrastructure using value as a key operational parameter". The TE principles presented are very similar to characteristic of Smart Grids presented in the end of twentieth century [16] what can be interpreted that good idea defined twenty years ago could not be applied and needs repeat once again.

## 2. Microgrids, renewable energy sources

Microgrid is defined in [7] as follows: "microgrids are distribution systems with distributed energy sources, storage devices and controllable loads operated connected to the main power network or islanded in a controlled coordinated way". Two fundamental changes in the distribution level of PS were caused by dispersed renewable sources which had to be connected to distribution network and smart houses with small RES mostly photovoltaic (PV) or wind power plant producing electrical energy for personal use or connected to distribution network exported energy to PS [11]. (Short term influence of DR on reliability of wind integrated power systems on demand-side uncertainty is considered in [12]).

Parallel to these processes is another one: exchange of old electromechanical meters by intelligent meters using two-direction data exchange with an electrical energy supplier. In result of that RES installed in smart houses arose growing group of prosumers consuming and producing EE according to their private decisions and retailers as brokers between small producers and PS utilities of electrical energy implying an energy market development [9]. Taking into account existence of the smart meters enabling two directional information processing, all above mentioned posts exchange data [10, 11] and necessity of the technical data transmission (part of them in real time) we receive collection of Big Data [13].

Smart houses and microgrids needs apply in the bottom level all management functions typical before for top- and medium level, i.e. analysis, forecasting, operating optimization [3], finance etc. necessary for brokers, retailers, DSO (Distribution System Operator). Of course not all results from these bottom EMS are interesting for the top EMS but it depends on an architecture of the distribution network, number of management nodes and regional regulations. Solving this problem needs to apply a new tool did not used in the hierarchical, natural monopoly PS. Although Smart Grids, Microgrids, Renewables exist in many countries from long time, further researches and investigations are developed in many countries, and one of important problems are to be searched is an Electrical Energy Market.

### 3. Energy Market

Applying VG and accompanying auxiliary services implies changes in an energy market and we can find number of papers, reports etc. and we can find different approach to trial of description, researches and the new energy market development. In bibliography it is possible to find two approaches:

- description of existing situation and some solutions taking into account growing role of RES in EE production influencing on market evolution [1] (see also [2, 5, 9, 15]),
- presentation of researches trying to define new market, it's business model and reorganization of distribution network [11].

In introduction to [1] where according to dominating opinion on fundamental role of wind- and PV among VG, there are list of questions concerning many problems arising in changing market and RES with ancillary services influence on the market development. Further discussion gives partial answers considering following problems: renewables – catalyst for change, energy markets when fuel is free, what role for market flexibility – a new product or business as usual, planning and investment, distributed generation and demand-side participation, conclusion giving the readers good view on current state of an energy market.

The second approach may be represented by [11] combining researches on defining new Business Model (BM) in one of EU projects, *e-balance* with an application of Internet of Things (IoT). “The *e-balance* aims at integrating the energy consumers into the future smart-grids in order to address future environmental problems with holistic technical solutions based on ICT, new business models and citizens' behavior under real life conditions”. The above aims cover most of contemporary researches in that area all over the world and for reaching them it is necessary to solve following objectives: building the future with ICT solutions, more efficient system, better environment, balancing the energy, defining new paradigm and new business model.

There are (and will be) also another new technical solutions influencing on organization, operation and management in PS; one of them is the direct current (DC) injection into the AC grid. Because of technical and economical benefits there are DC transmission lines connecting off-shore wind farm with inland AC grid (North Sea) [5]; upon consideration it is DC application in new designed microgrids as well as in LV and MV distribution networks [17]. But it does not imply growth of data number, only a little decrease number of electric parameters necessary to observe.

It is also worth of mention to look on presented in [2, 3, 8] an idea of DSO Market Model considering it's two types: Single-Sided Market Clearing and Two-Sided Market Clearing. In the same paper Transactive Energy means that decisions “are made based on a value”.

Special attention has to be paid for solving Big Data problem generated by all participants of distribution networks taking into account that group of these data needs to be used in real time. There are searching to find tools supporting to solve the problem of growing data flow, for example with help of IoT [19].

#### 4. Challenges in EE Systems

Coming back to the beginning of the paper we noticed that long-time stable power system organization with developed MIS is going to change because of RES injection into the grid. What will be in future? Trial of answer is presented in [14] where among number of megatrends one is most important: first time in history of power, consumer can decide where from he will use electricity – from power grid or produced himself? This decision will not be limited to prosumer energy only because also enterprises and local/regional administration are interested in using cheaper and more reliable energy. Process of decreasing EE cost produced outside of power system is continuous and in future will be lower than in big power plants.

Nevertheless it is necessary to remember that cheaper energy produced in PVs and wind farms has to be supported with conventional power plant the time of bad weather conditions. It implies paradox because in Poland many of old fashioned turbo generators must be replaced by new units, what when using the so called *merit order* (into power system there are included sources with lowest alternating costs only) whereas RES have zero alternating costs, nobody is interested in new power plants investment. We can not expect support from Europe because each of the European country is concentrated in own solving problem in future.

#### 5. Conclusion

All changes in the distributed part of PS due to RES application and investigations of better EE utilization, needs parallel investigations devoted to adaptation and development new modules of MIS according to particular regional needs. Special attention has to be paid for solving Big Data problem generated by all participants of distribution networks taking into account that group of these data needs to be used in real time.

But taking into account the forthcoming process of decreasing EE cost produced outside of power system will be lower than in big power plants, what may result fundamental changes in management information systems in divided PS into two parts: conventional power plants working as a reserves sources only and a distribution (LV and MV) continuously delivering EE to consumers.

There are (and will be) also another new technical solutions influencing on organization, operation and management in PS; one of them is the direct current (DC) injection into the AC grid. Because of technical and economical benefits there are DC transmission lines connecting off-shore wind farm with inland AC grid (North Sea); upon consideration it is DC application in new designed distribution networks

Abbreviations:

PE – IEEE Power & Energy,

PWRS – IEEE Transactions on Power Systems

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### **Omówienie**

Rozważono wpływ rozwoju systemu elektroenergetycznego (SE) na informatyczny system zarządzania. Podano historię wyboru rodzaju prądu zastosowanego w SE, (prąd stały lub prąd przemienny), wymieniono urządzenia przewodzące ten prąd od źródła do odbiorcy, co wobec istnienia monopolu naturalnego uzasadniało powstanie i rozwój hierarchicznego informacyjnego systemu zarządzania. Ten system, wspierany od lat siedemdziesiątych XX wieku przez informatyczne systemy zarządzania, utrzymywał się bez zmian do końca ubiegłego wieku. Wprowadzenie rozproszonych odnawialnych źródeł energii elektrycznej wymaga innych zasad eksploatacji, organizacji i zarządzania w SE (sieci inteligentne, mikrosieci, rozproszone źródła energii odnawialnej). Wprowadzenie prądu stałego w niektórych sieciach przesyłowych, rozważania nad zastosowaniem go w sieciach rozdzielczych wymagają zmian w modułach informacyjnego systemu zarządzania w SE.

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