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New idea in power networks development. Selected problems

Abstract. *Smart grids and thereafter open grids development implies changes in organizations, technical equipment Power Networks (especially ICT). These new grids influence also on organization and operation of the energy markets, for which it is very important to know correct forecast (mostly short-term) of an electrical energy demand. Excessive requirements concerning accuracy of the forecasting results implied new tools of informatics, especially artificial intelligence application.*

Streszczenie. *Sieci inteligentne, a potem sieci następnych generacji, spowodują zmiany w organizacji, wyposażeniu technicznym (szczególnie ICT) sieci elektroenergetycznych. Te nowe sieci wpływają także na organizację i działanie rynku energii wymagającego znajomości prawidłowej prognozy (głównie krótkoterminowej) zapotrzebowania na energię elektryczną. Wygórowane wymagania odnośnie do dokładności wyników prognozy spowodowało zastosowanie nowych narzędzi informatyki, głównie sztucznej inteligencji. (**Nowa koncepcja rozwoju sieci elektroenergetycznych. Zagadnienia wybrane)***

Keywords: smart grids, ICT, energy market, artificial intelligence.
Słowa kluczowe: sieci inteligentne, ICT, rynek energii, sztuczna inteligencja.

Introduction

Power Networks development is upon influence of Smart Grid idea. It does not exist one definition of the Smart Grid; in [30] one can find three definitions: from USA, Europe and China. In opinion of the authors the first one is most suitable for this paper and for that reason it will be citation from [30]:
- "It is self-healing (from power disturbance events).
- It enables active participation by consumers in demand response.
- It operates resiliently against both physical and cyber attacks.
- It provides quality power that meets 21st-century needs.
- It accommodates all generation and storage options.
- It enables new products, services and markets.
- It optimizes asset utilization and operating efficiency."

The above definition of the Smart Grid determines following problems being considered in the paper:
- Basic problems in developing smart grids.
- Microgrids.
- Selected problems of an energy market in smart grids.
- Load- and price forecasting.

Basic problems in developing smart grids [35]

Implementation of the smart grids idea needs new transmission- and distribution grids, large capacity storing devices and number of measurement, monitoring and control devices.

Distribution smart grids additionally must implement Advanced Distribution Management System (ADMS), Advanced Metering Infrastructure (AMI) and Wide Area Monitoring (WAM). All the above mentioned systems imply new problems that are to be solved by Information Communication Technology (ICT).

For example in Germany exist nearly about $3.5 \cdot 10^6$ measurement points and number of data stored necessary for market information growth 2 TeraBytes/year. It is foreseen generation 22 GigaBytes/day/10^6 consumers. Storing such number of data is nonsense and data management require data inspection in real time to discover future disturbances

When consider the smart grids development it is necessary take into account following challenges:
- Dynamic external environment unable exact determination of work completion.
- Replacing existing systems with new offering more functionality may be not accepted option from the operational – as well as economical point of view.
- Implementation projects are to be accepted by all partners.
- Increasing additional implementations can not negative influence on the existing solutions nor to disturb operation.
- It is necessary to have interfaces to external partners.
- Lack of standards and business practices.
- High implementation costs.

All the above mentioned influence on prediction time of smart grid implementation which seems be far away. Contemporary practice is development step-by step solving separate projects and implementing them.

Microgrids [24]

One of assumptions in smart grids is necessity utilization of Renewable Energy Sources (RES), what implies intrusion in the grid Dispersed Generation (DG) and Dispersed Storage (DS). Operation of the grid with great number of singular DG is difficult and much more easy is to operate a group of DG – Microgrid.

Microgrids it is interconnection of small modular generation to Low- or Medium- voltage distribution systems. Microgrids can be connected to the main power network or be operated islanded, in a coordinated, controlled way [13]

Intrusion of Microgrid into the distribution network (in future smart distribution grid) needs creation of Active Distribution Network (ADN) passing following stages [24]:
- remote monitoring and control of DG and RES,
- determination of great number of DG and RES management,
- full active power management together with real time communication and remote control.

ADN operation implies necessity of application one of two different strategy: microgrids or virtual consumers. Concept of virtual consumer (virtual energy market) is adaptation of a model similar to information and business ability of Internet. Electrical energy bought from conventional generators, RES or storage devices, according to demand is delivered to agreed nodes. The system would use new ICT technologies as well as advance power electronics and storing devices.

Diversity of RES and storage devices as well as architecture and collaboration with power system implies necessity to define control strategy in operation.

"Building Network " strategy emulate "vacillatory source" in islanded network . DER unit realizing this strategy controls voltage in the connection with the system node setting up the system frequency.

Power and energy management strategy is very important in islanded microgrid and it is more critical than in power system because of specific characteristics of the microgrid.

New ICT needs for an energy market in smart grids

Some countries in Europe such as Italy, UK, Germany and Spain have been largely implemented in the AMI and developed new business processes in the energy market also taking into account the distributed generation and distributed energy sources, including renewable energy. (the results of recent European projects such as EUDEEP, FENIX, MORE MICROGRIDS, SEESGEN-ICT).

The development of distribution networks in the direction of smart grids in Poland needs investment in infrastructure and ICT tools Some software and existing applications which are already adapted to the new needs of the energy market and intelligent networks in Europe will be summarized as follows in several main groups:

1. Energy flow calculation and market integration tools.
2. Power system analysis tools.
3. Customer portfolio and levels simulation tools.
4. Simulation and optimization tools for DR, DG and energy storage operation.
5. Forecasting and information systems tools.

In table 1 there are some ICT samples (you can see and compare: http://www.dconnolly.net/tools.html)

Table 1.

Same samples:	
Name of tool	Short Characteristic
Ad 1:**Wilmar planning tool**	**A Strategic planning tool for analyzing the integration of renewable power technologies** to be applied by system operators, power producers, potential investors in renewable technologies and energy authorities. The model optimizes power markets based on a description of generation, demand and transmission between defined model regions and derives electricity market prices from marginal system operation costs. The model is a stochastic linear programming model with wind power production as the stochastic input parameter. The model optimizes unit commitment taking into account trading activities of different actors on different energy markets. As a result the simulated output by different production forms, marginal price on each region, and others.
Ad 1: **EMPS (multi-area power market simulator**	The EMPS model is a stochastic model designed **for long-term optimization and simulation of hydro-thermal power system operation**. It allows the simulation of large hydro systems with a relatively high degree of detail.. The EMPS model is widely used in the Nordic countries for price forecasting. Large producers can directly employ EMPS in their scheduling decisions. Also thermal plants can be included. The time step is one week and planning horizon is up to several years.
Ad2: **Siemens PSSE - Transmission System Analysis and Planning**	PSSE is an integrated, **interactive program for simulating, analyzing, and optimizing power system performance**. It provides the user methods in many technical areas, including: Power Flow, Optimal Power Flow, Balanced or Unbalanced Fault Analysis, Dynamic Simulation, Extended Term Dynamic Simulation, Open Access and Pricing, Transfer Limit Analysis and others
Ad 2: **Powerworld Simulator**	PowerWorld Simulator is an **interactive power systems simulation package designed to simulate high voltage power systems operation on a time frame ranging from several minutes to several days**. Potential applications: Transmission Planning, Power Marketing, Simulation of Electricity Markets, Operator Training to improve operators' knowledge of the system and response to unexpected events, Real-Time System Monitoring, Planning and Operations
Ad3: **UPV Flexmod**	The tool can **calculate the available load reduction** and the following payback peak as a function of time when certain load control strategy is used (such as load reduction during morning peak, with allowed temperature drop of 1 °C). The results are specific to certain customer. Each customer is modeled separately.
Ad 3: **DER-CAM**	DER-CAM ((Distributed Energy Resource Customer Adoption Model) **is an economic model of customer DER adoption** implemented in the General Algebraic Modeling System (GAMS) optimization software. This model has been in development at Berkeley Lab since 2000. The objective of the model is to minimize the cost of operating on-site generation and combined heat and power (CHP) systems, either for individual customer sites or a micro grid
Ad4: **Flexprof**	Flexprof has been developed at VTT **for assessing the revenues of the aggregation of demand flexibility**, integrated with RES in the electricity market. Flexprof tries to simulate trading on the spot market, taking account the possibility of flexibility calls. The situation with and without flexibility can then be compared. It can dynamically allocate the flexibility calls based on market price forecasts. Flexibility allocation is done with linear programming, and the final flexibility calls are obtained with stochastic programming. Any time period can be used in the simulation. One year's simulation with six customer types takes about one hour. The model has so far been adapted to the English and German market.
Ad4**: Offpeak**	Offpeak tool can be used **for profitability assessment of DER aggregator business**. Special attention has been paid to the services that DER can provide within the Great Britain power system. The heuristic-based tool can quickly estimate the profits of several years of operation using historical price data.
Ad5: **PrevedoVento**	Part of PrevedoEnergia, a tool **for forecasting power output from variable renewable energy sources** for bidding on power market. PrevedoSole predicts the power output for each PV device according to the provincial solar radiation forecast. The individual outputs are then aggregated for each of seven market zones before bidding as a zonal whole schedule.
Ad5**: Inter-Regional Electric Market Model (IREMM)**	The IREMM model **is based on demand/supply precepts**, and is not a "traditional" cost-recovery plus pricing model. IREMM provides a broad-based, comprehensive view of competitive electric power markets: Forecasts market-clearing economy, energy prices, represents all buyers and sellers within an interconnected system simultaneously, identifies economic energy transactions, analyzes the interaction of supply and demand in a competitive bulk power market, is not a cost-based, franchise area-specific pricing model.

Source: on the basis of Seesgen-ICT internal materials: Jussi Ikäheimo VTT (Finland), 2009

Most of new tools must support much more dynamic processes such as demand response, planning, forecasting, dynamic pricing calculation, the settlement in a very short time on the intra day market. New tools require knowledge of the actual processes on time, clarity energy market regulation, and above all the insert of such solutions as smart meters and remote measurement, effective ways of financing for the development and implementation of ICT. Mentioned tools above address the needs of smart, future energy market. More detailed consideration on energy market, business models in Poland, one can find in [22].

Load forecasting

Energy Market operation needs knowledge on demand of electricity and prices in different intervals of time what implies necessity of application of load- and price forecasting tools. Historically the first method applied time series-based methods, but in 20th century the Artificial Intelligence (AI) tools dominate [34]

One of the first well reported application of Expert System (ES) in Short Term Load Forecasting (STLF) is the paper [29] written by S.Rahman and R.Bhatnagar. From that time number of papers presenting application of ES, Artificial Neural Networks (ANN), Fuzzy Logic (FL) and Hybrid Systems (HS) combining no less than one of AI tools with another models is growing. As an illustration of contemporary state of the art we did review papers printed in the three years of the IEEE Trans. on PWRS (2008, 2009, 2010 – Feb) with following results:

- Short-term load forecasting [1,2,3,4,6,19,20,26,29,31]
- Forecasting another power system problems: [8,9,11,12,28,33].

Taking into account tools used in these papers we van find: Expert Systems, Artificial Neural Networks, Fuzzy Logic, Wavelet Transform, Models, Statistics, Evolutionary Algorithms, Hybrid Systems. It is worth of mention that dominate application of hybrid system where we can find PSO (Particle Swarm Optimization) Algorithm in Hybrid System with Wavelet transform and Artificial Neural Network [4].

Final Remarks

Smart Grids – new idea in electric power need for designing, construction and operation new tools, devices, services and quite new market integration tools. Not all of them are mature what opens necessity of further researches applying new ICT solutions.

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Abbreviations: PE - IEEE Power & Energy; PWRS – IEEE Trans. on Power Systems

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