

LOW COST DATA ACQUISITION FOR HYBRID POWER SYSTEM USING LAB VIEW

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Abstract

Among the various renewable energy sources wind energy has emerged as the most viable source of electrical power and is economically competitive with conventional sources. Wind energy is the by-product of solar energy, available in the form of kinetic energy of air. Combining both these natural sources of energy, an excellent hybrid system can be brought forth to tackle today's energy crisis. However stochastic nature of wind blow, lack of sunlight due to climate changes amplifies the problems while hybrid system is intended to be installed. Forecasting the weather with good tracking system for wind energy still remains a challenge nowadays. Powering smart homes to mega grids is in the hands of development and maintenance of these energy resources and hence it is essential to conserve these reserves for a better tomorrow. The condition monitoring and data logging are very important because the operation and maintenance costs are increasingly higher; the prediction and mapping of wind energy is cumbersome. A wind monitoring system is built here for various physical quantities such as wind speed, voltage, current, acoustic emissions, strain on blades, temperature developed inside the nacelle, vibration in the drive train and at last the power quality.

Index Terms—data logger, insolation, wind speed, wind anemometer, power quality

I. INTRODUCTION

Condition monitoring, estimation and data logging of various parameters in hybrid power system comprising wind driven generators and photovoltaic panels require a high-quality data acquisition techniques. Data Acquisition is the process of sampling signals by which the real time physical parameters can be measured, the resulting samples are converted into digital values that can be manipulated by a computer. Data acquisition systems abbreviated with the acronym DAS or DAQ typically convert analog waveforms into digital values for processing. Here a software tool Lab VIEW, the virtual instrumentation package has been used along with arduino software. Drastic depletion in fossil fuels, rising load demand and search for pure energy all urges to choose renewable sources. The renewable energy sources included here are wind and solar energy with addition of battery back-up.

The proposed system incorporates the design of data logging for hybrid power system. Various parameters of solar and wind sources such as current, voltage, direction of wind and speed of wind can be measured and logged into a storage device. The data logger, or data acquisition system, is used to obtain the

performance curve of wind turbines continuously. Wind speed, rotational speed of the turbine, the turbine output voltage, charging current of the battery together gives the power output of turbine are some of the fundamental parameters needed to construct a good data logger or a good data acquisition system.

This paper is organized in such a way that the Section II deals with the parameter estimation in hybrid power system; Section III describes how the performance characteristics vary according to the fluctuating wind speed which rotates the turbine. Section IV explains various circuitry used for estimating the various parameters with arduino software. Results and conclusion has been given in Section V.

II. PARAMETER ESTIMATION

The main parameters needed to build a good data acquisition system are the output voltage obtained from the wind turbine, the charging current, wind speed and the rotational speed of the wind turbine. The output voltage nearly equals the battery charging voltage combined with the charging current gives the power output of the turbine and generator combination. If the winding resistance of an alternator is known; here it is 3.2Ω , then it is easy to calculate the input power of the

wind turbine. The power available at the wind turbine can be obtained from the formula given in equation (1) as

$$P_{wind} = 0.5\rho Av_w^3 \tag{1}$$

if the swept area A in m^2 , ρ the air density and the wind speed v_w in m/s are known. The swept area is the effective area covered by the wind turbine blades. From the corresponding voltage and current measurements the input power of generator and the output power available at wind turbine, the efficiency can be found. The rotational speed of the turbine can be obtained from the frequency of the AC current from the generator. From this the tip speed ratio of the turbine can be calculated. Each pair of magnets in the alternator will produce one AC cycle, so an alternator with 12 magnets produces 6 cycles per revolution. The voltage will be held constantly near above 12V by the battery, but could rise much higher if the battery is disconnected. It is also desirable to take the frequency measurement at a low rotational speed well before charging started. The various battery output voltages and the state of charge (SoC) of battery in % are given in Table. I

Table 1 attery output voltage with its SOC

Battery output voltage(Volts)	State of Charge (%)
12.63	100
12.54	90
12.45	80
12.39	75
12.27	60
12.18	50
11.97	25
11.76	Completely discharged

III. PERFORMANCE CHARACTERISTICS/WEIBULL DISTRIBUTION CURVE

The performances characteristics of the wind turbine in terms of wind power density can be derived by noting down the wind speed in m/s at the chosen site regularly. Here the calculation and ultimate prediction of power from the wind turbine is done by careful observation on mean wind speed data on quarterly basis. i.e. the wind speed in m/s has been noted from the University website which is been daily updated from the available readings from meteorological tower.

It is highly impossible to record the data continuously varying constantly changing data. A site with an average wind speed of $5m/s$ near the meteorological tower in the university campus has been chosen and hence it is easy to obtain real time wind speed data continuously. The histogram with its normal distribution curve drawn using Matlab for various wind speed on different dates starting from 29th June'13 to 22nd September '13 is shown in Fig.1. Around 50 samples have been collected at random intervals to do the analysis.

Ultimately it is easy to predict the Weibull Distribution curve from the obtained histogram and can be drawn in Microsoft excel spread sheet. The average wind power density is found to be approximately $28.34 W/m^2$.

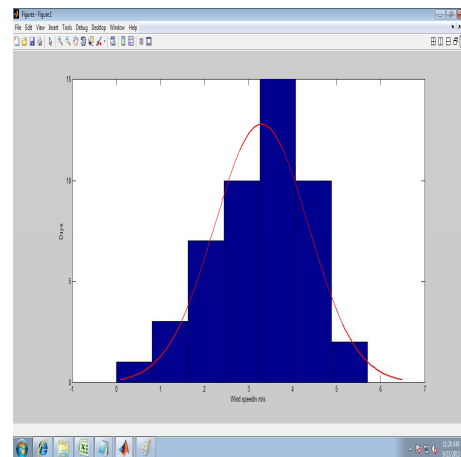


Fig.1. Histogram with its normal distribution curve

IV. USING LABVIEW/ARDUINO

The data acquisition can be well carried out either in LabVIEW environment [1] or by using Arduino. Even

though the NI device had a great resolution and sample rate, the entry cost per circuit for the complete hardware exceeds the proposed budget. Furthermore the Lab View software is rather expensive, even for student pricing. The data-acquisition card is controlled by a properly developed interface, using LabVIEW software, running on the PC. It consists of two parts first is a graphical environment with components such as displays, buttons and charts in order to provide a convenient user environment for system operator called front panel, and second is the program code, which is in block-diagram format and consists of built-in virtual instruments performing functions such as analog channel sampling, mathematical operations, file management etc.

Wind power density can be calculated for a real time data for wind speeds ranges from 1.2 m/s to 5.7 m/s can be read and the wind power density can be obtained for those windy speeds as shown in block

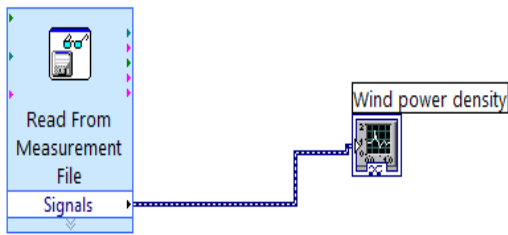


diagram Fig.2

Fig.2.Wind Power Density calculation

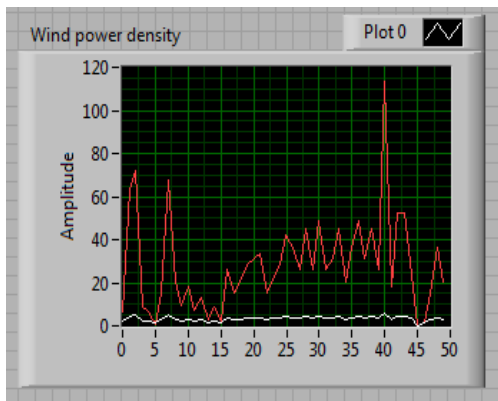


Fig.3.Wind Power Density in Front Panel

The red line in the front panel in Fig.3 shows the corresponding wind power density for the wind speeds which is depicted as white line in Lab VIEW.

Fig.4.Histogram for Wind Power Density

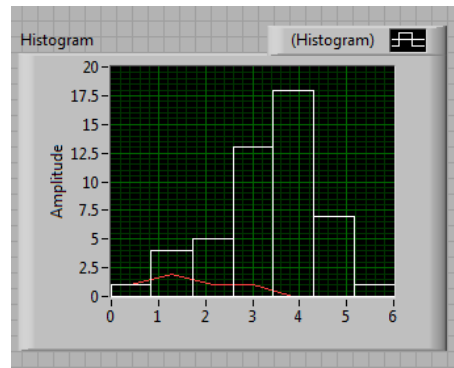
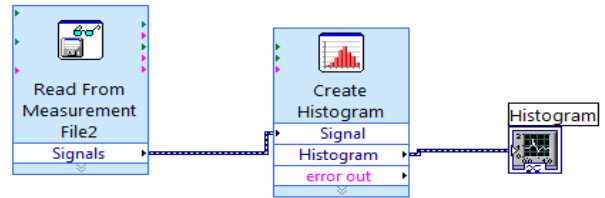


Fig.5.Histogram

With the use of Fig.4 and Fig.5, the histogram obtained in LabVIEW has been brought out. The maximum power obtained is of 113.5W/m².

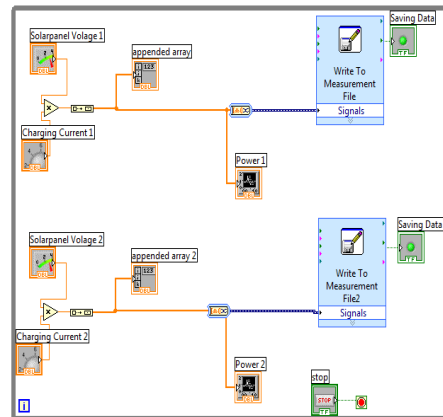


Fig.6.Block Diagram to get PV cell Characteristics

Similarly the panel open circuit voltage and the short circuit current are obtained and the corresponding readings are written in a separate file. The block

diagram in LabVIEW for these readings are shown in Fig.6

Arduino microcontroller is an easy to use yet powerful single board computer that has gained significant interest among the researchers and developers. The arduino is open-source, a reasonably priced hardware and development software. Arduino runs a simplified version of C programming language, with some extensions for accessing the hardware. Programs are created in the arduino development environment and then downloaded to the arduino board.

A data logger based on an arduino processor is used to record the wind speed and power of a wind turbine. The output voltage obtained from the wind turbine after being rectified by 3 ϕ bridge rectifier nearly equals the battery charging voltage fluctuating between 12.63 V to 11.76V. But the operating voltage of arduino board Atmel ATmega328 microcontroller is simply 5V. Hence it is necessary to reduce the approximate 12 V to nearly 5 V by a suitable electronic circuit.

A simple voltage divider with a 4.8 volt zener diode across the arduino input is employed to control any over voltage. This worked not to the fullest satisfaction since zener diode did not have a clean cut off point and the voltage went off before reaching 4.8 volts. Hence a voltage divider to drop the input voltage to a low value (approx 1/28 of the input) and then MPC 6283 a rail to rail

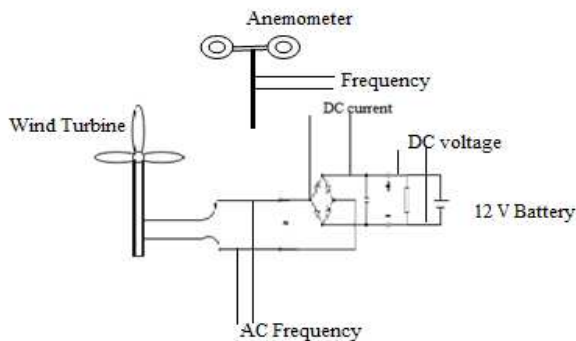


Fig.7.Experimental Set-up

op amp is used in the current measurement to amplify the signal back to the required value.

Fig.7.depicts the whole experimental set-up which measures the ac frequency, dc current and dc voltage for various wind speeds can be continuously had from the handmade anemometer. When the input voltage goes out of range the op amp is saturated but the voltage into the ADC does not exceed 5V. The Arduino's ADC and digital ports are based on a 0 to 5V input range. The depicted figures from Fig.8 to Fig.11 show all the possible circuits to find dc voltage, dc current and wind speed respectively.

The sensor signals filtered first and are fed to the PC after amplification by precision electronic circuits through the data card [2].

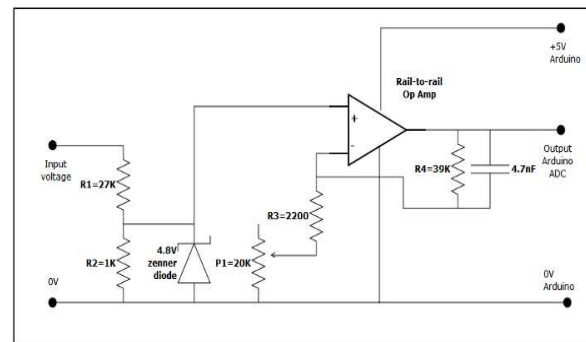


Fig.8.Circuit for voltage measurement

Here the voltage divider R1 and R2 reduces the input voltage by 1/28. If the typical range was 0-20 V the voltage divider would be less than 1 volt. It would take a voltage of $5 * 28 = 140V$ to exceed the 5V limit on the op amp and this should be protected by the zener diode anyway.

The op amp is used in non-inverting mode. The gain is calculated from $1 + (R2/(R1+P1))$. This gives a gain of $1 + (39000/2200) = 18.7$ to $1 + (39000/22200) = 2.7$ with a potential input voltage range of 7.5V to 51.8V. When the input voltage goes out of range the op amp is saturated but the voltage into the ADC does not exceed

5V. The Arduino's ADC and digital ports are based on a 0 to 5V input range.

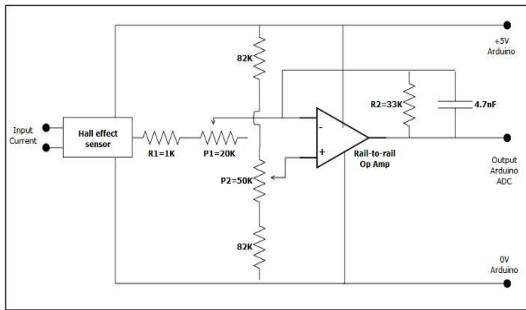


Fig.9. Circuit for current measurement

Fig.4 shows the circuit used for current measurement. Since the built wind turbine with the two solar panels is intended to produce only limited power, a current ratings possibly will not be more than 10A. There are two methods to convert the current into 0-5V range to be adaptable for Arduino ADC.

Either by measuring the voltage drop across the shunt resistor or by selecting a suitable Hall Effect current measurement sensor, current measurement can be done. Since it is advisable to minimize the number of resistors and to isolate the Arduino board from the charging circuit, the option readily goes for the Hall Effect current measurement sensor. This has an operating range of -50A to +50A which is far greater than the range required. The sensor is measuring the DC current behind a bridge rectifier so will be used in only one direction. The output with no current flowing is half the input voltage (i.e. 2.5V).

The trimmer resistance (P1) allows adjustment of the gain of the amplifier. The gain is determined by $R2 / (R1 + P1)$ which in this case gives a range of 33 to 1.5 depending on the value of P1. The trimmer potentiometer (P2) on the voltage divider allows the zero current position to be adjusted.

The circuit used for frequency measurement in Fig.5 is a modified opto isolator level shifting switch. Here the state of the digital pin toggles between zero and one so at the diode the input is half wave rectified. The interrupt is triggered on rising (or falling) edge of

the cycle when the output from the opto isolator crosses 2.5V

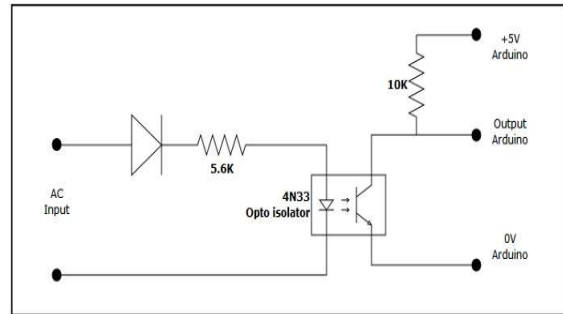


Fig.10.Circuit for frequency measurement

The calibration of wind speed is little bit harder than all other parameter estimation. Each pair of magnets produces one cycle per revolution so that the turbine frequency is obtained by multiplying the ac frequency with 2 and divide by the total number of magnets. As the wind power is proportional to the wind speed cubed so a small error in the wind speed has a large effect on the power and efficiency calculations [3].

Alternatively a small handmade anemometer is used to note down the wind speed continuously. The axis of rotation of the turbine hub is along with batten and the cups rotate in the same speed as wind blow. The hub is balanced using a couple of G clamps. The anemometer can either be fitted on the tower and the wire from it passes down the centre of the axle or handheld and can be manually operated.

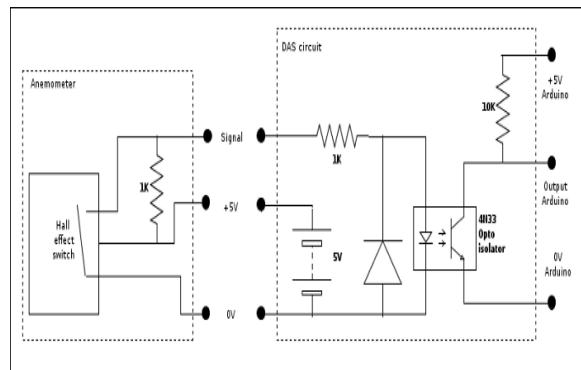


Fig.11.Calibration of wind speed

It is necessary to periodically reverse the direction of rotation to stop the anemometer cable winding up too much. It was then simple to take the alternator rotation speed data, convert it to a speed using the length of the

batten, and then plot a graph against the output from the anemometer. The data logger would not register the speed of the hub below about 30 RPM (half a rotation a second) so a shorter batten can be used to get the slow speed results. Two voltage signals from anemometer one from wind speed and another from wind direction are fed to the isolation amplifiers and the output is fed back to the Data Acquisition Board DAQ as found in the article[4]. Simultaneously two photovoltaic panels are used in conjunction with wind generator and the corresponding outputs are taken for real time analysis with the help of LabVIEW[5]

V. CONCLUSION

Thus using an Arduino-compatible board for data acquisition with LabVIEW would save a lot of money, reducing expense and also allow many other uses. A perfect solution with fast sampling speed and good resolution and a low cost data acquisition system can be arrived by the use of simple sturdy Arduino-compatible board. References cited below [6, 7] aids in bringing this paper worth in conferring the experimental values.

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