Wind turbine remote control using Android devices

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Abstract. This paper describes the remote control of a wind turbine system over the internet using an Android device, namely a tablet or a smartphone. The wind turbine workstation contains a LabVIEW program which monitors the entire wind turbine energy conversion system (WECS). The Android device connects to the LabVIEW application, working as a remote interface to the wind turbine. The communication between the devices needs to be secured because it takes place over the internet. Hence, the data are encrypted before being sent through the network. The scope was the design of remote control software capable of visualizing real-time wind turbine data through a secure connection. Since the WECS is fully automated and no full-time human operator exists, unattended access to the turbine workstation is needed. Therefore the device must not require any confirmation or permission from the computer operator in order to control it. Another condition is that Android application does not have any root requirements.

1. Introduction

Distance learning laboratories have gained popularity in the academic community, supported by advances in remote monitoring technologies. This gives remote users the possibility to experiment with a wind turbine device, namely a tablet or a smartphone. The wind turbine workstation contains a LabVIEW program which monitors the entire wind turbine energy conversion system (WECS). The Android device connects to the LabVIEW application, working as a remote interface to the wind turbine. The communication between the devices needs to be secured because it takes place over the internet. Hence, the data are encrypted before being sent through the network. The scope was the design of remote control software capable of visualizing real-time wind turbine data through a secure connection. Since the WECS is fully automated and no full-time human operator exists, unattended access to the turbine workstation is needed. Therefore the device must not require any confirmation or permission from the computer operator in order to control it. Another condition is that Android application does not have any root requirements.
an increasingly important aspect for system improvement [8]. The WECS also has a workstation which contains a LabVIEW program that monitors and controls everything that happens in the plant simulation. The Android device connects to the LabVIEW application, working as a remote interface to the wind turbine. The purpose of the proposed system is to take remote measurements via mobile devices. Two technological solutions are proposed and analyzed, revealing their advantages and disadvantages [9].

2. Wind Energy Conversion System

Small-scale power-generation systems based on renewable energy sources have been proven to be efficient and cost effective, reducing both CO\textsubscript{2} emissions and primary energy use, thereby saving energy resources. Renewable energy technologies range from the well-established, such as hydropower, to the emergent, such as hybrid systems [10, 11].

Wind energy or wind power describes the process by which wind is used to generate mechanical or electric power. The wind turbine is the typical component through which wind energy is converted into mechanical energy, by means of the aerodynamically designed blades. The function of the wind turbine is to capture power from the wind, but, according to the Betz theory, the entire wind energy could not be completely absorbed by the turbine. The output power is highly dependent on the constructive features and characteristics of the turbine, being determined by factors such as power coefficient, air density, the radius of the wind wheel and wind speed [10, 12].

There are several wind turbines types proposed in literature. The two most important types are vertical axis wind turbines (VAWT) and horizontal axis wind turbines (HAWT). HAWTs are the most frequently used, being able to operate at higher wind speeds than the VAWTs [13, 14].

The wind turbine used in this paper is a 5 kW fixed pitch variable speed horizontal axis turbine; its characteristics being presented in the following table.

| Table 1. The parameters of the wind turbine |
|-------------------------------------------|
| Name                        | Value          |
| Rated power                 | 5.5 kW         |
| Rated wind speed            | 11 m/s         |
| Maximum speed               | 126 rpm        |
| Turbine inertia             | 140 kg\textsuperscript{m2} |
| Blade swept area            | 19.6 m\textsuperscript{2} |
| Radius of the turbine blade | 2.5 m          |
| Nominal tip-speed ratio     | 3              |
| Specific density of air     | 1.225 kg/m\textsuperscript{3} |

The wind turbine is directly coupled to a three phase permanent magnet synchronous generator (PMSG). This arrangement offers high reliability, high efficiency, low maintenance and low cost, being considered a robust solution for wind power generation. The wind turbine, being a variable speed turbine, when connected to a PMSG, permits operation over a wider range of speeds, resulting in higher power harvesting from the turbine to the generator [10].

The PMSG is a standard synchronous machine, where the DC excitation circuit is replaced with permanent magnets, placed on the rotor surface. Thus, the electrical losses in the rotor are eliminated and the thermal characteristics of the machine are improved. Also, the absence of the mechanical components such as brushes and slip rings makes the machine lighter, having a smaller physical size, a low moment of inertia leading to a higher power to weight ratio, which means a higher efficiency and reliability [15]. Due to these advantages, the permanent magnet synchronous generator is an attractive
solution for wind turbine applications. The disadvantages are: high costs for the magnets and a fixed excitation. Since there is no excitation system and associated voltage controller, the generator output voltage is variable and directly influenced by the rotor speed [10].

The PMSG used in this simulator has the magnets mounted on the surface of the rotor, being a Surface mounted permanent magnet synchronous generator (SPMSG) [16], [17]. The considered PMSG has the following parameters:

| Name                  | Value     |
|-----------------------|-----------|
| Rated power           | 5 KVA     |
| Rated current         | 12 A      |
| Rated speed           | 120 rpm   |
| Rated frequency       | 32 Hz     |
| Pole pairs number     | 16        |
| Permanent magnets flux| 1.32 Wb   |

Table 2. The parameters of the PMSG

The PMSG output voltage and frequency is governed by the machine speed and hence needs a full rated power converter in order to interface with the AC load, which needs a fixed voltage and frequency. The conversion of the electrical energy obtained from the turbine system is based on an AC/DC/AC conversion system. The PMSG generator is connected with a PVI-Wind Interface 4000 rectifier (a three phase rectifier with overvoltage protection) to a PVI-12.5-TL-OUTD-W Wind Inverter (a dual stage transformerless wind inverter). Both these devices are produced by ABB. The ABB 4000-WIND-INTERFACE rectifies and filters the alternating currents, thus producing a direct current output to feed to the inverter. The wind interface actually controls the power output of the wind inverter through an external signal. The wind inverter uses a very precise high speed algorithm (MPPT) that maximizes the total energy harvested. Through the inverter the wind turbine simulator is connected to the main grid, which represents the AC load. The entire ensemble constitutes the wind energy conversion system (WECS). The integration of the WECS into the existing grid saves cost and improves the reliability of the power supply [10], [18], [19]. The characteristics of the equipment can be seen in Table 3.

Table 3. The characteristics of the equipment used in the conversion system

|                        | ABB Wind Inverter | ABB Wind Interface |
|------------------------|-------------------|--------------------|
| Input Voltage          | DC 140-530(V)     | AC 400(V)          |
| Input Current          | 32 (A)            | 16.6 (A)           |
| Output Voltage         | AC 230(V)         | DC 600(V)          |
| Output Current         | 20 (A)            | 6 (A)              |
| Output Power           | 4.2 (kW)          | 4 (kW)             |

The WECS diagram can be seen in Figure 1.
The wind turbine system is simulated in LabVIEW. The LabVIEW program also has the task of controlling a 7.5 kW three phase squirrel cage induction machine through an ABB ACS800 drive. The induction machine is connected through a gearbox to the aforementioned PMSG. The induction motor (IM) with a gearbox (GB) represent the wind turbine equivalent, driving the generator as if it were
connected to the wind turbine itself. The LabVIEW program is responsible for real time acquisition and monitoring of the WECS data [11].

A view of the front panel of the LabVIEW application can be seen in Figure 3.

![Figure 3. The front panel of the LabVIEW application](image)

The scope of this study was the design of a remote control software capable of visualizing real-time wind turbine data through a secure connection. The interaction of the user with this system can be remote or in the laboratory [9].

3. Android Remote Control

Android is a ready-made, low-cost, customizable, mobile operating system developed by Google for such high-tech touchscreen devices as smartphones, tablets, televisions, cars, wrist watches, notebooks, game consoles, digital cameras, etc., each with a specialized user interface [20]. An Android mobile device can be a handy means of remote parameter monitoring. It also creates the possibility of remote data processing and analysis far from the microgrid laboratory [9]. The block diagram of such a system can be seen in Figure 4.

![Figure 4. The structure of the Android remote control system](image)

Two remote communication technologies have been used for this purpose: the LabVIEW Web Services and the Remote Control framework for LabVIEW.
3.1. Remote Control framework for LabVIEW

RCF (Remote Control framework) for LabVIEW from TOOLS for SMART MINDS (T4SM) is a powerful toolkit for LabVIEW that transforms an Android device, such as a smartphone or a tablet, into a remote control capable of displaying data, charts, tables, etc. RCF provides the LabVIEW application an interface towards mobile devices. Running as a background service, RCF gathers requests from connected clients, sends these requests to the LabVIEW application for processing, retrieves results and publishes them to clients. RCF is responsible for maintaining the connections, validating requests and notifying changes to the Android interface. Connections are password protected and data is transferred in encrypted format, optimized to minimize consumed band. RCF passes to the Android device only selected data that the remote viewer is allowed to see, rather than publishing the entire LabVIEW panel. This is an advantage when it comes to security, but also regarding transmission speed and Android storage capabilities. RFC also allows streaming of real-time data on Android smartphones and tablets, these devices becoming remote controls for the LabVIEW application in charge of monitoring the microgrid laboratory [21].

The schematic of the measurement system is presented in Figure 5.

3.2. Data Dashboard for LabVIEW

Data Dashboard for LabVIEW 2.3. is a mobile application that enables the creation of custom views of NI LabVIEW applications. The resulting Data Dashboard application can monitor and control LabVIEW applications remotely from iOS and Android mobile devices. Users can monitor and control the LabVIEW interface from Android tablets or smartphone. They can even view real-time measurement data. Data Dashboard for LabVIEW is capable of reading/writing data or commands over the network through network published shared variables and/or a secure LabVIEW web service with the object of monitoring and control [22].

3.2.1. Shared Variables. When using shared variables, the input and output data used in the application are network-published shared variables. They can both read and write data to the host system. Single-process shared variable, as used here, are similar to the LabVIEW global variable.
Shared variables interact with the host application through the LabVIEW Shared Variable Engine (SVE) operating over TCP-based network communications.

The Data Dashboard application is updated when it receives information from the server, the updates being handled through the Publish Subscribe Protocol (NI-PSP). The NI Publish and Subscribe Protocol (NI-PSP) is a networking protocol optimized to be the transport for Network Shared Variables [8], [23] and [24].

Shared Variables support primitive data types (Numeric Doubles, Booleans and Strings) as well as arrays of those primitive data types. The disadvantages are that the limited resources of the mobile devices must be taken into consideration when selecting the data to share and the lack of means of encrypting the data being sent via shared variables. The advantages are the simplicity and robustness of the method [8]. The Block Diagram of the LabVIEW program when using shared variable can be seen in Figure 6.

Figure 6. The Block Diagram of the LabVIEW program

3.2.2. LabVIEW Web Services. LabVIEW Web Services require the installation of Microsoft Silverlight 4.0. This tool provides the means to create a user interface. However, limitations regarding the number and type of front panel objects and their functionality are still to be evaluated [1], [9].

By using secure LabVIEW web services, dashboard users login using ID and passwords for authorization and have the digital API key to access the application. LabVIEW does not support built-in encryption, but it does use digital signatures. Secured requests between clients and LabVIEW Web services are sent unencrypted or "in-the-clear", yet "digitally-signed", with a secret key intended to be known only by authorized applications. Hence, LabVIEW Web services security is accomplished by validating the signature to verify the request was created by an application with authorization to access the requested resource. An API security key for a web service allows only requests coming with that
particular key access to the data. LabVIEW’s key generation algorithm creates a highly randomized string of characters. At runtime, the Web services runtime engine inspects every request as it arrives, looking for the "digital signature". If the runtime does not find a digital signature, the request is automatically rejected. If it finds a digital signature, calculates what the signature should be for that request and compares the two strings. If the two do not match, the request is rejected [22, [25].

If the communication takes place via Web Services, the remote user can only monitor designated variables. The front panel of the Data Dashboard application can be seen in the following Figure.

Figure 7. The front panel of the Data Dashboard application

4. Conclusions
This paper presents a means of remotely connecting to a microgrid laboratory, which consists of a wind turbine simulator directly coupled to a permanent magnet synchronous generator. The PMSG is connected to the electrical load (main grid) through a power conditioning system composed of an industrial wind turbine rectifier (Wind Interface) and a voltage source inverter (Wind Inverter). LabVIEW software is used to locally monitor and control the simulated plant. This LabVIEW application can be accessed remotely by an Android device [10].

This technology can provide a means of accessing measurement data from anywhere, a human-machine interface (HMI) for remotely viewing and controlling systems. Engineers can monitor data for trends, view historical data over periods of time, instantly receive alarms based on measurements, or remotely control an application or test sequence.

The remote control of a wind turbine system over the internet using an Android device presents, generally speaking, security concerns, but it is required in order to access to the turbine workstation. Remote Control framework for LabVIEW does cover most of the security requirements, but the solution is more complicated to implement than Data Dashboard. Data Dashboard for LabVIEW is capable of reading/writing data or commands over the network through shared variables or a LabVIEW web service. Shared variables are a simple and robust solution, but they can overload the memory of the Android device and are sent through the network unencrypted, being vulnerable to security threats. LabVIEW web services, however, can be secured using ID and passwords for
authorization and a digital API key for user validation, yet secured requests between clients and LabVIEW Web services are sent unencrypted. Using these technologies requires the workstation to have a static IP address which may in itself cause security issues. None of the technologies require the Android mobile device to be rooted, which is a serious advantage.

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