Open Source SCADA System for Hybrid Power System for Francois, NL

Karankumar Patel, Dharmik K. Kachhadiya, Dhruvkumar R. Kapatel, and Mohmmad T. Iqbal

***Abstract* — A hybrid power system needs monitoring and measuring the power system parameters using a data logger. In this paper, a low-cost, open-source Arduino- based data logger is designed. The formation of voltage and current of the solar-diesel generator, along with the battery storage system that the proposed data logger records, will be analyzed and determined. The open-source platform and remote terminal unit will display the result. The design can illustrate how much energy Francois uses, and how much energy is produced by various sources.**

***Keywords* — Data Logger, Hybrid System, SCADA, Open-Source.**

I. Introduction

The hybrid power system consists of multiple energy-generating units such as wind-solar, solar-diesel-electric, and wind-diesel power. Also in hybrid energy source, it consists of an energy storage facility. Hybrid energy sources may have many benefits, of which the major is the less costly power system; as the load demand increases. So, making hybrid energy systems on existing energy infrastructure helps reduce the cost of making new power plants and reduces environmental impacts.

In this research work, we designed a Hybrid power system for the location Francois located in NL, Canada. For the system sizing, the load data is gathered from NL Hydro. Also, analyzing the geographical information of the location, we decided to consider suitable sources for the location, which are Solar PV, Diesel generators, and battery systems, as backup options for hybrid systems.

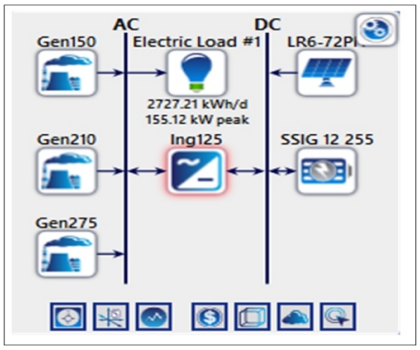

Fig. 1. Hybrid power system for Francois.

Fig. 1 demonstrates the proposed hybrid system for the Francois location, where three generators supply the energy demand whenever required. Along with system sizing, the dynamic simulation of the hybrid power system is carried out in MATLAB Simulink [1]. However, the power generation from the various generation resources needs to be controlled. For which a data monitoring system is required, it also consists of data logger, which is typically a microprocessor device. It processes the signals measured from the sensors it a processes signals such as voltage, temperature, light, and other physical entities, to analyze the system. It can be used for several purposes, such as controlling and diagnostics the system it also has a feature of storing the data at a specific location. Along with it, system monitoring is also essential to determine the power generation from the different sources to supply the load with a reliable and consistent SCADA system is also proposed in Fig. 2 shows a block diagram of data logger.

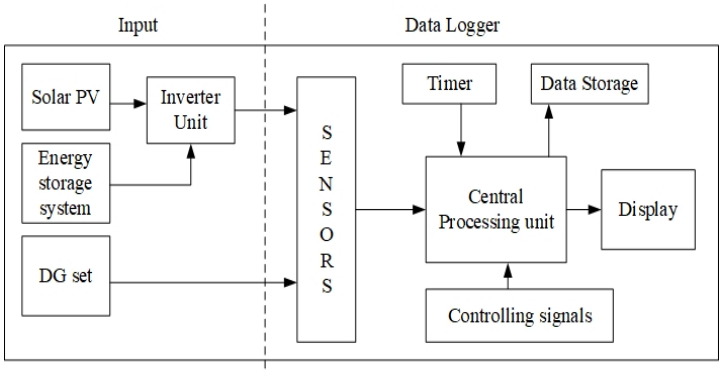

Fig. 2. Block Diagram of data logger [1].

II. Literature Review

One of the significant reasons that power plants associated with renewable sources work poorly is the size of a renewable energy power plant that is planned to use less reliable data from its energy sources [1]. At this point, a data logger comes into action, which is a piece of electronic equipment that can accurately record the formation of data and the essential thing to have in a hybrid power system Another purposed data logger is shown in Fig. 3.

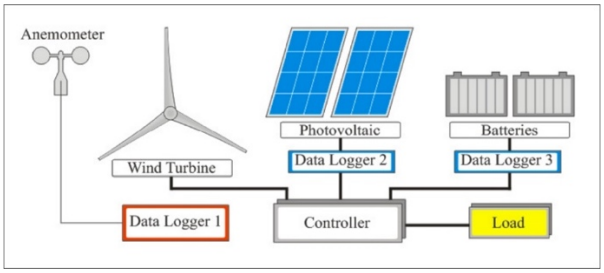

Fig. 3. Schematic of data logger [2].

Submitted on December 18, 2022.
Published on June 19, 2023.
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The data logger can be installed at each source point to measure input quantities and can be visualized by a data acquisition system for data analysis of the hybrid power system [2]. While considering the flow chart in Fig. 4, the result of the experiment determined that the average LCOE of the system is lower after resizing than before resizing the hybrid system and only needs 520 Ah capacity of battery storage, consisting of two quantities [2]. Another study has been carried out to demonstrate the difference between commercial and Arduino-based data loggers for a photovoltaic monitoring system that is performed on a small 240-watt PV system. The result illustrated that the percentage error for output voltage and current of battery and inverter by comparing the average data taken from both data loggers is 0% to 1.4% [3].

The storage limitation in the data logger is considered a primary issue while developing a data logger. Many schoolers proposed a data logger design containing multiple memory cards. It was discovered that the file saved on the SD card produced a size of 2.78MB for 24-hour logging [4]. As a result, a 4GB SD card has a maximum storage capacity of 31079 hours, equal to 1294 days. By setting the logging time and sampling time to 1 second and employing four analog sensors, this amount of data may be stored for roughly three years [4]. Thus, using two SD cards, the data logger may record data for six years without supervision [4]. With the assistance of Solar monitoring ltd. and the Faculty of Engineering of the Czech University of Life Sciences Prague, Beránek, *et al.* [5] demonstrated a novel monitoring system, named Solarman 2.0, with third generation software for photovoltaic arrays. Operators of big photovoltaic arrays will benefit from the increased number of input lines, particularly the service log, automatic error reports, and their precise localization. It is also advantageous to gather more data from other power plant components [5].

A new data logger based on the Arduino open-source electronic platform has been created to address the current issue of low-cost monitoring of photovoltaic (PV) systems, particularly in remote areas or regions of developing countries shown in Fig. 5. As a result, in comparison to the other available options, Arduino stands out due to the simplicity of its hardware and software. The Arduino UNO is a basic microcontroller with a price comparable to the least expensive one [6].

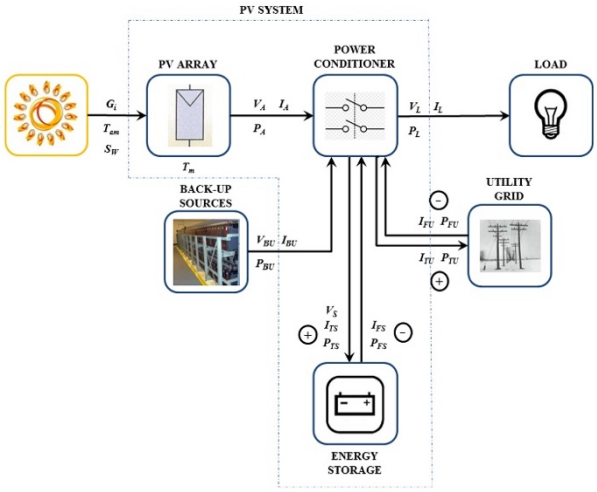

Fig. 4. Real-time parameters for photovoltaic system [6].

Results from the four-month testing period showed that the new Arduino data logger monitored and recorded the data correctly for the entire period of 123 days, in contrast to the commercial system that monitors both the weather station and the PV installation at the test facilities in the University of Jaén, which was either out of commission or having issues with the data acquisition for ten days during the four months [6]. Storm-related power outages caused issues with the commercial system, forcing the technicians to initialize the software and perform maintenance because the Arduino data logger is built to restart on its following power outages, the data did not alter [6] Fig. 6 shows the pin layout of the arduino.

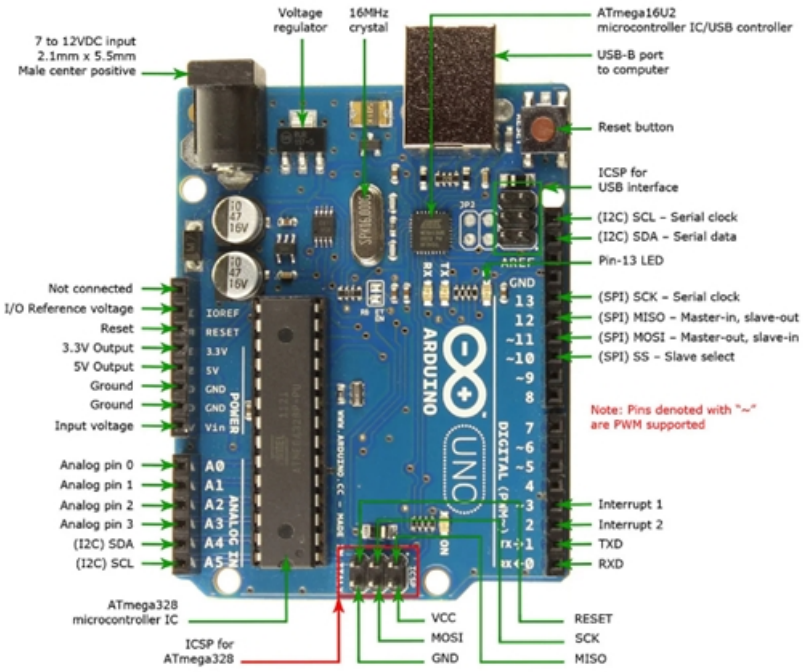

Fig. 5. Pin description of Arduino [7].

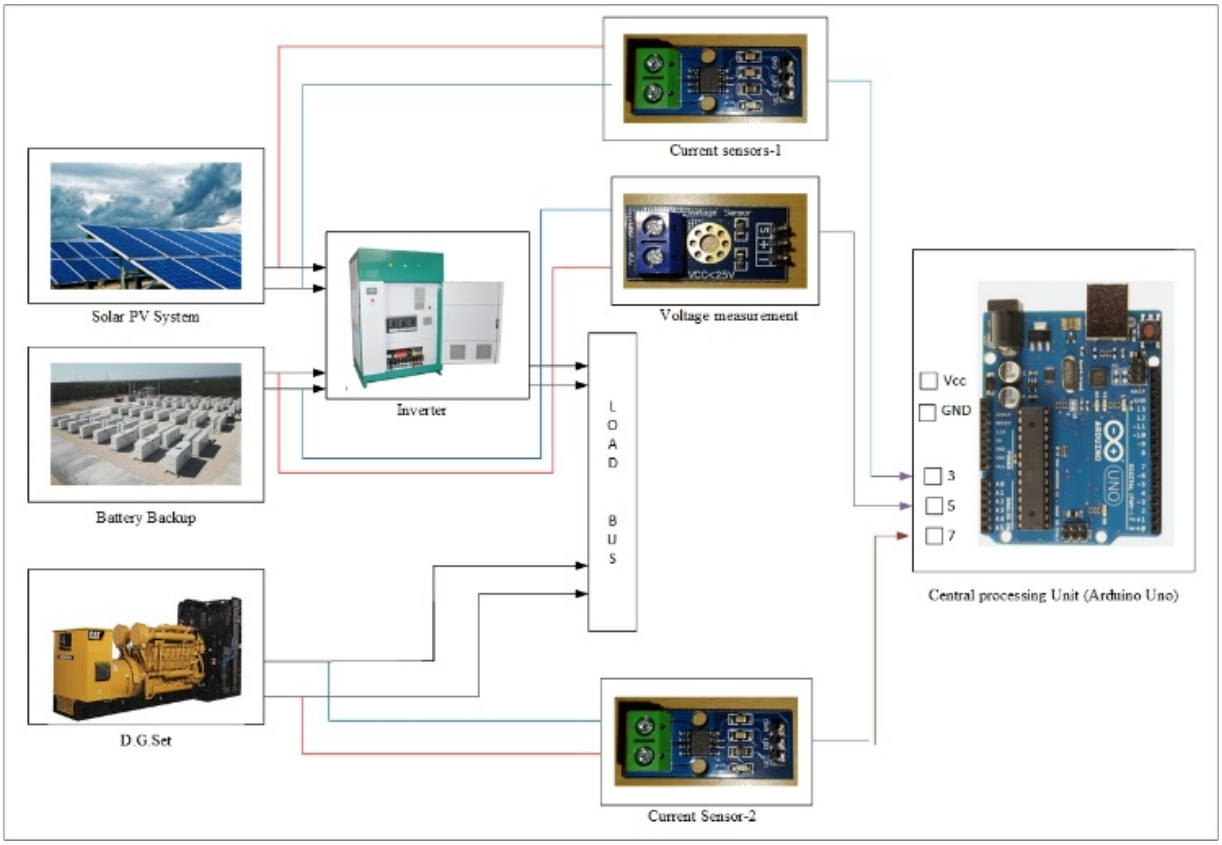

Fig. 6. Circuit layout of data logger [9].

III. Design of Data Logger

In order to design a data logger, the significant component is the processing unit in which microprocessor-based circuits are used to execute the program to provide functionality [7]. In this research, we are designing the data logger to measure the energy analysis of the hybrid power system. There are many commercial data acquisition systems with sensors to measure values and log the data. Every data logger has different data acquisition, and its design is kept a secret due to the manufacturer's policy. We design an Atmega328P microcontroller IC; however, it also consists of other components, such as a crystal oscillator and voltage regulator, along with one digital and output port for serial communication [7].

For the hybrid power system, ACS712 hall effect base sensors are required to measure current in Solar PV system, Battery backup, and diesel generator, and one voltage sensor is required to place in battery bank to measure the state of charge [7].

Data logger requires sensors to measure the physical quantity. Also, it consists of 2 × 16 LCD, which is used by the PCI18F450 microcontroller to present processed data [9]. The storage module Atsamd21G18 helps store the data directly and save it to a separate file on an SD card which can be further transferred to the computer for further system analysis [9]. The data is recorded with the headers as per the connection between the serial monitor and the computer [9].

The current sensor is connected to the series with the supply delivered to the load bus as the hybrid power system consists of three different power supply sources, including the energy storage facility. For which the hall sensor-based current sensor is useful; it can generate the ac voltage signal proposal to the measured value of the supply current [9].

The output signal generated from the current is converted to the DC with the help of a converter; the IC AD737 is helpful for it; also, an amplifier is used to convert the signal between the ranges of 0-5 Volt [9]. Three current sensors are required as the power supplies from Solar PV, Diesel generator, and Battery storage system as shown in Fig. 6.

Arduino is used as a processor in the data logger, which is the most crucial element in the system. To program Arduino requires sketching a program written and uploading it.

The ACS 712 is a hall effect-based current measurement sensor; it has iterated low-resistance current conductor with 2.1 KV RMS voltage isolation [10]. It has a bandwidth of 80 kHz, capable of filtering out low-noise signals with minimum magnetic loss [10]. The IC can offer stable output, and the total error in the measurement is 1.5% with a temperature change of 25 °C [10]. It works as the current flows through it, the sensors detect the magnetic field generated in it, and it is proposed to flow through the line used for the measurement. For the data logger design, we require three current sensors for the hybrid power system; one is used for all the sources of the hybrid power system.

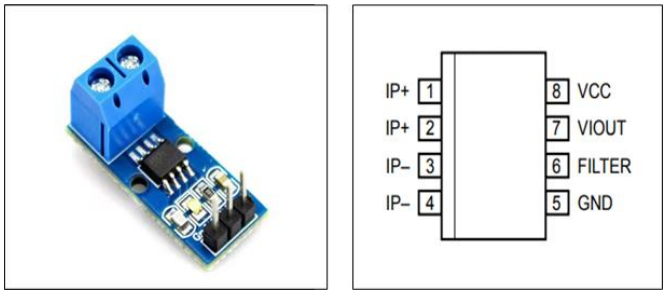

Fig. 7. ACS 712 Current sensor design [11].

For the current sensor, the measuring values vary continuously, due to which the accuracy of measurement affects after continuous usage of it in which the sensitivity of the sensor changes with or change of flow of current in the primary system. Along with the change in measuring value, some noise and other such disturbances will affect the performance of the sensors; it has an inbuilt amplifier it provides noise reduction and filtration from unwanted noise, which reduces the non-linearity in output.

For the voltage measurement in a hybrid power system, the requirement is to log the voltage level of the battery system of the energy storage facility. The Arduino is capable of processing both analog and digital signals for the hybrid power system; it mainly requires in the energy storage system for battery banks in which the voltage level of the storage system fluctuates because of its charging and discharging. Arduino consists of an inbuilt analog-to-digital converter. It works according to the analog signal sent from the measurement equipment, such as CT and PT, because the operating voltage of the hybrid power system is relatively higher in KV [11]. In contrast, the Arduino has a few microamperes operating range of a few voltages, 0 to 25 voltages [11]. Thus, CT send signals to the voltage sensors, and the Arduino processes the sensor's output signal. In this, the linearity plays a vital role as the number of stages for signal conversation takes place in the linearity between the change in its output concerning fluctuation in system parameters. The voltage sensors are based on two types based on capacitors or registers, according to the requirement of the consumers, and capacity-based voltage sensors are used for higher ranges. In contrast, for accuracy, resisters are used [11].

The voltage sensor consists of a voltage divider; it has two discrete resisters the voltage signal for CT is applied to it and the values of the resistors depend upon the operating voltage of the system; it can be from a few kilo ohms to 30-kilo ohms [12]. The accuracy of the measurement system depends upon the voltage drop between the connecting cables and the losses in components; it is around 80-90% [12].

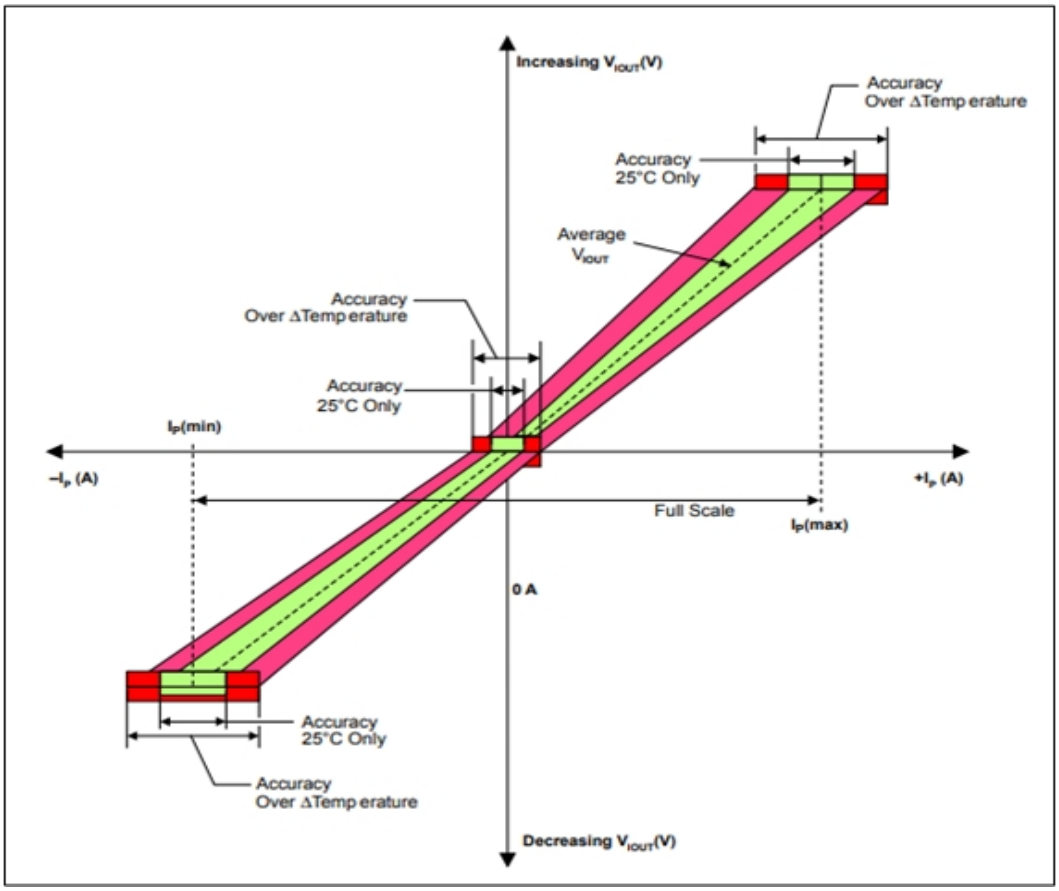

Fig. 8. Characteristics of ACS72 current sensor [11].

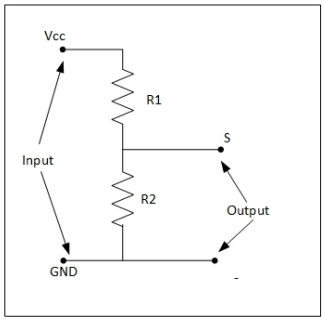

Fig. 9. Resister based voltage sensor [12].

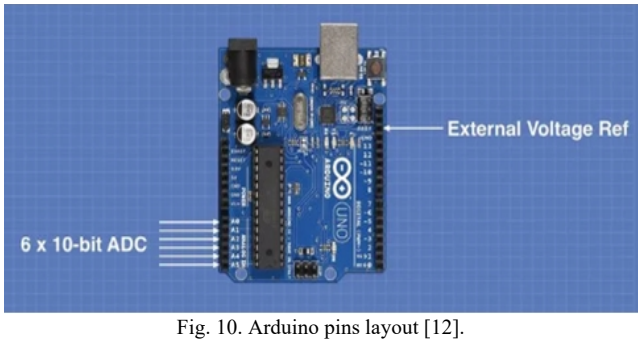

Fig. 10. Arduino pins layout [12].

For the voltage measurement, the connection of the sensor requires a reference value, a power supply voltage of 5 volts [12]. Additionally, the barrel connector is helpful for the liner regulator; it gives accuracy for the functioning; 6 pins of 10 bits are used for ADCs [12] as shown in Fig. 11.

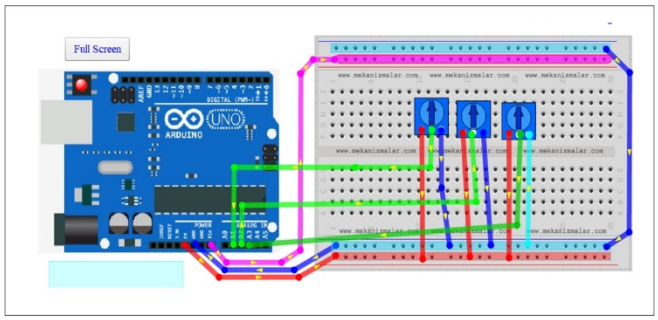

Fig. 11. Circuit layout of data logger.

IV. Programming of Arduino

Arduino is a programming-based device that can compile the program, and an algorithm is designed according to it [10]. In our case, the reading of sensors collects the current values from all sources of the hybrid power system. The time duration of data collection depends upon the programming and clock frequency of the selected Arduino. The data logger system requires sensors for measuring the parameters, such as the current ACS 712 sensor. For voltage measurement, a resister-based voltage divider is required for data logger design.

Designing a data logger for a hybrid power system for Francois, NL, requires three sensors to measure the system parameters. The flow of data logging is as:

1. Initialize the data bus to read data from sensors.
2. Reading data from current sensors (Solar PV, DG set), voltage sensor for Battery voltage.
3. Interface of sensors and PLX-DAQ system with Arduino.
4. Register the data with Date, Time, Solar PV, DG set, and Battery Voltage.
5. Store data in Excel Sheet running in PLX-DAQ system running on device.

Constructing a data logger requires step-by-step programming according to system and data specific. In our case, the sensors will measure the values of current and voltage irrespective of the source and log it with the date and time for which the programming of Arduino is followed as: the first step is maintaining data in track with time, for which the microcontroller has an inbuilt clock frequency. However, it requires the logging date and time to keep the record of data. For the analysis, the span of two days is taken, and the time between two readings is an hour is selected; however, the Arduino can measure two minutes difference initialization steps are shown in Fig. 13.

In the second stage, three sensors are required to measure the input values for each source of the power system, for which there is a total of 7 digital input pins in Arduino; to receive the signal from sensors, our system requires three pins to send signals to Arduino and pin number 3,5, and 7 are used for each sensor.

In step three, further, to initiate the data logger, it can be done by instructing to read the data from sensors; it can be 8-bit data that the microcontroller unit of the Arduino processes. However, Arduino has a default library with specific commands that can help log the data received from the sensors.

After programming the Arduino to process the data received from the sensors to organize the data, Arduino contains a memory unit to store the output data for which there are several ways to register data, which for industrial bases, can be dependent upon manufacturers and consumers requirement among of in general RTC module DS323 SD card module are used then file generated from the data logger is used for the analysis purpose for our case PLX-DAQ which is parallax Data Acquisition tool it is a software which can be sink on the Microsoft Excel with its 26 channel data bus to create a spreadsheet it can plot a data sheet from the serial communication with the sensors and microcontroller for our case the Arduino Uno is connected with sensors and the measured values which is an output of the microcontroller is useful. The PLX-Data acquisition system can register 26-column data in real time, which is helpful for the analysis of the performance of the hybrid power system measures the different values with the help of sensors and process the measured value to develop a report. With the Arduino, the PLX-DAQ system is used to organize the number of measured values concerning time in a datasheet format which can be helpful for the performance analysis of the hybrid power system the interface of PLX DAQ system is shown in Fig. 12.

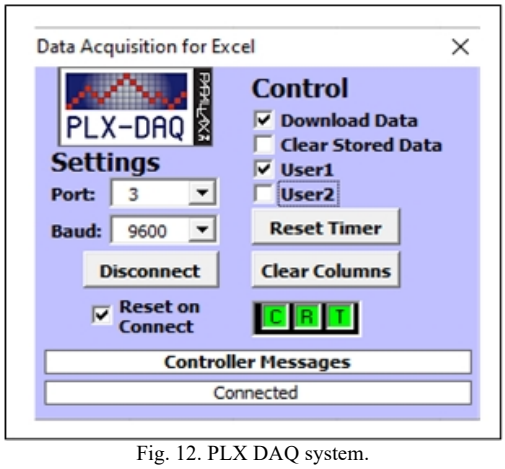

Fig. 12. PLX DAQ system.

V. Result and Discussion

For the Hybrid power system, the design of the data logger based on Arduino is a software-based application that gives a platform to the custom design of the microprocessor-based system to perform the simulation.

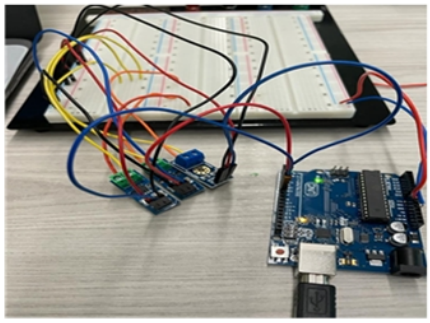

Fig. 13. Execution of the programming.

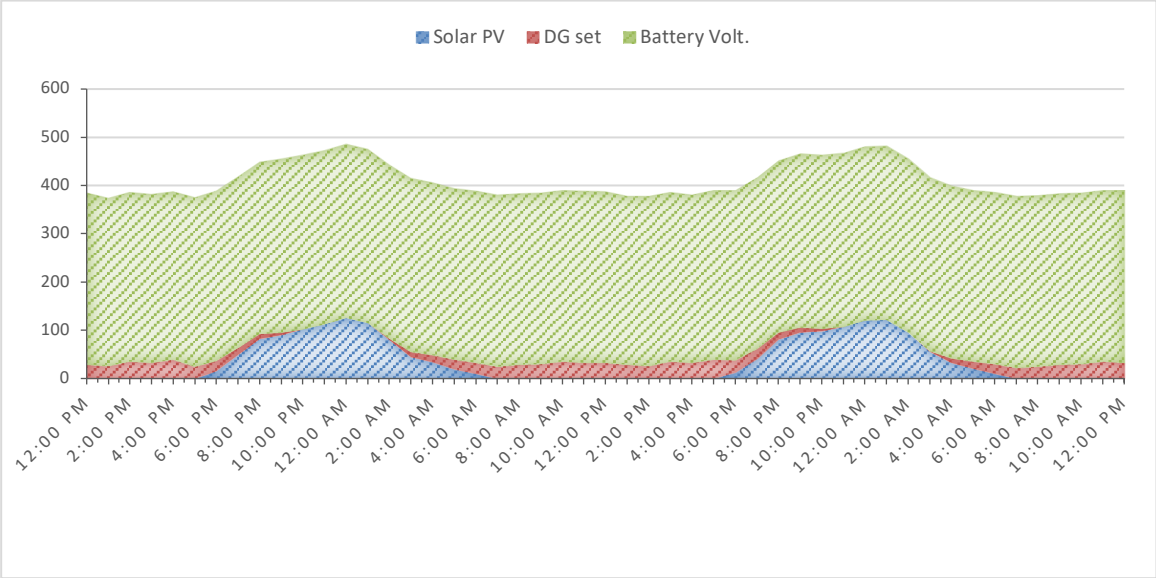

Fig. 14. Output of PLX-DAQ System.

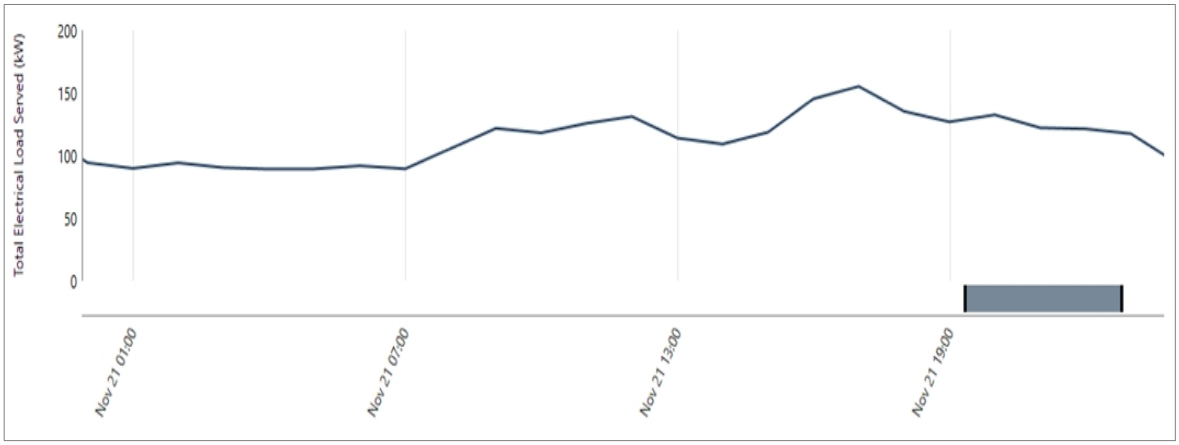

Fig. 15. Load served and unmeant load data.

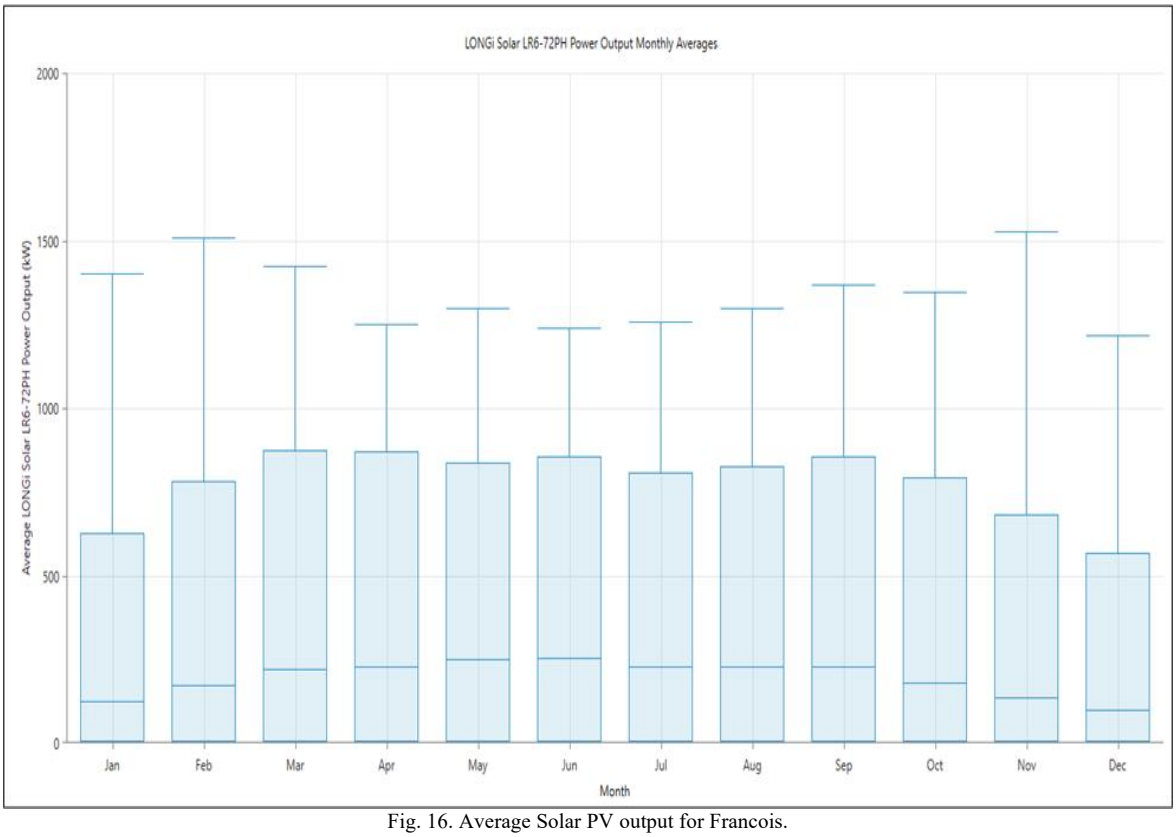

Fig. 16. Average Solar PV output for Francois.

For Hybrid power system, system availability is essential. For it average of the active and inactive time of the all the sources are taken for our case solar PV generation is not remain same throughout the day it varies according to the available solar irradiation throughout the year. Whereas for the D.G. set and battery backup system the availability of the supply is assumed for 24 hours.

Furthermore, in a hybrid power system, throughout the time of supplying power to the load, there is a certain period in which the system cannot serve the load demand. However, having appropriate supply distribution from all sources of the hybrid power system, the unmeant load time can be reduced; the graph below shows the load served between two days.

$$Hybrid\ power\ system\ availability\ =\ MTTF/(MTTF + MTTR) \quad (1)$$

From (1), the system performance can be determined, by installing the hybrid power system, the load served by it will be capable of fulfilling the load demand through time. In which MTTF is the mean time to failure to restore the supply. Also, for battery backup system it is depends upon the state of charge from it the availability. However, there is a small-time frame in which the transition between two sources will take places in which the unmeant load demand can be seen it can occur due to between transition of solar PV to DG set to supply the load demand mean while throughout the daytime solar PV system with Battery backup system is capable of supplying to the load demand.

Overall, for the analysis purpose span of two day are taken in which each day solar PV system is availability is 13-12 hours, and the D.G. set is available throughout the day but the load demand is supplied through solar PV and Battery backup system due to which power generation from D.G. set is minimum. Whereas the state of charge for the battery backup system can be seen in Fig. 16.

According to the programming, the data file generated is used to analyze the hybrid power system performance. In these cases, the data file generated is accessible only to the system which is connected with the Arduino, but in advance data loggers available in the market from different manufacturers can exceed the data file from remote devices; in this case, the Arduino is connected with the online servers from which the data file of the Arduino is uploaded with using internet connectivity However it depends upon the manufacturers designing and consumers requirement. However, it can be helpful to analyze the system performance from a remote location and transfer the data to another place.

Fig. 17. Data logger results connected with server.

VI. Conclusion

The solar PV, Diesel generator, and battery system are the sources of the hybrid power system, which fulfills the load demand continuously; however, the power system's analyses and comparing the sources' actual contribution are essential, and the data logger will be fruitful in it. The data accumulated from the sources can also be helpful to derive the efficiency of individual sources throughout the year, from which the effectiveness of the hybrid power system over the conventional power system is achieved. Adding to it, the information received from the data logger can help schedule the maintenance of the sources from their changes in the operation. Sinking the data logger data to online servers can act as a remote analysis of the system performance as one can access the data logger file from it the next generation of electricity from individual sources is calculated. According to the available natural resources, the hybrid power system for Francois solar is suitable for monitoring the system. The Arduino-based data logging system is a flexible design to integrate the physical system with the software.

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