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The role of communications and standardization in wind power applications – A review

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ABSTRACT

Harvesting energy from the wind as an alternative to fossil fuels has many advantages in terms of protecting the environment and promoting sustainability. However, the increasing penetration of wind power in electrical networks presents many challenges such as the intermittency of wind power, its relative high cost as compared to conventional sources, and technical impacts on the distribution systems. Information and Communications Technologies (ICT) are fast becoming integral components of the 21st century electrical grid at all levels including the generation, transmission, distribution and even at the consumer level. The use of ICT in the modern wind power plants has also become the norm and offers numerous benefits in addressing the challenges of wind power integration. ICT can support the efficient scheduling of wind power generation and energy dispatch, and can be used in automation, protection, and even in reactive power control applications. The International Electrotechnical Commission (IEC) has been playing a key role in the transition to a modernized ICT-based electrical grid by developing many communication standards. These standards have opened the path to a unified and interoperable communication platform in different aspects of the power system network. This paper provides an in depth overview of the relevant wind power communication standards and presents a review on their worldwide applications. The key focus is on the application of the two most relevant IEC standards, the IEC 61850 and IEC 61400-25, in wind power systems, the current status of the literature and ongoing research projects. The paper also identifies potential research directions for future development in this field.

Contents

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1. Introduction

Currently, many countries are faced with increasing demands of electricity, but yet limited petroleum resources. Environmental concerns due to the release of greenhouse gas emissions in fossil fuel combustion have become a major issue all over the world [1]. These concerns have resulted in a trend towards higher penetration of renewable energy generation systems in power networks and more investment in these types of energy resources [2–5]. Governments all over the world are implementing renewable energy targets and/or emission trading schemes to encourage and direct investment in the use of cleaner resources [6]. Such policies are more critical when it comes to developing countries where high population and subsequent increase in energy demand result in the urgent need for renewable and sustainable energy systems [7].

Wind power is one of the fastest growing and abundant renewable energy resources. In relation to the advantages of wind power, it could constitute an easily available, cost effective, sustainable, and environmentally-mild energy source [8]. Energy harvest from wind in the European Union was over 100 GW in September 2012. This amount of energy equalled to the total amount of electricity generated by wind in the US and China in August 2012 [9]. The global wind capacity in 2012 was around 282 GW, 10 percent higher than the capacity in 2011. It increased by 12.4 percent to around 318 GW in 2013 and leaped to a new peak at around 336.5 GW in 2014. This amount of energy is, however, enough to provide only about 4% of worldwide electricity demand [10]. This is while the global potential for wind energy is estimated to be 26,000 TW h/yr [11]. Considering the advancement of the wind industry and the increased size of wind farms all over the world, more research and investigations are needed and are being carried out into the design, control, regulation, and integration and monitoring of Wind Power Plants (WPPs) [12]. This research is aimed at increasing the technical efficiency, cost effectiveness and ease of grid integration of wind farm systems bringing wind power on par with the traditional fossil-fuel based systems. The use of advanced ICT in modern WPPs is paramount to achieving this aim as an appropriate communication system is critical in allowing for seamless exchange of information and between different applications and participants involved in a WPP. Such participants often include the wind turbines, local controller, remote control centre, weather forecast services, and electrical market [13]. The accuracy of such a communication system is subject to on-line monitoring and control of WPPs based on real time data. Such a seamless information exchange can aid in many WPP related processes such as generation forecasting, reactive power control and energy dispatch. However, the complex nature of WPPs is a challenge for development of ICT systems in WPPs [14]. The ICT systems have to enable effective Operation and Maintenance (O&M) and seamless control of individual wind turbines and the WPP as a whole.

Each plant or wind farm may be composed of many wind turbine units manufactured by different vendors. Each manufacturer typically supports its own proprietary standard for the communication of data to and from wind turbines. Such proprietary standards are appropriate when wind turbines manufactured by a single vendor are communicating but lack of interoperability is a common issue in the case of the communication of wind turbines from different vendors [15]. Standardization is the key to provide a generic interface to different partners. International Electrotechnical Commission (IEC) has come up with such a generic interface to address the interoperability concerns in power system networks. Currently, there are more than 100 IEC standards that define different components of the Smart Grid (SG) [16]. This paper focuses primarily on the following two communication standards that relate to the wind power sector:

- IEC 61850 – Communication networks and systems in substation [17]: This standard focuses on information modelling for substations. The status, control and analogue information can be gathered from different protection devices in a wind power substation and sent to the control centre using the communication services defined in the IEC 61850 subset of standards.
- IEC 61400-25 – Communications for monitoring and control of WPPs [18]: The standard involves a comprehensive range of information about the different part of the wind power system. Five mapping method have been defined in IEC 61400-25. Depending on the communication system, each one of them has some advantages and disadvantages.

Apart from these two standards, other standards concerned with a unified communication in WPPs are also discussed in this paper. In this regard, IEC 61970 focuses on the Application Program Interfaces (APIs) in Energy Management Systems (EMS) and plays an important role by providing a set of guidelines for the real-time exchange of power system public information (external information on the generation, distribution, and transmission systems) with the EMS control centres [19]. Taking advantage of these standards, the interaction of multiple devices and subsystems of an electrical network over one common protocol is possible. This, in turn, enables online monitoring, control and adaptive protection of WPPs, eases the design of the system, and improves the operation and maintenance practices saving many costs [20].

This paper presents an in-depth overview of the role and significance of IEC-based communications in wind power systems by reviewing the existing knowledge and worldwide application examples in this field. The paper highlights the two key IEC standards, IEC 61850 and IEC 61400-25, in wind power systems, summarizes their main features and sets out their differences. The work presented investigates the problems and challenges in wind power systems and how ICT technologies and communication standards are aiding in the solution of these challenges. The main focus in this article will be the three main sub-topics of research: control, protection, and energy management in wind power systems. Section 2 introduces the IEC 61850 and IEC 61400-25 standards and the related communication services, while Section 3