Oct 27th, 3:00 PM - 4:30 PM

Smart Grid Operation: A Survey

Kozeta Sevrani
University of Tirana, kozeta.sevrani@unitir.edu.al

Romina Muka
University of Tirana, romina.muka@unitir.edu.al

Smart Grid Operation: A Survey

Kozeta Sevrani[1], Romina Muka[1]

[1] Department of Statistics and Applied Informatics, Faculty of Economy,
University of Tirana, Albania
{kozeta.sevrani, romina.muka}@unitir.edu.al

Abstract. Creation of Smart Grid meets the energy requirements of the 21st century in a high-tech manner with real time approach by providing a significant improvement in power reliability and services, and integrating the latest digital communications in the current power grid. This grid improves the ability of consumers and utilities to monitor, control, and predict the use of energy. The main goal of this paper is to present and justify the need to study electricity distribution grid, and to present the practical ways in which the proposed study should be focused. The focus will be in enabling a cost-efficient realization of the future robust and flexible electricity distribution grid. This will prepare the way for increased distributed generation from renewable sources, more efficient use of energy, and electrification of transport. The sustainability targets for the future energy system cannot be met without addressing the necessary transformation of the electricity distribution system.

Keywords: Smart Grid, Distribution System Operation, Digital Networks, Architecture.

Introduction

The future grid of 2030-2040 years will be a complex system-of-systems [1], combining numerous intelligent devices for controlling, sensing and making decisions. Primary new security needs must be addressed and technologies need to be integrated to support customers in making informed choices about the energy they use [2]. The foremost new benefits for the future electricity distribution system result from the communication between these technologies. Consequently, this paper focuses on system innovation [3], i.e., detecting and achieving the benefits that result from this interaction. This approach obliges long-term, holistic and multidisciplinary research in close cooperation with the most innovative key technologies, Distribution System Operators (DSOs) and software providers. In this case, this research is beyond the capacities of a conference paper work, but we will give a general overview on this matter for long-term research and innovation as well as to be an international reference research work. This paper will play an important role in accelerating implementation of the required system innovation through high-quality research on topics that are crucial for the power grid industry.
In EN 50110[1] operation is defined as:

"All activities including work activities necessary to permit the electrical installation to function. These activities include such matters as switching, controlling, monitoring and maintenance as well as both electrical and non-electrical work."

[1] Operation of Electrical Installations – European electrical safety standard

The work and decision-making process in distribution system operation can be arranged in distinctive ways and level of details. An appropriate high-level structuring of operation is proposed in [4] and involves four key components:

- Monitoring
- Planning
- Response
- Documentation

The goal of distribution system operation is to optimize and enhance distribution system performance by minimizing operation expenses within the appropriate restrictions, like environmental, technical, etc. The main goal of this paper is to present and justify the need to study electricity distribution grid, and to present the practical ways in which the proposed study should be focused. The focus will be in enabling a cost-efficient realization of the future robust and flexible electricity distribution grid. This will prepare the way for increased distributed generation from renewable sources, more efficient use of energy, and electrification of transport. The sustainability targets for the future energy system cannot be met without addressing the necessary transformation of the electricity distribution system.

Distribution System Operation

Power system operation practices and instruments are not future proof to meet the opportunities and new requirements for next generation power system operation 2030/2040. Increased decentralization because of Distributed Energy Resources (DER), which include distributed generation (DG), or Microgrids together with new and traditional flexibility options, pervasive monitoring, control and automation, (e.g. self-healing, Phasor Measurement Units (PMUs) increasing market influence, TSO/DSO interaction etc.), calls for new solutions. Distribution Management Systems (DMS) will play an important role in real time operation and decision support and DMS instruments should be able to exploit and manage new data for increasing control room and field personnel system state and threat awareness.
The traditional DMS systems need to be customized to save, process and present the progressively increasing monitoring data volume, taken from a plethora of various data sources. Current communication solutions are either proprietary, inflexible, expensive solutions designed for one specific application [5], or flexible [6] but not prepared for the very strict real-time [7], security and reliability requirements given by the power grid monitoring and control applications. To empower deployment of all the new opportunities provided by ICT systems in smart grid operation, it is needed an Industrial Internet of Things" (IIoT) [8] that is simply reconfigurable to meet new regulations, requirements, and standards. Regarding the safety domain, there has been a shift from a focus on reactive actions to prevent accidents from happening, towards resilient systems [9] where the focus is on guaranteeing that things go fine also when dealing with the unpredicted. Such a shift is also needed for cyber security and incident management to improve the awareness in operation of a critical infrastructure such as the power system, which has an integrated ICT system to support/assist its operation.

Smart Grid Operation

The objective of this paper is to enhance the fact of developing and testing a group of new solutions and concepts that optimally utilize new emerging control and monitoring technologies qualified to exploit extensive, real time monitoring to/from all assets and network customers and flexible resources. The estimated effect is a more flexible operation of the distribution grid,

resulting in cost reductions, enhanced energy efficiency and improved system security and reliability, as well as consistent solutions.
In this paper, we will suggest a use of combination of methods to address the objective. This includes developing use cases (for smart grid operation in 3.3, and CIIP in 3.4), methods to exploit new sensor data (3.1), development of new modelling framework to investigate control hierarchy and infrastructure utilizing new sensors and controllers (3.2), implication on operations (3.1 and 3.2, and testing in 3.5).

Application of new sensors and controllers for DSM

The goal is to develop new methodologies for a smarter, cost efficient and more reliable distribution system operation exploiting the potential in new technologies, such as a huge amount of new sensors, over new media and with new features, widely deployed automation, controllable power devices, which connect to advance IT-solutions by communication networks with industry-grade requirements. Methodology needs to be developed for distributed and hierarchical state estimation, utilizing the new sensor data for new voltage and power control and fast system reconfiguration, enabled by new power electronic controllers, and enhanced real-time operation supported by faster and more reliable communication networks.

Architecture for future monitoring and control

The goal is to develop a new control hierarchy and architecture for power grid and ICT system, integrating the new technology options identified in 3.1. The challenges are: to find the optimal balance between distributed and centralized control functionality and automation (centralized/decentralized, manual/semi-automatic/automatic) between layers, domains and zones (e.g., as in the SGAM [10] model), and to integrate a communication network with real-time, reliability, and security requirements, that enables dynamic network resource (re)allocation with easy upgrading of the remote devices.

Use cases for future (2030-2040) smart distribution grid operation

The objective is to develop and evaluate the most promising use cases for distribution system operation (2030-2040), utilizing the new data and technologies identified. Some characteristics in the power system and electricity use are quite different among countries; therefore use cases solving these unique challenges need to be addressed.

Use Case for Communication interoperability, ICT security and privacy (CIIP)

The main objective is to specify and evaluate CIIP requirements for the use cases developed in 3.3, as well as to construct use cases specifically addressing real-time performance, robustness, graceful degradation, anomaly detection and mitigation of, and response to, cyber-attacks. The knowledge building in this research task will provide valuable input to enhance CIIP guidelines and standards.

Smart distribution system control centers

The goal is to develop new solutions for future control centers for prediction, diagnosis and operational planning support to maximize situational awareness for control room personnel. This is a prerequisite for optimal system operation, which will improve resilience through better proactive operation, and allow for more timely and correct reactive actions with shorter down time. Preparedness exercises are crucial for increased situational awareness and to prepare for the new and unknown landscape of ICT-related threats in the future distribution grid [11].

Future Work and Conclusions

The current research related to the future distribution grid and its components is immense [12], and prominent actors are working systematically and strategically to meet the future needs of the electricity distribution system [13]. Both nationally and internationally [14], demonstration and pilot projects play an important role in knowledge building and in gaining experience on important challenges and technological solutions. The future work of this paper will consist in performing technological research to achieve needed functionality [15] in the grid, such as using microgrids for incorporating distributed energy resources on a large scale, and modelling and controlling how flexible resources can be used for more efficient grid operation, including auxiliary services, as well as for defense and renovation by Transmission System Operators. We recognize that for these functionalities to be used in real-life, there is a need for technological advances in supporting technologies, e.g., related to IT and communication solutions that meet the requirements related to scalability, security, robustness, and timeliness. Additionally, planning methodologies used by DSOs need to incorporate new technologies and, with them, new types of threats towards power system reliability (e.g., cyber threats). The large increase in available real-time and historical data provides major opportunities for more advanced planning and operation of the grid. These opportunities will not be realized without cutting-edge analytical capabilities, advances in grid operation, and being able to balance information use towards privacy requirements and implications. Finally, socio-economic and social implications need to be properly addressed and taken into account. Currently, the relation between the ICT and power domains is not adequately understood [16], and limited research has been done on how to effectively respond to incidents that affect both types of infrastructures.

References

1. . Kröger, W. and Zio, E. Vulnerable systems. Springer Science & Business Media, 2011.
2. . 2014 Smart Grid System Report to Congress, August 2014, US Department of Energy.
3. . European Electricity Grid Initiative (EEGI) Research and Innovation Roadmap 2013-2022, 2013.
4. . NTNU report Next Generation Control Centres – State of art and future scenarios, ISBN-no: 978-82-7200-052-2.
5. . IEC 62898-1, IEC 62898–2, IEC 61850.
6. . Zhang, J. et al., Application-aware secure multicast for power grid, Int. J. Security and Networks, 6(1), 2011.
7. . Georg, H., et al., Performance evaluation of time-critical communication networks for Smart Grids based on IEC 61850, in Proc. IEEE Conf .Comp. Comm. Wkshp, 2013.
8. . Dolin, R. Building an IoT for industrial control: Part 1 – What is Industrial IoT? 2014, http://www.embedded.com/
9. . Hollnagel, E., et al., Resilience engineering: Concepts and precepts. Ashgate Publishing, Ltd., 2007.

10. . Smart Grid Architecture Model (SGAM), CEN-CENELEC-ETSI Smart Grid Coordination Group, Nov. 2012
11. . Line, M. B., Understanding information security incident management: A case study in the electric power industry, PhD Thesis, NTNU, 2015.
12. . Illustrated by the focus on smart grid advances in journals and conferences (e.g., IEEE Transactions on Smart Grids).
13. . E.g., European Technology Platform (ETP) on Smart Grids, International Smart Grid Action Network (ISGAN).
14. . Demo Norway, www.smartgrids.no, Smartgrid.gov, http://www.smartgrids.eu/EU_Projects
15. . IEEE Smart Grid Newsletter, Compendium 2015, EU/ETP Smartgrids: SmartGrids SRA 2035, 2012.
16. . Tøndel, I. A. et al., Towards improved understanding and holistic management of the cyber security challenges in power transmission systems. In Availability, Reliability, and Security in Information Systems and HCI, Springer 2013.