Development of an Efficient, Cheap, and Flexible IoT-Based Wind Turbine Emulator

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Chapter 14
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14.1 Introduction

Energy is always the most crucial need for growth and development of a nation. Due to the rapid growth of the world population, changes in technology, and other political and economic scenarios, the energy demand is increased immensely. As of now, though more than 80% of the energy is generated by conventional sources of energy, it is gradually depleting. So, the development of an efficient and reliable renewable system becomes the prime motive [1]. Wind technology is rapidly improving in efficiency and scope. Energy researchers have high future goals for wind energy development. The main difficulty for the development of the wind energy system is the natural disruption of these resources. If units are too large to meet demand, severe imbalances can endanger system security. IoT has emerged as a smart and effective solution for monitoring the renewable energy system. Internet of Things (IoT) can be explained as a digital network that connects various elements of a particular system and regulates the data according to the situation using advanced embedded systems, including controllers, meters, and sensors. IoT brought the third revolution in the field of technology [2]. In the near future, IoT is expected to be widespread and will cover all aspects of human life, including the production and management of renewable energy.

An advanced version of IoT is introduced named as the Internet of Energy (IoE), which includes the arrangement of energy ecosystem and ICT. The implementation

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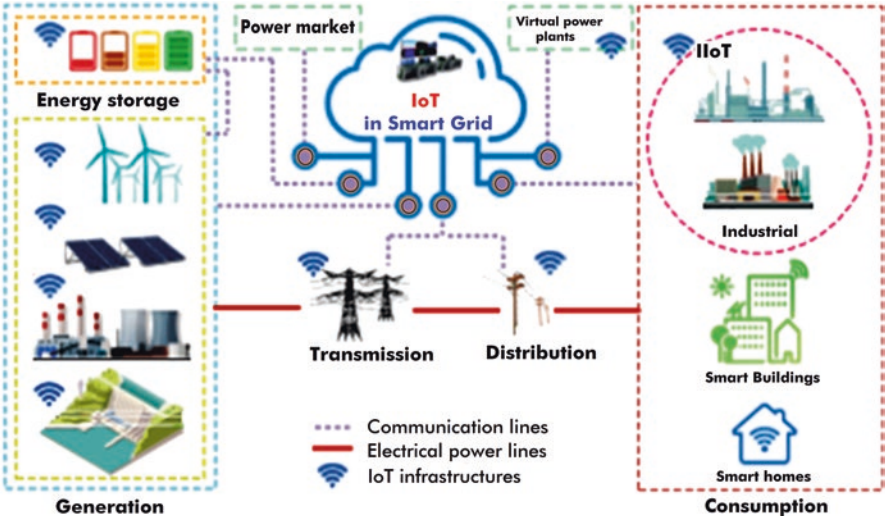


Fig. 14.1 Application of IoT in smart grid [4]

of IoT as a monitoring system in the smart grid is described in this study [3]. Nowadays, IoT is considered a vital part of the designing and execution of smart building schemes and smart cities, as shown in Figure 14.1. With the advancement in the field of IoT, a new theory is propounded defined as smart grid 2.0 which is also known as the second generation of smart grids. It refers to the improved model of the smart hybrid system with the IoT and is expected to be implemented in the next few years [4].

In the new concept (smart grid 2.0), the power exchange between the hybrid energy system and the power grid is regulated using the advanced-level smart electric metering system. The amount of energy exchange, the plug and play capability, and the vital information about the parameter between seller and buyer could be shared using informatics infrastructure. Plug and play feature indicates that a demand-side electricity source can inject power to the grid as easy as inserting a plug into an outlet, i.e., ability to inject even a very minimal power generation into the power grid like vehicle-to-grid (V2G) power transfer. Such types of consumers which have the ability to deliver power to another system are defined as prosumers [5]. Still, now there are no technologies that can disconnect and connect the distributed generation system with a grid at each desired moment. It is sensible to study wind energy conversion system (WECS) with respect to cybersecurity. The overall effect and significance of cybersecurity on the reliability of WECS have been studied [6, 7].

14.2 Wind Energy System with IoT

Wind energy is nowadays emerging as one of the most promising technologies. However, the output of the wind energy conversion system (WECS) is dependent on wind flow, which is sometimes erratic and at times unpredictable. By this time, developing a control scheme and ensuring a reliable WECS has been a significant area of focus. However, the efficacy of the control scheme can be assured by several experiments with an actual wind turbine (WT). The actual wind turbine is ultimately dependent on environmental conditions. Such dependency may cause indefinite delays. Moreover, several worst cases for which system needs to be tested may never occur, and thus performance and reliability of controllers for those cases are always questionable. Another way is to set up a WT in the laboratory. But it is difficult to set up a WT in the laboratory because of challenges like space and controlled environment, for example, wind tunnel.

A solution to these problems can be found in a wind turbine emulator. Wind turbine emulator mimics the behavior of actual wind turbine under controlled manner. Line diagram of wind turbine emulator and power conditioning unit is shown in Fig. 14.2. Essentially it simulates the same operating pattern at hardware level in real time similar to what an actual wind turbine does at given operating parameters of wind speed and pitch angle. The term emulation is coined for simulation practices which involve hardware platform. It provides a fast-configurable testing platform. Usually these are performed in real time. Emulator is similar to hardware-in-the-loop simulation concepts. Wind turbine emulator can find applications in numerous fields. It provides a flexible testing platform for the study of dynamic and steady-state behavior of wind turbine. Beginners can learn about power/wind speed, torque/turbine speed, and power/turbine speed characteristics of a wind turbine and can perform comparative studies about how changes in parameters of wind turbine affect the behavior. For other applications, this emulator can be coupled to the generator (induction, PMSG, DFIG) followed by power electronics in place of an actual wind turbine. So, researchers would not have to rely on environmental conditions which are appropriate for driving the wind turbine at some desired operating point. Since the operating point of wind emulator can be controlled, researchers can simulate all possible scenarios of operation of a wind turbine and accordingly can modify the power electronics and control algorithms. Consequently, it will improve the product quality and reliability. The operating point of wind emulator can be controlled using IoT. The block diagram of wind operating system with IoT system is shown in Figure 14.3.

IoT topology in combination with ICT infrastructure allows the wind power producers to regulate the output power at maximum efficiency and provides the accurate maintenance reminder of each component at regular interval in order to avoid any huge disaster. There are various algorithms which help in formulating the desired schedule for maintenance like machine learning, fuzzy logic, neural network, etc. For instance, on-time maintenance can reduce the index of levelized

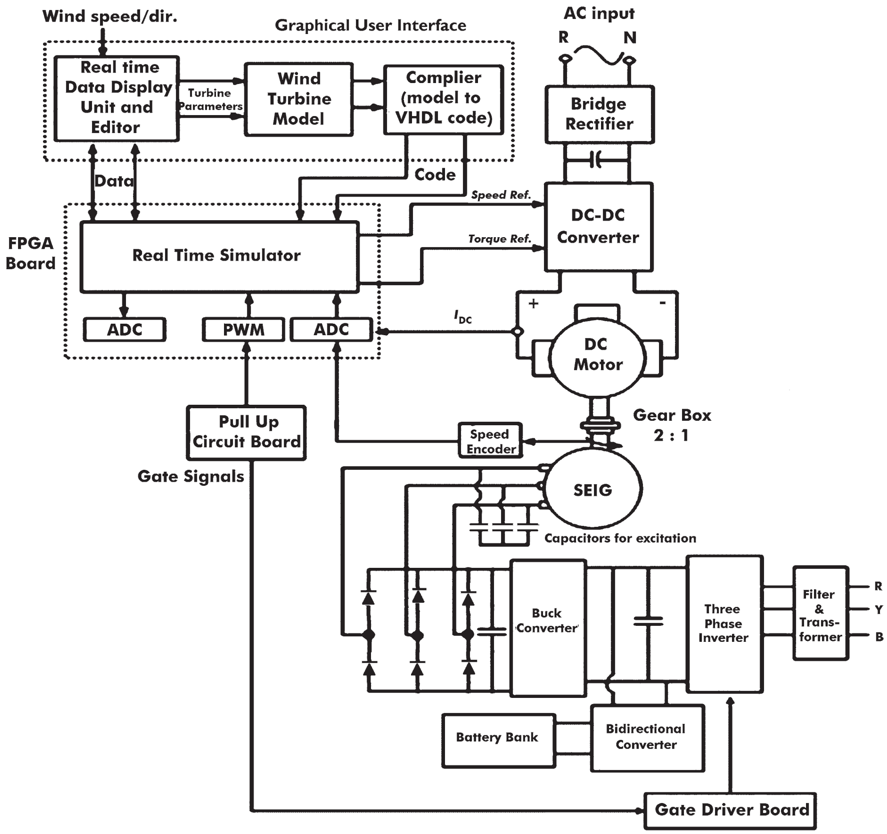


Fig. 14.2 Line diagram of wind turbine emulator and power conditioning unit

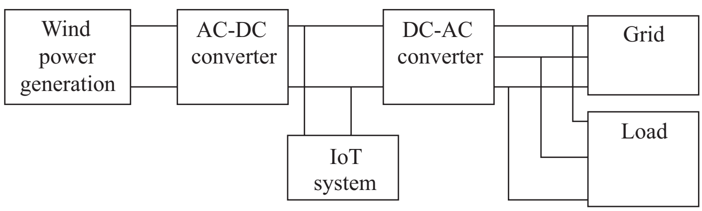


Fig. 14.3 Block representation of wind operating system with IoT system

energy costs (LCoE) for wind assets that denotes the net present value of the unit power cost over the lifetime of the turbines [8].

In digital communication system, the beneficiary data of each element of system is collected and processed using machine learning algorithm [9]. The main two problems related with the IoT system are the delay in information transfer especially in offshore wind farms and limitation on the bandwidth for exchanging information. Therefore, if essential information could be received and processed at a faster rate, then corrective measures for the system at the time of failure can be automated like shutting down of turbine system in case of turbulence. Therefore, we need the deployment of more IoT systems with improved algorithm for monitoring the wind power generation system [10].

14.3 Results

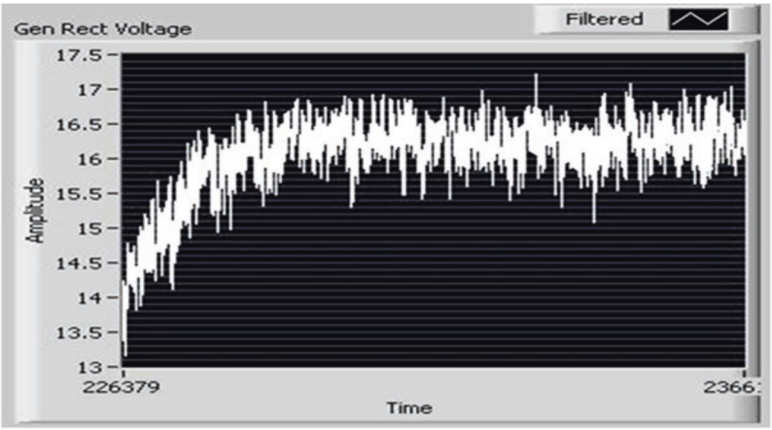
The wind emulator system developed is run at varying motor buck duties in order to obtain the effect on the various output parameters such as generator voltage, generator current, generator speed, battery voltage, DC link voltage, and motor armature current. The following results are also obtained using LabVIEW software. Their variation with time is shown in Table 14.1.

Thus, all the output parameters are obtained in the graph with respect to time which are shown in Figure 14.4 and are presented in two parts.

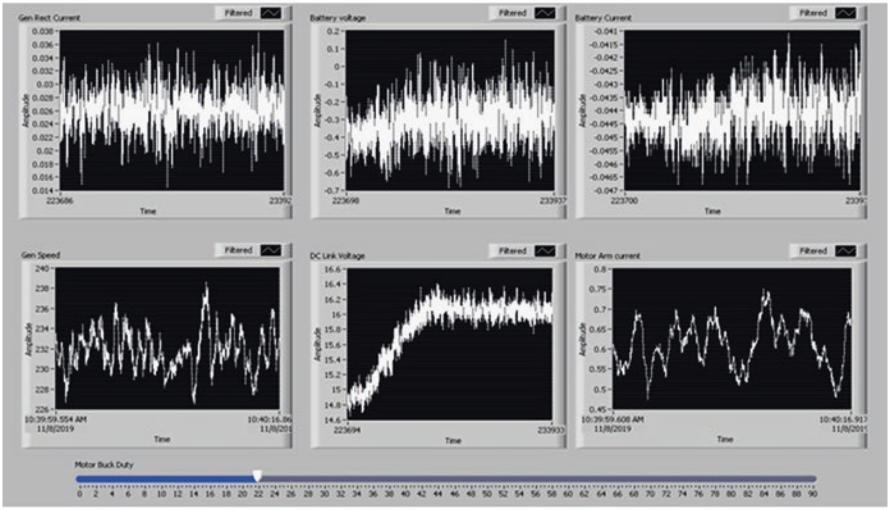
Speed is varying with change in the duty ratio while field and armature voltages remain invariant. The graph shown in Fig. 14.4 provides the variation of the motor output parameters versus the time. Thus, an efficient, economical, and flexible IoT-based wind turbine emulator is successfully developed in this chapter.

Table 14.1 Results of motor parameters

Motor buck duty (%)	Field voltage (V)	Armature voltage (V)	Speed (rpm)
2	230	229	60
4	230	229	74
6	230	229	96
8	230	229	116
10	230	229	131
12	230	229	146
14	230	229	164
16	230	229	180
18	230	229	199
20	230	229	215
22	230	229	229



(a)



(b)

Fig. 14.4 Variation of motor output parameters with time

14.4 Summary

The proposal for a highly efficient, cost-effective, and flexible IoT-based wind turbine emulator is thus presented in this chapter. The monitoring can be performed using a web-based service which would receive the wind turbine data and convert it into useful information. The challenge however still lies with the feasibility of the amount of data that can be accumulated from each and every element of a wind power system in a real-time environment.

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