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Surveys on the reliability impacts of power system cyber–physical layers

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ABSTRACT

Information and communication technology (ICT) is a vital addition to modern society living and is a crucial feature of the smart grid. It boosts the power system with the advantage of using intelligent infrastructure to aid monitoring, protection, bidirectional communication, supply safety, security and self-healing characteristics. ICT infrastructures are integrated into the power network by using technologies, such as active distribution networks, smart cities and societies, dynamic line ratings, special protection schemes and demand-side management programmes. Deployment of these technologies has beneficial impacts on the reliability of power systems. However, these infrastructures are naturally prone to failures and cybersecurity issues because of Internet of things standards, which can further jeopardise system reliability. Various studies have examined the effect of these technologies on the reliability of power systems whilst ignoring that the associated ICTs could be unavailable. Thus, this work comprehensively reviews studies that go beyond component-based reliability assessment and accounts for the impact of ICT integrations on system-wide reliability whilst explicitly considering the effects of malfunctions of the cyber system. Moreover, the paper presents quantitative and qualitative information about the impact of ICT deployed with various smart grid technologies and applications on the reliability of modern power systems.

1. Introduction

The evolution of the smart grid has gained increased attention in recent years. The smart grid, which is characterised by having diverse functionality, is a system of systems (SoS) that is composed of a cyber addition to the physical network of electrical power components. The smart grid can efficiently integrate the activities of the generation, transmission and distribution system operators and the end-users to ensure an economically efficient and flexible power system with increased sustainability and reliability. These modern power networks are commonly referred to as cyber–physical systems or cyber power networks. Information and communication technology (ICT) is a vital addition to modern society living and is a key feature of the smart grid that boosts the power system with the added advantage of using intelligent infrastructure to aid its operations.

Communication technologies in modern power systems allow bidirectional power flows, which are useful for distributed generation (DG) amongst other applications. In the case in which a station generates surplus power, the excess can be channelled for use at a different location rather than causing safety concerns on the same location on the network. This way increases the flexibility of the network. Deployment of demand-side management (DSM) features that aid load balancing and adjustment, peak shaving and pricing incentives improves the efficiency of the ICT integrated networks. Addition of ICT features also supports increased penetrations of distributed energy resources (DERs), such as renewable energy systems (RESs), DGs, electric vehicles (EVs), energy storage systems (ESSs) and microgrids, which make the power network sustainable. Another advantage of ICT implementation from the flexibility feature encourages two-way interaction between energy suppliers and consumers, such as in active distribution networks (ADNs), smart homes and smart city applications, demand response (DR) and peer-to-peer transactions. Thus, the electricity markets become an enabling environment for investments from all stakeholders. The implementation of ICTs also promotes improved fault detection and self-healing in power networks by using sophisticated applications, such as WAMS/WAMPAC, dynamic thermal rating (DTR) and special protection schemes (SPSs), all of which improve the overall reliability of the network (Di Santo, Kanashiro, Di Santo, & Saidel, 2015; Panajotovic, Jankovic, & Odadzic, 2011; Sooriyabandara & Ekanayake, 2010; Supriya, Magheshwari, Sree Udhyalakshmi, Subhashini, & Musthafa, 2015). Intelligent infrastructures, such as intelligent electronic devices (IEDs) including sensors, circuit breakers, smart metres, reclosers, protective relay units and phasor measurement units, are important components of the smart grid that facilitate deployment of

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