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DESIGN AND INTEGRATION OF AC/DC HYBRID MICROGRID BY IMPLEMENTING MAXIMUM POWER POINT TRACKER AND ENERGY METERING SYSTEM

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***Abstract*— Renewable energy sources are the future energy hub that developing countries are investing in. Due to ever increasing power demand of the world inefficient techniques for power extraction from these resources are not viable. Therefore, efficient methods are being developed. One Such important practical technique is Maximum Power Point Tracker (MPPT) which extracts maximum power available from PV cell or wind turbine regardless of the continuous changing conditions. Moreover, an uninterrupted reliable power supply system is the key for development of any country and satisfaction of its people. To achieve that power system must have the flexibility of drawing out power from more than one supply. In addition, it must provide a backup storage system which takes over in case the main supply is interrupted. This paper introduces such uninterrupted hybrid power system using MPPT technique for the PV cell and wind turbine along with energy metering system to monitor the input and output parameters such as voltage, current, output power and the power factor.**

***Index Terms*— Energy Management System, Maximum power point tracking, Micro grid, PV Cell.**

I. INTRODUCTION

The knowledge that conventional energy resources (fossil fuels, gas, petroleum) are fast depleting and increasing concern of environmental damage these traditional resources generate, calls for immediate measures which are being taken to switch towards clean and green energy. Prevalent green energy exploited in power generation comprises: solar, wind, geothermal, biomass and tidal [1]. The latest trend of renewable energy development is a combination of distributed power sources and energy storage subsystems to configure a small micro-grid [2], [3]. As notified in an international energy agency report on world energy investment in 2017, the United States, Europe, China, Russia, India, and South Africa have invested a substantial amount to employ renewable energies in contrast to other countries [4].

Similarly, as per the international energy investment report [5], many nations have begun spending much in solar and wind comparatively than other renewable energy resources. As indicated in international report, widely promoted renewable energy resources are that of solar energy and wind energy. The graph in figure 1.1 displays the trend of renewable energy resources in different countries.

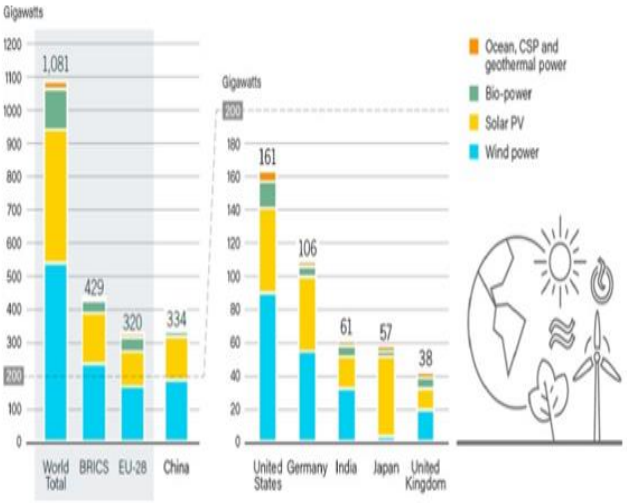

Fig. 1.1 Top countries' total renewable generation to the end of 2017 [6]

Micro grids are further sub-classified into three categories: DC, AC, and hybrid [7]. AC micro grid have an advantage of directly using power incoming from WAPDA. Notwithstanding, it requires complicated controllers for the purpose of synchronization with WAPDA and maintaining stability. In contrast, DC micro grid is immune to this particular problem. Also, myriad of commercial appliances require DC power owing to their electronics nature. Thereby, hybrid micro grid is developed to utilize both types in tandem to fulfill DC as well as AC loads requirements.

In hybrid micro grid for extracting the energy, PV cell for solar energy and wind turbine for wind energy are being used. To store the energy available batteries are utilized. Dry batteries are most compatible for PV cell thus for our system

we make use of dry battery for storage purpose and backing up the main power supply. In our country Pakistan the WAPDA supplies the electric power to consumers but due to its unreliability because of the load shedding and other factors, power failure occurs. It is unwanted situation for the consumers especially where continuous supply of power is must case scenario. Also, supplying power from grid to remote areas in Pakistan is uneconomical. Thereby, convenient system is developed in which electricity is generated and utilized in same area. This is achieved by generating DC power from solar and wind energy and then converting it to AC power by electronic switches for AC loads. For backup storage dry battery is used. As a result, reliability of the system is achieved. In development of green and clean energy system it is required to make use of an efficient technique to extract the maximum available power form the renewable resources. Likewise, a control technique is needed to optimize energy distribution of a micro-grid system. Accordingly, such control method is necessary for solar energy, wind power, and storage devices, such as dry batteries, to maneuver dynamic changes of the renewable energy for effective energy distribution. For the project, we have exploited solar and wind resources. The maximum power point tracker (MPPT) is prevalent control method in PV system. It effectively extorts power from the PV cell.
Additionally, buck-boost mechanism is embedded function of MPPT device used for changing the output voltage to the required value. The MPPT device also shows the voltage, current and power value to the digital screen. Figure 1.2 shows the MPPT device used for the proposed hybrid micro-grid system.

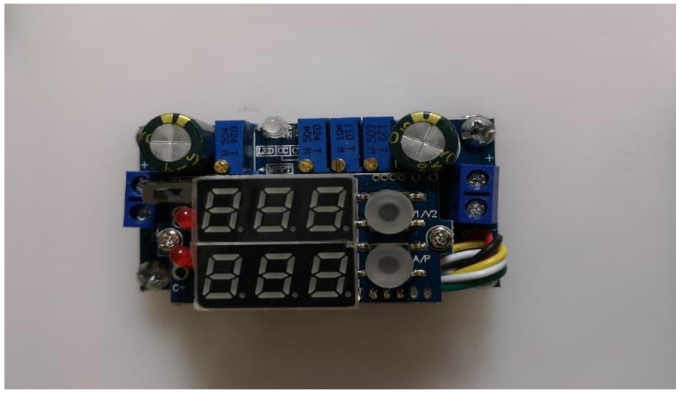

Fig. 1.2 The Maximum Power Point Tracker

Maximum power point trackers (MPPT) are connected with PV panels and wind turbines to extract maximum power. Then, it is fed into the DC bus. The DC loads are connected to the DC bus and supplied from the bus directly [8]. For AC loads the UPS kit, comprising inverter mechanism, gives signal to the power switches to change the polarity within specified period to get the AC output voltage having frequency of 50Hz. For monitoring the output parameters Energy meter in installed between ups kit output and AC loads and is programmed to show voltage, power output and power factor. Thus the system that we developed will have 3 main power sources but flexibility is provided to include more than 3 main sources. The 3 power main sources are WAPDA, PV cell and Wind turbine, for backup and storage dry battery of the ratting 18AH is used. In no-load condition battery generates 12.9V, while during on-load condition it produces 12V. The transfer of electrons from one electrode to another generates current. The open circuit voltage of the battery can be verified from the potential difference that exists between the positive and negative electrodes [9-12].

II. METHODLOGY

For understanding the idea and mechanism of micro grid the basic definition and previous researches done on this subject were studied. At first two MPPT were tested by connecting in parallel. Subsequently, power supply is provided to check its output voltage and current. The MPPT has built-in sensors to change the values of voltages to required value by buck and boost voltage function of the device. MPPT comprises DC-DC converter which reduce power loss through matching the photovoltaic panel and the load impedances by varying the duty cycle of the switch used in the converter circuit [13]. The load sharing between the two MPPTs was observed by varying the voltage levels. In accordance with the block diagram developed for the project, suitable wiring connections were done in the supervision of our professor. Upon materialization of complete hardware system, results were analyzed under different conditions and at various hours to study the behavior of developed system. Table I. shows reading of MPPT connected to solar PV cell at different time of day when different voltages are produced by PV cell.

TABLE I: Showing MPPT and Solar Panel Readings

S.no	Instantaneous timings	Solar panel (V)	MPPT (V)
1	9:00 AM	10 volts	13.6 volts
2	12:00 PM	16 volts	13.6 volts
3	3:00 PM	18 volts	13.6 volts
4	5:00 PM	9 volts	13.6 volts
5	7:00 PM	3 volts	0

As seen from the Table I. Voltages generated by the solar panel greatly varies at different times of day. The MPPT is set at 13.6V by altering its output voltage regulation sensor. As long as values of solar panel is within the range of MPPT rating that is 6V to 24V, it is programmed to always give set value at the output. This is done through bucking and boosting the voltage to get set value, which is 13.6V. Since two MPPT are being used both will share equal load. All

built-in sensors of MPPT by which parameters can be set manually can be seen in figure 2.

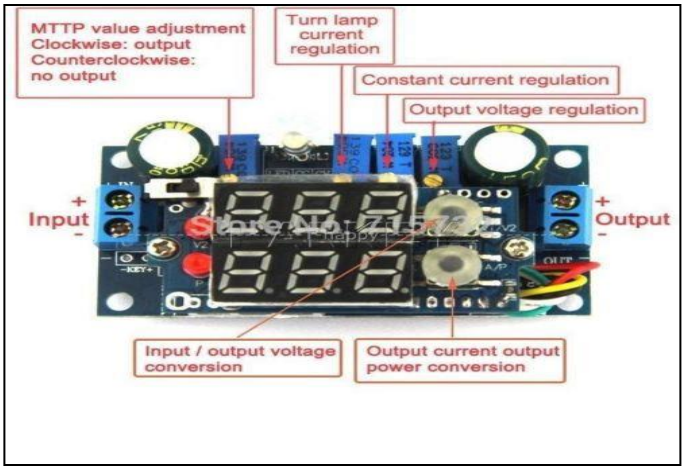

Fig. 2 MPPT manual sensors

MPPT is linked with both PV cell and wind turbine. Inherently, MPPT will extract power from the source, which produces greater voltage than others. Hence, automatically MPPT will switch over to the source, which is generating higher potential at the time of an operation.

III. System Description

The block diagram is shown in the figure.3 which shows how different parts of the system that we developed is connected with each other.

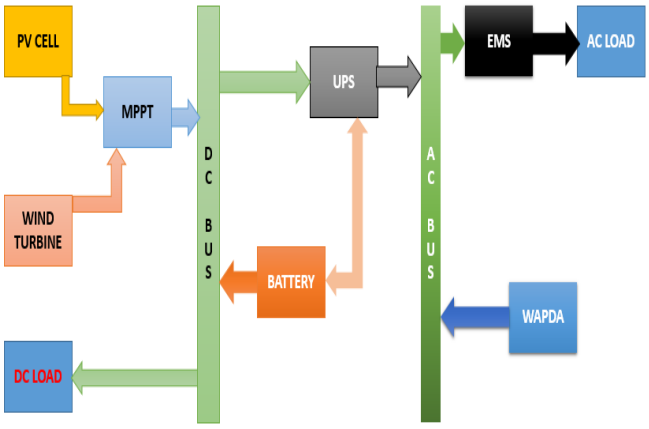

Fig. 3.1 Block diagram of developed system

The system is based upon these main components; smart grid part which includes input source via PV cell connected to two parallel MPPT DC-DC buck-boost converter which conducts the maximum power point algorithm for PV panel and sends the output to UPS kit consisting inverter for providing DC-AC conversion and by using transformer required level of voltage for the AC load is achieved, for storage purpose dry battery is used and for the monitoring the input variables Energy Metering System is developed. The DC loads are connected directly through MPPT. Battery is connected directly to DC load but for AC load it first is connected with UPS charging module which gives signal to power module electronic switches to convert to DC to AC then supplies to the AC load. The MPPT has built in monitoring system thus input output voltage current and power is digitally seen from MPPT screen. EMS is implemented in order to show the instantaneous values of voltages, currents, power factor and wattage of the AC loads. In the project, there are three main sources to supply power to the load that are WAPDA as conventional AC source, solar and wind as renewable energy sources and battery is a backup source. Battery is continuously charged while main supply is present. When failure of AC supply from WPADA occurs the power is transferred from either PV cell or wind turbine. This is decided based on the level of voltage i.e. whichever source is producing more voltage than other the power is taken form that source. Thus if PV cell is developing more voltage during day time then power is transferred from PV cell and wind turbine remains stand-by. But during night time or when clouds restrain the function of PV cell less voltages will be developed and if wind turbine generates more voltage power now will be transferred from wind turbine to the loads. When all three main supplies are unable to provide power ups kit will switch to the backup battery to provide power to the AC and DC loads. The hardware model of complete proposed system is shown in figure 4.1.

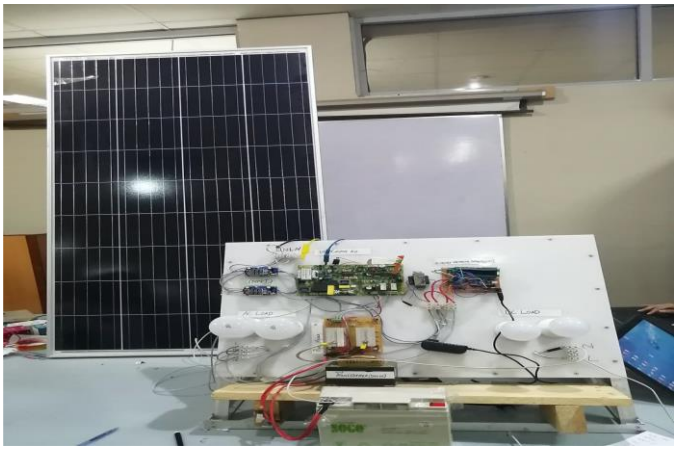

Fig. 3.2 Hardware model of the system

For indoor observation wind turbine was replaced by DC power supply for convenience. The solar panel utilized in this project is of INVERPERFECT technology company, Model Inver-150watt poly. Solar cell datasheet is presented in figure 4.2. For indoor observation wind turbine was replaced by DC power supply of for convenience.

Rated Maximum Power (Pmax)	150W
Tolerance (Tol)	0 - +3%
Voltage at Pmax (Vmp)	18.10V
Current at Pmax (Imp)	8.29A
Open-Circuit Voltage (Voc)	21.75V
Short-Circuit Current (Isc)	8.95A
Nominal Operating Cell Temperature (NOCT)	47 +- 2 °C
Maximum System Voltage	1000VDC
Maximum Series Fuse Rating	15A
Operating Temperature	-40 °C to+85 °C
Application Class	Class A
Cell Technology	Poly-Si
Weight (kg)	11.0
Dimensions (mm)	1485*666*30

Fig. 3.3 Data table of Solar Cell

IV. Energy Metering System

For monitoring the output current, voltage and power factor energy meter is developed on Vero board mainly consisting of potential transformer, LCD and Arduino Nano as shown in figure. 5.1 and its circuit diagram is demonstrated in figure 5.2. It is connected between UPS and AC loads thus digitally showing voltage, current and power factor parameters on LCD. Arduino Nano is suitably programmed to calculate and display the required parameters, the power for Arduino Nano is supplied by the DC source. Components required for its fabrication are: An Arduino (Uno used here), LCD Shield (Or LCD Screen), Acs712, current sensor, 56Ω Burden Resistor, 10µF Capacitor, 2 x 100 K Divider Resistors. Energy metering system can help enhancing the performance of the system based on continuous analysis of the concerned parameters. Similarly, prospect of theft can be greatly reduced due to continuous monitoring of any un-authorized usage. Incorporation of the EMS system with SCADA is also possible, which further modernizes the system. It regularly gathers data about energy consumption by the customers. Thereby, if demand of energy increases then different grid can supply power accordingly. Additionally, it assists the consumers to effectively use their appliances, in order to get their bill decreased.

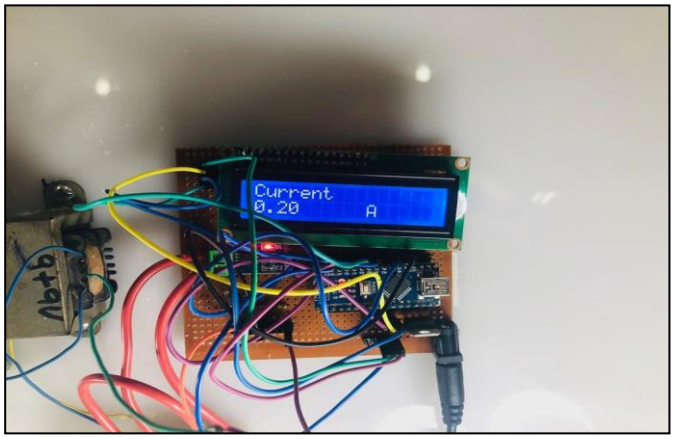

Fig. 4.1 Energy metering system

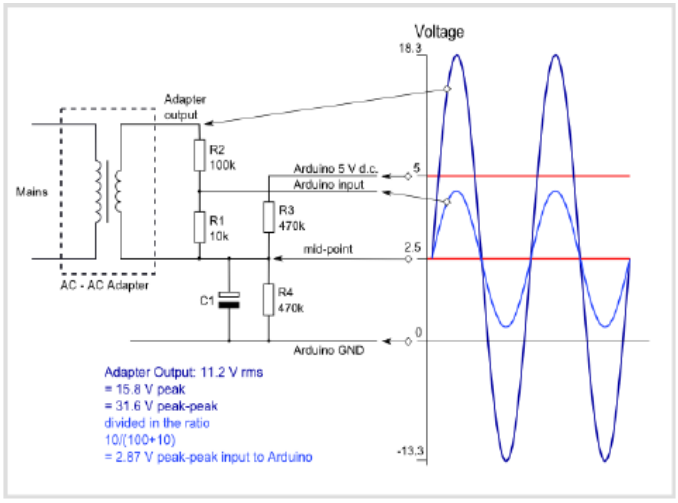

Fig. 4.2 Circuit diagram of EMS

V. Conclusion

Owing to depletion of natural resources and apparent environmental pollution caused by conventional power generation methods, entire world is gradually adopting renewable energy resources. Reliability of power supply is necessity for any prospering country. As Pakistan is a country which has several seasonal variations and the load demand is increasing due to the increase in population. Therefore, to face the immediate energy crisis power should be supplied to the consumer under every weather conditions. Continuity and uninterrupted power is the main goal of power system. Hence, power should be supplied to all the customers. In this regard, to attain undisturbed power supply, decentralized systems should be introduced, additionally with centralized power systems. Consequently, under peak load hours when the cost of consumed energy is high, DC power sources should be utilized like solar, wind etc. On the contrary, during off peak hours the power should be supplied by the main WAPDA. This will reduce the energy bills of the

customers, power theft will be decreased and ultimately load shedding will be reduced.

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