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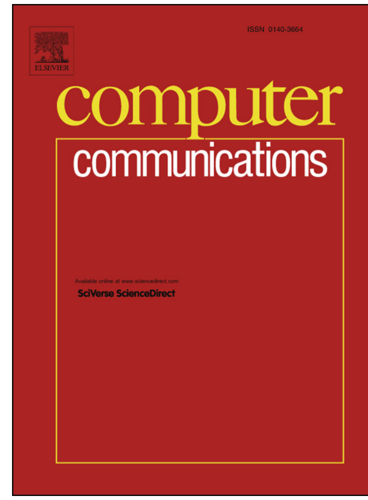

Review

The Role of Communication Systems in Smart Grids: Architectures, Technical Solutions and Research Challenges

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The Role of Communication Systems in Smart Grids: Architectures, Technical Solutions and Research Challenges

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Abstract

The purpose of this survey is to present a critical overview of smart grid concepts, with a special focus on the role that communication, networking and middleware technologies will have in the transformation of existing electric power systems into smart grids. First of all we elaborate on the key technological, economical and societal drivers for the development of smart grids. By adopting a data-centric perspective we present a conceptual model of communication systems for smart grids, and we identify functional components, technologies, network topologies and communication services that are needed to support smart grid communications. Then, we introduce the fundamental research challenges in this field including communication reliability and timeliness, QoS support, data management services, and autonomic behaviors. Finally, we discuss the main solutions proposed in the literature for each of them, and we identify possible future research directions.

Key words: smart grid, distributed energy resources, communication architecture and protocols, control and management, middleware, security, standards

1. Introduction

The term smart grid is commonly used to refer to a modernized electrical system, in which new and more sustainable models of energy production, distribution and usage will be made possible by incorporating in the power system: *a*) pervasive communication and monitoring capabilities, and *b*) more distributed and autonomous control and management functionalities [1, 2]. As a matter of fact existing electric grids are a large-scale, unidirectional and centralized systems in which the electricity is delivered from remote power plants through a tree-based distribution system to local customers with pre-established load profiles [3]. However, a number of technological innovations, as well as environmental and economical concerns, have emerged in the last decade that have made traditional electric power systems outdated and not well suited to meet the reliability, efficiency and sustainability requirements posed by those changes [4].

Although there might be different views on what will be the definitive model of a smart grid, the following key capabilities are widely recognized as essential for the successful implementation of smart grids [5]:

- To enable the massive deployment and efficient use of distributed energy resources, including renewable energy sources and energy storage systems;
- To enhance the efficiency, resilience and sustainability of an electric grid by incorporating real-time distributed intelligence enabling automated protection, optimization and control functions;
- To allow the interaction of consumers with energy management systems to enable demand-response and load shaping functionalities;
- To enable real-time, scalable situational awareness of grid status and operations through the deployment of advanced metering and monitoring systems;
- To support the electrification of transportation systems by facilitating the deployment of plug-in electric vehicles and their use as mobile energy resources.

From a practical point of view the above vision requires the pervasive deployment of "intelligent" devices [6] (e.g., sensors, actuators, smart appliances, smart meters, embedded computers, etc.) that are capable of collecting real-time and fine-grained information about electricity usage patterns, as well as about the status of distributed energy resources and other components of the electric grid. This huge amount of heterogeneous information collected by the metering and monitoring infrastructures that will be incorporated in a smart grid must be shared in a reliable and secure manner to a multitude

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