SMART GRIDS CONCEPT IN ELECTRICAL DISTRIBUTION SYSTEM

by

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This paper defines key business processes in electrical distribution systems and key elements and priority components that should be (re)defined in these processes in order to enable the goals of smart grids concept to be fulfilled in the cost effective way. Activities undertaken in the Power Distribution Company "Elektrovojvodina", which provide the basis for fulfilling the smart grids goals and thus enable full implementation of smart grids concept are presented in details.

Key words: *smart grids, electrical distribution systems, business process*

Introduction

In the last decade, a new wave of changes has been taking place in the power systems, known under the name smart grids (SG), which has a significant influence on the electrical distribution systems (DS), as well [1]-[10]. The strategic goals to be fulfilled under the SG concept are:

- fulfilling 20/20/20 targets of the EU by the year 2020 [1-3], [7-10],
- increasing reliability and security of supply [1-10],
- improving efficiency of supply [1-10],
- ensuring energy independence [1-5], and
- enabling new technologies (*e. g.*, plug-in electrical vehicles) [1-10].

In order to fulfill the above global goals, future power systems and thus the distribution systems have to enable, among other things, the efficient integration of large-scale intermittent generation of different sizes and technologies (*e. g.*, wind farms, solar thermal generation, photovoltaic, *etc.*). Furthermore, the change of a distribution network from being "passive" and dependent on human operator's intervention into an "active" one should be enabled. This is required due to the increasing complexity of network operations, to the wide deployment of distributed generation and to the increasing challenges in ensuring security and quality of supply. Hence, the SG concept will induce new technologies as well as new goals in the distribution system's design and operation. In this environment, the existing business processes in the distribution system have to be changed, *i. e.* redefined. Detail overview of goals and activities/changes in the relevant business processes in DS that will enable fulfilling the above global goals are presented

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in the second and third sections. In the fourth section, there is an overview of activities that have been realized so far in the Power Distribution Company "Elektrovojvodina" (PDC "Elektrovojvodina") in the course of the development of the SG concept while in the fifth section, the emphasis is on key elements for successful SG implementation in the distribution companies.

The main goals of smart grids in distribution systems

The main goals of smart grids concept in the distribution systems, which will enable fulfilling of the above mentioned global goals, are the following [1-3, 6, 11]:

– *To integrate distribution generators (e. g., renewables) of different sizes and technologies in the DS*
  Integration of distribution generators (DG) of all sizes and technologies (photovoltaic, wind generation, small hydroelectric generation, biomass generation, *etc.*) should be enabled in the medium and low voltage distribution networks so as to ensure the maximal production of electric energy from those resources.
– *To optimize operation and usage of distribution network infrastructure*
  Decreasing peak loads, postponing capital investments (building new elements and/or upgrading existing elements), and reducing power and energy losses should be enabled by using:
  – SG components, such as DG, energy storages (ES), microgrids, plug-in electrical vehicles (PEV), AMI systems, smart appliances in households/commercial, home area network (HAN), smart sensors, *etc.,*
  – new/advanced tools for managing distribution networks – advanced distribution management systems (DMS), and
  – in addition, improvement of asset management and especially maintenance strategies should be enabled by using higher volume and quality of data gathered through SG components – AMI systems, smart sensors, intelligent electronic devices (IED).
– *To provide consumers with better information and options for the choice of supply and to allow them to play a part in optimizing the system's operations*
  Active influence of consumers on the operation of distribution networks should be enabled by allowing consumers easy and flexible change of their load profiles in response to electricity prices and/or to different kind of incentives. These demand response capabilities require advance tools on the consumers' side (HAN, smart consumer's appliances, consumer's energy management tools), advanced information and communication tools able to manage the complexity of multiple inputs, consequent intelligent actions and provision of easy and flexible interaction between customers and the system.
– *To maintain and improve existing levels of reliability, quality and security of supply in DS*
  Improvement of reliability, security and quality of supply in DS should be enabled by using SG components, above all DG, microgrids, AMI systems and demand response (DR), as well as advanced information, communication and software tools. The advanced DMS applications, such as OMS (Outage Management System) function and FLISR (Fault Localization, Isolation and Service Restoration) function, should be enabled in order to allow the higher levels of automation to be implemented in the distribution networks in which the SG components will be integrated.

The key building blocks (components) of the SG concept in DS are presented in fig. 1. Presented components and their interrelations will enable fulfilling of the SG goals through (re)defining key business processes [12] in the DS. These processes are discussed in more details in the next section.

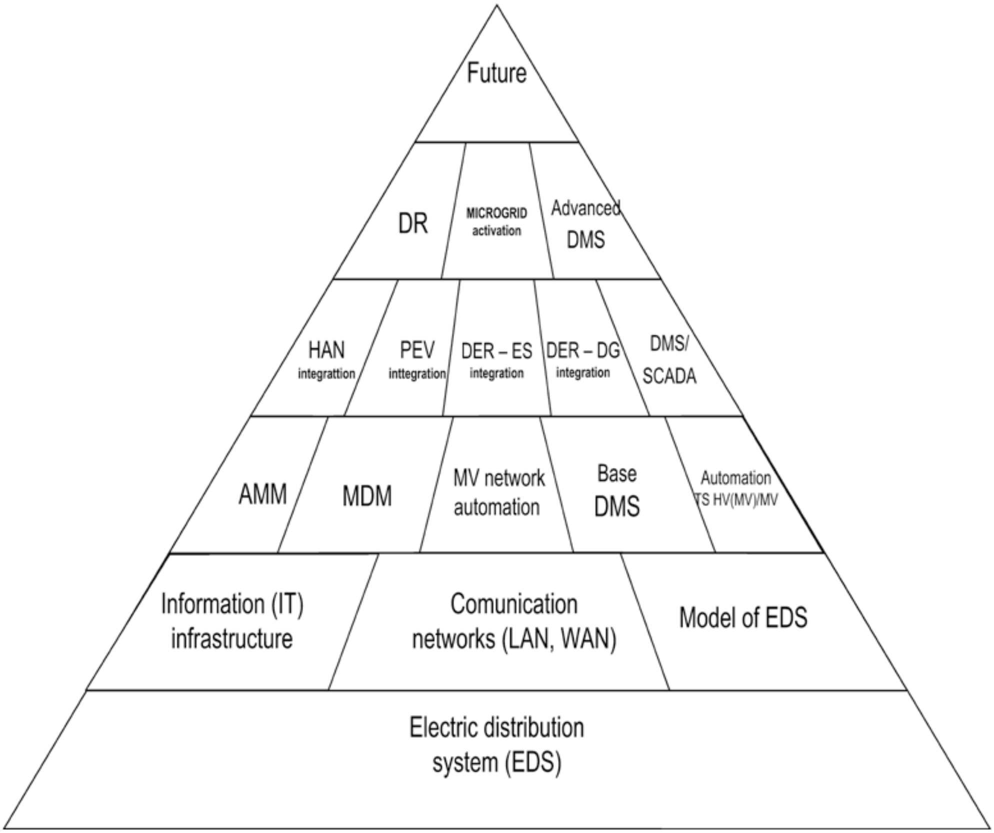

Figure 1. Building blocks of smart grids concept in distribution systems

(Re)defining business processes in distribution systems in the SG environment

The key elements and priority components that should be (re)defined in relevant business processes in the DS are given in the sequel.

- **Development planning of distribution networks**
  - Define forecasting tools that take into account the increasing level of uncertainties related to future load/production growth and higher volume and quality of data gathered through SG components (*e. g.*, AMI systems, smart sensors) [13].
  - Define multi-objective approaches and models for (optimal) multi-year development planning of distribution networks that take into account possible influence of DG, DR, PEV and micro grids, as well as different levels of uncertainties related to load growth and intermittent generation [14].
  - Define network element characteristics (*e. g.*, switchgear characteristics) in the presence of DG [15].
- **Distribution network operations**
  - *Network operations in normal conditions*
    - Define objectives and approaches (*e. g.*, centralized, distributed, combined) to voltage-reactive control in distribution networks for different levels of DG pen-

etration (*e. g.*, 5%, 10%, 15%, 20%) and for different DG sizes and technologies. The objectives shall take into account existing regulations as well as possibility of DG being supervised and controlled by the distribution system operator [16, 17].
    - Redefine relay protection coordination in the network in the presence of DG [15].
    - Redefine tools (software and/or hardware) for determination, implementation and supervising (monitoring) of optimal state of distribution networks in the presence of SG components, especially DG, ES and static VAR compensators [16, 18].
  - *Network operations in emergency conditions*
    - Redefine fault management process (FLISR function) in the presence of SG components, especially DG, DR, AMI systems and microgrids. For example, in the localization step data from AMI systems and IED in the network/substations should be taken into account while potentials of microgrids and DR should be used in the restoration step as well as in the emergency (e. g., overloading) conditions [19, 20, 21].
    - Define automation scenarios (e. g., centralized, local, combined) in distribution networks in the presence of SG components [22, 23].
    - Redefine relay protection coordination during unplanned outages in the network in the presence of DG [15].
- **Operational planning and optimization**
  - Redefine procedures for managing planed outages (*e. g.*, safety conditions, relay protection coordination, process of isolation and restoration of supply due to planed outages) in the network in the presence of DG [24].
  - Redefine tools for short-term forecasting of demand in consumption nodes and energy production in DG [13].
  - Redefine multi-criteria approaches and models for determining optimal configuration of distribution networks in the presence of DG [25, 26].
  - Define tools that enable postponing of new constructions and upgrades of existing elements in the network by taking into account DR resources, microgrids and Volt/Var resources [24, 27].
- **Asset management and maintenance**
  - Define software tools (*e. g.*, OMS function) that improve the process of monitoring and forecasting conditions of network components taking into account higher volume and quality of data gathered through SG components (AMI systems, IED, smart sensors) [28].
  - Redefine existing or introduce new maintenance strategies (*e. g.*, predictive maintenance, condition based maintenance, risk based maintenance) that would be based on the information gathered form the previously mentioned software tools [29, 30].
- **Customer relationship**
  - Define DR scenarios that can be enabled in the presence of SG components, especially HAN, BMS (building management systems), EB, smart appliances [31].
  - Define possible usage of different DR scenarios in optimizing the operation, operational planning and development planning of the DS [27, 31].
  - Define information and communication tools and technologies that can improve relationship with consumers [32].
- **Meter management and control**
  - Define AMI/AMM systems and software tools for managing and storage data obtained from these systems [33, 34].
  - Define architecture and necessary performances of AMI/MDM systems so that they enable fulfilling of above mentioned SG goals [34].

It is important to emphasize again that proposed key elements and priority components should be (re)defined in the key business process in the DS so that the fulfillment of previously stated main goals of the SG concept is ensured. In order to enable integration of the above mentioned SG elements and components in the DS, it is necessary, as it can be seen in fig. 1, to define and realize base components of the SG concept: information and communication infrastructure. The key elements that should be defined within these components in the SG environment are given below.

- **Communication systems**
  - Define and realize communication system based on applicable standards and protocols. The possible solution must be chosen so as to ensure that the functional requirements, resulting from the previously (re)defined components of the business processes, will be fulfilled (reliability, availability, capacity, response time, transmission speed, data throughput, error rate, redundancy, the way of monitoring performances, *etc.*) [35, 36].
  - Define and implement the necessary levels of security and data protection [37].
  - Define the possible solutions for "last mile" communication, *i. e.* technologies and processes to be used to connect end customers and their smart appliances to the communication network [32].
- **Information systems**
  - Define software systems and services that ensure functionality defined in the above described business processes and that enable managing of the huge amount of data (data from real-time and static systems and data bases, manually updated data, *etc.*). Special attention should be paid to data security, based on risk assessment, and the required level of privacy [38, 39].
  - Define standards in the domain of software systems and services, as well as in the domain of data modeling in order to enable date exchange between different systems/subsystems that will appear in the SG environment [39].
  - Define architecture, hardware platform and computer network infrastructure of the integrated information system in the distribution company on the basis of requirements resulting from previously (re)defined business processes in the SG environment [40].

(Re)defining above mentioned components of business processes must be based on appropriate cost-benefit analysis in which all costs and benefits related to meeting stated global goals have to be considered [41]. Benefits that should be taken into account from the standpoint of customers, distribution companies and the society are:

- *Direct financial benefits,* including lower costs, avoided costs, stability of costs and pricing choices for customers.
- *Power reliability and power quality benefits,* including reduced number and the length of outages, reduced number of momentary outages, "cleaner" power and reliable management of distributed generation in line with load management and/or microgrids.
- *Safety and security benefits,* including increased visibility of unsafe or insecure situations, increased physical plant security, increased cyber security, privacy protection and energy independence.
- *Energy efficiency benefits,* including reduced energy usage, reduced demand during peak hours, reduced energy losses and the potential to use "efficiency" as equivalent to "generation" in power system operations.
- *Energy environmental and conservation benefits,* including reduced greenhouse gases and other pollutants, reduced generation from inefficient energy sources and increased use of renewable energy sources.

It should be emphasized that in some benefits, particularly those which directly reduce costs for distribution companies, customers also "benefit" from either lower tariffs or by avoiding increased tariffs although the connection may not be direct. Also, benefits for the society are often more difficult to quantify but they can be equally critical for the assessment of overall benefits relevant to the particular SG alternative and thus should not be neglected.

Course of developing the SG concept in the PDC "Elektrovojvodina"

In order to provide the basis for the full implementation of the SG concept and to enable the fulfillment of the above mentioned SG goals, the following activities are undertaken in the PDC "Elektrovojvodina":

- *Increasing the level of automation in the MV network* – Almost all supply substation (TS 110/x kV/kV) in PDC "Elektrovojvodina" are integrated in the high voltage (HV) SCADA system as well as the part of 35/10 kV/kV substations. In the nearest future, it is planned to integrate all supply substations in the HV SCADA system as well as the most important 35/10 kV/kV substations. In the past two years, the HV SCADA system was renewed in all control centers of PDC "Elektrovojvodina", *i. e.,* the improved version of the old HV SCADA system was installed offering advanced features and functionalities.
- In recent years, different systems for automation of operations in the medium voltage (MV) network have been tested in PDC "Elektrovojvodina". The main goal of these demonstration projects is to compare benefits and costs of different scenarios and levels of automation, different equipment, different MV SCADA systems and various communication solutions. Based on results of these projects, the direction and the extent of automation of the MV network in PDC "Elektrovojvodina" will be defined.
- *Utilizing base and advanced DMS functions* – The DMS system used in PDC "Elektrovojvodina" is a complex control and information system that consists of relational database, graphical environment (single-line diagrams of electrical objects, logical and geographical schemes of electrical network) and the set of base analytic functions (state estimation, distribution power flow, short circuit calculations). This system is used as support in decision making process in distribution network operations in normal and emergency conditions, as well as in the operational planning and optimization. The new modules (advanced functions) are about to be integrated in the existing DMS system. The network planning module will enable more effective and efficient planning of distribution networks taking into account, among other things, the presence of various types of DG and uncertainty of future load growth. Further, the module for modeling and automated management of low-voltage networks and their connection with SCADA, AMR/AMI and GIS, Billing and other business applications will extend the functionality of the existing DMS system, which is necessary for supporting SG concept. Finally, the new OMS module is designed and it will enable handling of planned and unplanned outages in the most efficient way. The part of this module will be, among other things, the advanced FLISR function that will enable managing fault localization, isolation and service restoration in the closed loop, *i. e.* without the dispatcher's participation.
- *SCADA/DMS integration* – One of the main goals in PDC "Elektrovojvodina" is to integrate HV SCADA, MV SCADA and DMS system. The full integration of these systems will enable more efficient utilization of advanced DMS functions, especially those that enable closed loop operations. At this moment, data (measurements and status of remotely controlled switching devices) from the HV SCADA and MV SCADA are enabled and

used in the DMS analytic functions. In addition, the pilot project has been started in which two-way connection between the existing HV SCADA, MV SCADA and DMS system is tested, *i. e.,* the possibility of supervising and controlling equipment in supply substations only through the DMS system .

– *AMR/AMI systems evaluation* – On the basis of the experience and knowledge gained in recent years from the development and exploitation of several pilot systems in PDC "Elektrovojvodina", the specification of functional and technical requirements are defined that AMR/AMI system should meet (functionality and standards that electricity meters must meet, architecture and standards for the communication of subsystems and network equipment, layout and functionality of software tools for supervising and controlling AMI network) [42]. The activities on purchasing the referent AMI/MDM system are ongoing, after which the installation will be followed as well as the integration with other technical and business information subsystems. Massive roll-out is expected in the next 5-7 years.
– *Enhancing communication infrastructure* – The implementation of fiber optic infrastructure is underway and it will allow connecting several supply substations (TS 110/x kV/kV) with dispatching centers in branch office buildings of PDC "Elektrovojvodina", as well as with business headquarters in Novi Sad. In addition, the work is intensified on the modernization of the radio communication system through transition from analogue to digital broadcasting. In this way, better communication will be provided between dispatchers and mobile teams as well as the introduction of new services (positioning mobile teams on the geographic background and sending text messages) which represents the basis for the implementation of the advanced OMS system.
– *Enhancing information systems* – In recent years, PDC "Elektrovojvodina" has committed significant resources to the realization of numerous development projects in the field of information technology and its application in the domain of business and technical systems that support the business processes in the company. With a vision that all processes are supported by one system, PDC "Elektrovojvodina" is working on the integration of existing information subsystems with the ultimate goal to unify all of them in a tightly connected system in which redundancy will be avoided and the flow of data between the individual parts will be enabled. In addition, the formation of the IT (data) center of PDC "Elektrovojvodina" is underway where virtualized server resources and storages will be concentrated. Finally, the computer network, operating systems and systems for database management have been constantly improved.

Conclusions

The full implementation of the SG concept will lead to significant changes in the DS and thus in key business processes in distribution companies. In order to enable successful implementation of efficient, economical and sustainable SG solution in the distribution company, the following steps should be accomplished:

- Clear definition of the SG strategy in the distribution company, *i. e.* definition of:
  – SG goals,
  – SG alternatives, and
  – changes in business processes.
- Consideration of all costs and benefits related to different SG alternatives.
- Organizational structure for promoting and coordinating all SG activities.
- Education and increasing employees skills.
- Promotion of the SG solution to all stakeholders (end-users).

Acronyms

AMI – advanced metering infrastructure
AMR – automated meter reading
BMS – building management system
DER – distributed energy resources
DG – distribution generator
DMS – distribution management system
EB – energy box
(E)DS – (electrical) distribution system
ES – energy storage
FLISR – fault isolation, localization and service restoration
GIS – geographic information system
HAN – home area network
HV – high voltage
IED – intelligent electronic device
IT – information technology
LAN – local area network
MDM – meter data management
MV – medium voltage
OMS – outage management system
PEV – plug-in electrical vehicles
SCADA – supervisory control and data acquisition
SG – smart grids
WAN – wide area network

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