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Online Monitoring of Distributed Generation Systems

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***Abstract*— As renewable energy is intermittent in nature, its integration in to the power grid is challenging task. Hence remote monitoring and data acquisition of various performance parameters from the renewable energy systems has become of paramount importance. Round the clock monitoring of the system ensures the stable and reliable operation of the system, by proper management, in this way an individual at a remote location can know whether the system is producing sufficient energy or not which is essential for its stable operation. This feature can be ensured by the use of real-time performance monitoring. If it is observed the sources is not working properly then an immediate remedy can be done to it before it sets in a chain of events and make things worse. The proposed monitoring system formulates unified data acquisition standard for distributed RES and real-time monitoring of RES such as solar PV. The system is an IoT server based using an Arduino to send the real-time power production to the cloud for remote access by the operator or the owner.

***Keywords*— Distributed Generation Systems (DG), Photovoltaic (PV), Internet of Things (IoT) and Power Plant Management Platforms (PPMPs)

I. Introduction

Drawbacks or disadvantages of the conventional power generating systems are slowly and gradually becoming more and more prominent with time due to the advancement and development of the society. To cope with the disadvantages of conventional power generating systems the world is moving in the direction of developing renewable or new energy systems. New energy commonly called renewable energies engulfs various green energy sources such as wind energy, solar energy, biomass energy. Furthermore, energy from small hydro power stations can also be categorized as RES. The characteristics of RE like, being pollution-free, clean and resource regenerating are drawing glaring attention of the people towards these it. Hence, the development and application of RE is becoming unavoidable trend of smart grid development which is based on internet information technology and is supplemented with grid supply.

In Pakistan, at present the RE and new energy projects have entered into a phase of rapid expansion due to which a lot of problems are becoming prominent. The main problems faced by the experts in development and application of DG projects are as follows:

First and foremost is that of safety problems which cannot be found immediately and easily because of the decentralized generation equipment, complex operation environment, low manual routing efficiency.

Due to external environment the power quality,short circuit current, voltage shape and other performance parameters of these generation projects are greatly obstructed. Therefore, abnormal or unusual fluctuations can't be notified in time.

As there are various types and scales of these generation projects; Furthermore, these projects are also deployed on the scattered locations, the protocols of communication are also different for distributed new energy and RE generation projects. Therefore, it is difficult to obtain centralized management, statistics and dispatch for these RE generation projects.

Due to the above mentioned problems the utilization of these RES and the sustainable development of relevant industries are severely impeded by the above mentioned problems. Therefore, in order to ensure stable, safe and efficient operation of these scattered generation projects a monitoring platform and a centralized data center for remote and real-time monitoring of the various performance parameters and closely analyzing the relevant data of these generation projects are in dire need to be developed and built.

In order to support your system effectiveness and obtain proper output from your system, efficient equipment is required along with a number of other factors which affect your system efficiency and effectiveness. Hence, the importance of carefully watching and monitoring the distributed new energy and RE generation system closely for its production has increased many folds during the last two decades. By monitoring the production and other parameters of these generation systems various issues can be identified as when your system is not performing at its best potential. An online distributed energy and RE generation monitoring system has the capability of analyzing the real-time

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consumption and generation of the energy, optimizing the energy usage, various parameters related to the performance, analyze and supervise the functioning and progress of different components used in these distributed new energy and RE generation plant. The online DGs monitoring solution takes data from various remote DG systems and give information about the energy production of your system along with the information about the energy being supplied to the grid in real-time. The online DG monitoring solution is centralized i.e. a person sitting at one place can monitor the scattered distributed generation sets and ensure their best possible operation by interpreting the real-time data.

While designing and implementing a power system with distributed generation, selection of the DG monitoring solutions holds great importance. The information regarding system performance by monitoring of various performance parameters can be provided by online remote monitoring solutions. The information or data can be obtained on any portable device such as your cell phone, allowing the personnel who is monitoring the system a leverage to view the data anywhere on the device with internet access.

RE based Power Plant Management Platforms (PPMP) helps installers with easy integration and enable the supervisors of these systems to get real-time view of how much energy has been generated and how much has been supplied to the grid. By interfacing a web browser with your DG system a cloud-cloud based solution for monitoring can be incorporated and integrated in the RE based system. This provides highly interactive tool to the plant managers to optimize their decisions and accelerate the alignment with business goals by getting real time access to the key performance parameters or metrics.

An online monitoring system is not all about showing the energy generation and consumption data, it also provides information and helps us understand the setup of the system. Detection of various problems in RE generation systems such as defects in panel strings of a solar PV plant or blades of wind mill in wind energy plant and recommending repairs after detection of these defects. Furthermore, historical data from the system can also be tracked. For example, in order to know that how weather has effected the power production of the system in the past and what future prospects it can have, a monitoring systemcan help us achieve that as well because it offers data on historical weather-based data based on that information we find weather based performance of the system. Many existing online monitoring and management systems usually installed at homes, offices and other local systems monitor a single generation station that is why in all these cases a single monitoring object is found. Hence, there is no concrete report of that there exists a real-time monitoring platform which is inclusive of the evaluation of operation and generation capacity of DGs which are multiple and scattered.

II. MODELING AND DESIGNING

A. Prototype Development

In hardware implementation and development of the prototype, gaining the basic concept of hardware development is of key importance. Concepts of using burden resistance, using a breadboard, making proper connections and connecting capacitors for filtering results for accurate results.

As Arduino Uno only reads voltage signals. Whereas, the output of current sensors i.e. of CT, is a current signal. The Arduino Uno can’t read current signals therefore there is a need for the conversion of the current signal from the CT into the equivalent voltage signal for the Arduino to read. For this purpose, we use a burden resistor. As we know that only the voltages between 0V to 5V can be handled by anArduino thus it is essential to convert the current signal into the voltage signal that lies within this acceptable range. In order to achieve that a burden resistor is added to the circuit. As the signal obtained from the CT is alternating and changes between negative and positive value. For maximizing the measurement resolution, the maximum voltage at burden resistance should be:

$$\text{(Maximum accepted voltage)} / 2 \quad (1)$$

As we know that the maximum accepted voltage here is 5V so the answer comes out to be 2.5V. Now the calculation for better burden resistance value is done:

$$R(\text{burden}) = U(\text{sensor}) / I(\text{sensor}) = 2.5V / 0.0707A = 3.5\Omega \quad (2)$$

The value 35.4Ω comes out to be the ideal value of the burden resistance, as the resistor is not a current resistor therefore we use a 33Ω resistor. As we also know that an Arduino cannot measure negative voltage, so inorder to make the value measurable by the Arduino we add 2.5V to U (sensor).

So we add:

Two resistors i.e. R1 and R2 as shown in the figure 1. We choose 10kΩ value for R1 and R2 because it avoids too much of the energy consumption.

The capacitor C1value is chosen to be 10uF which shows that it has a low reactance which is of the order of few hundred ohms and thus provides an alternative path for the flow alternating current (AC) to bypass the resistor and reduce the error in the values.

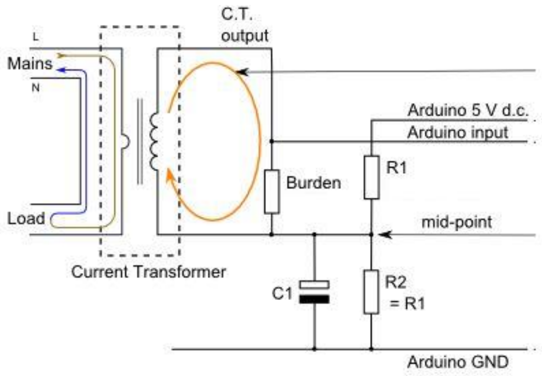

Fig. 1

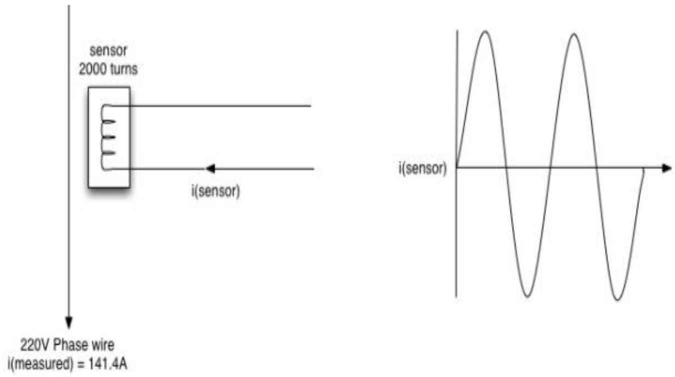

Fig. 3

B. *Interfacing the sensors with Arduino*

The sensors used here are YHDC 100A current sensors. The sensors measure the current of the line and generates a signals that is in direct proportion to the amount of current flowing in the line.As discussed earlier the Arduino Uno can't read current signals therefore there is a need for the conversion of the current signal from the CT into the equivalent voltage signal for the Arduino to read as shown in figure 2. It means that in order to interface a CT with an Arduino the use of burden resistor is very essential.

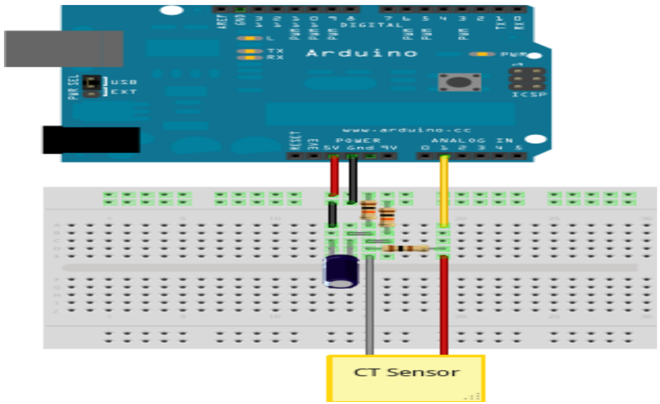

Fig. 2

The current that is measured by the CT is AC current. The CT sensor is standardized to measure a maximum of 100A AC, this 100A is actually the RMS value so therefore we need to find the maximum peak current that the CT sensor can handle shown in figure 3.

So it is essential to measure the peak current first:

$$i(measured)= \sqrt{2} \times i(rms\_current)= 1.414\times100A = 141.4A \quad (3)$$

The output current of the sensor is defined by its number of turns; here in this case it is 2000

$$i(sensor)=i(measured) / nb\_turns = 141.4/2000 = 0.0707A \quad (4)$$

C. *Connecting the Arduino Uno and the Thing speak cloud via internet*

For sending data to ThingSpeak cloud server using an Arduino UNO that has a built in Wi-Fi module i.e. ESP8266, it is essential that the Arduino board is connected to a network. There is a library for ThingSpeak in Arduino. In order to obtain the functionality of ESP8266 it is essential to download and install this library. The library is thus used by the Arduino device which enables it to send data to ThingSpeak cloud server. A user account is required on the ThingSpeak cloud, in the account various channels are thus created. Each channel has its own channel ID and name. So for Arduino to send the data to the desired channel the particular channel ID is provided in the code which is later burned on the Arduino board. The channel has the feature of storing the data for indefinite time. The Arduino board send data to the ThingSpeak cloud every milli second which is displayed on the channel field. More than one value can be sent to ThingSpeak cloud server as the server can support up to 8 different channels. To send multiple value to ThingSpeak from an Arduino, you have to use ThingSpeak.setField(#,value) for each value to send to a separate channel and then use ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey) to send data or information to ThingSpeak cloud.

Fig. 4

III. RESULTS

This section explains in detail the results obtained from the research after the successful development of the prototype. The main objective of the research was defined in the first chapter. The chief points of the objectives were to develop a centralized online monitoring system for RES based on the principle of distributed generation which is cheap. The advantage of having such a monitoring system is that in case of any abnormal behavior of any of the generation plants the owner or the operator of the plant is notified and necessary control actions can be taken. Furthermore, proper monitoring ensures reliable operation of the system so that maximum output can be obtained from the system.

A. Explanation

The developed prototype was installed on various remote locations on RE generation plants. One prototype was installed on IRA Fulton school, one was installed in Engineering research center (ERC), Tempe, Arizona. Each prototype was connected to the internet and the sensors were clamped on each phase of the inverter output. The sensors senses current of each phase and as the voltage is constant i.e. 110 volts in USA it calculates the corresponding power generated. Whereas in Pakistan as the voltage is 220 volts so based on the measured current the corresponding power is calculated by the Arduino code and sent to the ThingSpeak cloud.

B. Results obtained from Engineering Research Centre (ERC)

1) Background

The solar power generating plant on ERC has a 6000 VA rated apparent power output with a rated frequency of 60 Hz. It is an on grid system with 24 solar panels and used the concept of net metering. Each solar panel has a peak power output of 180 W with a maximum power voltage of 44.3 V, maximum power current of 5.76 A. The panels are connected in such a way that there is a series connection of 3 panels in 8 rows. The general block diagram of the on grid system of ERC is shown as under figure 5.

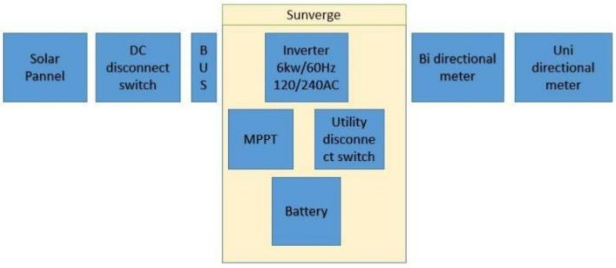

Fig. 5

The results obtained from the on-grid system of solar PV installed on top of the ERC building are as under:

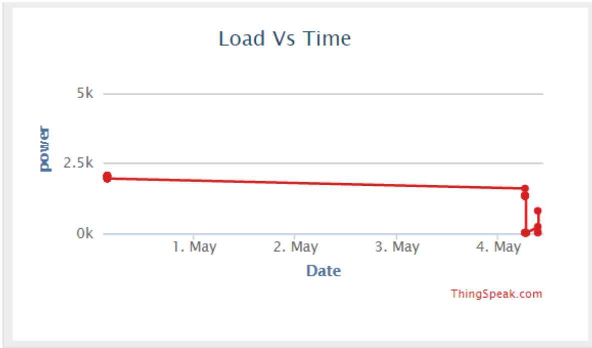

Fig. 6

The y-axis show power while x- axis shows time in the above figure 6. The Load Vs Time graph is from "ThingSpeak" which is cloud accessible data server. The power is decreasing with time. Apart from graphical visualization of the power production, we can also get a .csv file which can be used for further analysis of the system.

C. Results obtained from IRA Fulton School of Engineering

The solar PV generation plant on rooftop of IRA Fulton school of engineering is identical to that of Engineering Research Centre (ERC) with the same equipment, ratings and output. The results obtained from the on-grid system of solar PV installed on rooftop of the building are as under:

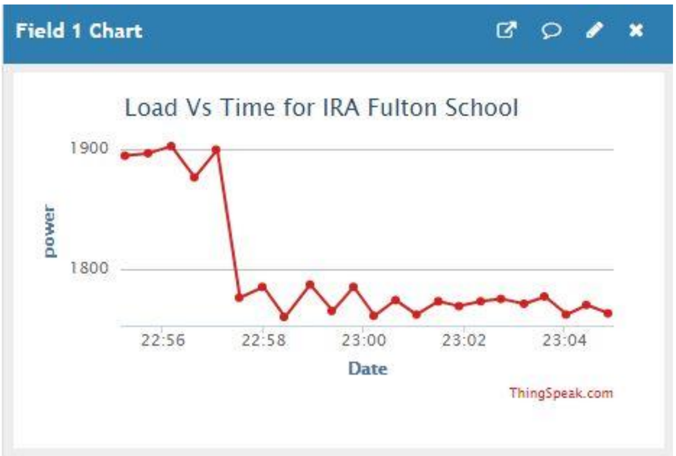

Fig. 7

The y-axis show power while x- axis shows time in the above figure 7. The Load Vs Time graph is from "ThingSpeak" which is cloud accessible data server. The power is varying with time as evident from the graph. This feature gives an operator an opportunity to monitor various distributed generation systems in real time. Apart from graphical visualization of the power production, we can also get a .csv file which can be used for further analysis of the system.

CONCLUSION

This research aimed to resolve the problems faced by the experts in development and application of distributed energy generation projects. The problems faced by them were as follows:

First and foremost is that of safety problems which cannot be found immediately and easily because of the decentralized generation equipment, complex operation environment, low manual routing efficiency. Due to external environment the power quality,short circuit current, voltage shape and other performance parameters of these generation projects are greatly obstructed. Therefore, abnormal or unusual fluctuations can't be notified in time. As there are various types and scales of these generation projects; Furthermore, these projects are also deployed on the scattered locations, the protocols of communication are also different for distributed new energy and RE generation projects. Therefore, it is difficult to obtain centralized management, statistics and dispatch for these RE generation projects and expensive monitoring system.

The developed system which is explained in the paper successfully resolved the above problems. The developed system is an Arduino and IoT based online monitoring system which is cost effective and is centralized. The Arduino gets its input from the sensors i.e. CTs. The CTs measures the current flowing in the line and send it to the Arduino. The Arduino reads the sensor data and through coding it calculates the corresponding power. It then uploads the current along with the corresponding power values to the ThingSpeak cloud every millisecond. The ThingSpeak cloud stores the data, we can also visualize the data and power flow in the form of graphs. Furthermore, we can obtain a .csv file from ThingSpeak which can also be used for further experimentation. The online monitoring system for RE based DG system based on Internet of Things (IoT) technology is developed in this paper which provides certain technical services for users, including monitoring of remote DG systems. By monitoring the DG system we can real-time data, the data obtained can be analyzed and evaluated to ensure efficient operation of the system and obtain maximum output from it. For assessing the system'sperformance and also for timely detection of possible breakdowns of the facility monitoring of the DG system is frequently employed. This monitor could show the unusual operating condition of the system. All new or existing RE generation projects that lies within dominion of this system, the performance parameters are acquired in real time and in a centralized way which are then available for the operator to view. The system will steadily explore and connect to various other clean energies and deeply mine and analyze the data to further promotion of popularization of the developed prototype for monitoring of new energy and renewable energy in energy field.

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