MODELLING OF MICRO GRID POWERED BY RENEWABLE ENERGY

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Abstract: This paper presents voltage control of microgrid powered by wind and solar energy. An MI Cuk converter is used to integrate the renewable energy to the main D.C bus for maintaining constant voltage. Also, high step-up switching technique was adopted on the source side to increase the output power of the converter. Battery acts as an energy storage system (ESS). Electrical energy generated by renewable energy resources are stored in the battery when the load demand is low, and it will get discharged when the load demand is high thereby maintaining the constant voltage. Maximum power Point Tracking (MPPT) technique is used in both renewable energy system for tracking the maximum power according to the variation. The proposed system was modelled and simulated using MATLAB SIMULINK environment. Hence, the output maintains constant voltage at the microgrid.

Key Words: Energy Storage System, MI CUK converter, MPPT, photovoltaic system, Wind power generating system.

1.INTRODUCTION

RECENTLY, clean energy resources such as the solar array, wind generator increases power production. In this case, the multiple-input dc–dc converter is useful to combine several input power sources whose voltage levels and/or power capacity are different and to get regulated output voltage for the load from them[1].For example, in the solar array power supply system with a commercial AC line, the maximum power point of a solar array can be easily tracked (MPPT) while simultaneously the output voltage can be easily regulated by receiving adequate power from the commercial AC line, even if the load is changed[1].

An MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load .A dc/dc converter (step up/ step down) serves the purpose of transferring maximum power from the solar PV module to the load. A dc-dc converter acts as an interface between the load and the module Fig 1 [5]. By changing the duty cycle, the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power. [2] it deals about compression of MPPT controller for different converter topologies such as buck, boost, and Cuk converter with different solar radiation changes .Among this three configurations, Cuk converter performance is better than other converters. In old power generating systems require separate converter for each and every renewable energy sources it increases the power production cost[3].But the proposed renewable energy generating system use MI DC-DC such as MI Cuk converter to connect one or more renewable energy sources the use of MI converter reduces unnecessary additional parallel converters for each energy sources. Renewable energy resources will use both normal and grid power outage time for balancing the voltage level. However, the disadvantage is that renewable energy generating system is intermittent for depending on weather conditions.

Thus, the Energy storage using Battery is used to get a stable and reliable output power which will improve the performance of whole generating system [6].So the proposed micro grid is also equipped with energy storage device, such as battery. A utility grid connection is provided in order to replenish energy level in case of power shortage from the renewable energy sources. Due to its driver’s sources, power supply availability of such system may exceed that of the grid. Power outage possibility in this power system is close to zero. The functional block diagram of proposer system is shown in Fig1.

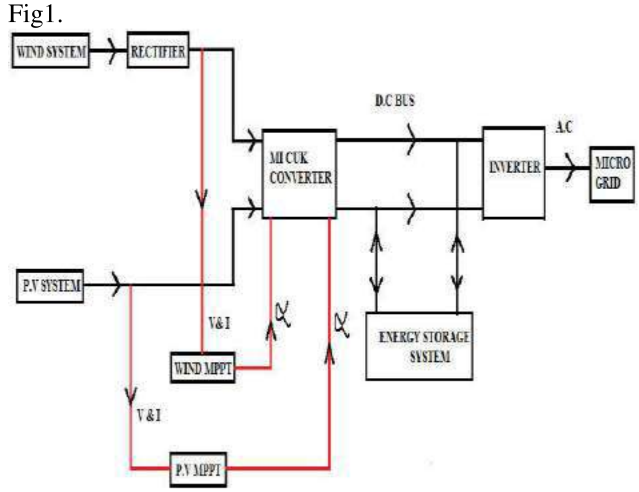

Fig 1. Block Diagram of Proposed System.

It consists of wind and photovoltaic module, MI cuk converter, MPPT, Energy storage system and inverter section. In this system inverter is controlled by using hysterics band current controller for maintaining the constant output at load side.

Perturbation and Observation method is used to track the maximum power according to variation in the input sources correspondingly it gives firing signal to the converter to obtained maximum power from it .

The main advantage of this method is easy to implemented and effective method. The paper presents detailed transient models of the grid connected hybrid system. MATLAB/Simulink Software is used to simulate the models.

2. PROPOSED MICRO GRID SYSTEM MODULES

This section explains detailed modules of wind photovoltaic, Energy storage system and MI converter module.

2.1 WIND TURBINE MODEL

Wind turbine of the proposed micro grid is driven by aerodynamic input torque. So that the wind generator rotate and generate the electrical power. In this paper we use direct driven Permanente magnet synchronic generator (PMSG) for generate the electrical power. This PMSG does not require frequent maintenance because it does not use gear between wind turbine and generator. In order to explain the wind turbine model the mechanical power capture by the wind turbine is described in equation (1), [7]

$$P_m = \frac{1}{2} C_P(\beta,\lambda)\rho\pi R^3 V_{wind}^3 \qquad (1)$$

Where C_p is rotor power co-efficient, β is blade pitch angle, λ is tip speed ratio, ρ is air density, and Vwind $_{is}$ wind speed, R radius of wind turbine. Rotor power co efficient is given in equitation (2)

$$C_P = (0.44 - 0.016\beta)\sin\frac{\pi(\lambda-2)}{13-0.3\beta} - 0.0184(\lambda-2)\beta \qquad (2)$$

Tip speed ratio can be defined as the function of wind speed. [7]

$$\lambda = \frac{W_m R}{V_{wind}} \qquad (3)$$

Torque produced by the wind turbine module is given in equitation (4).

$$T_m d = \frac{C_P(\beta,\lambda)\rho\pi R^5}{2\lambda^3}\omega_m^2 \qquad (4)$$

Simulation circuit module of wind turbine is shown in Fig 2.

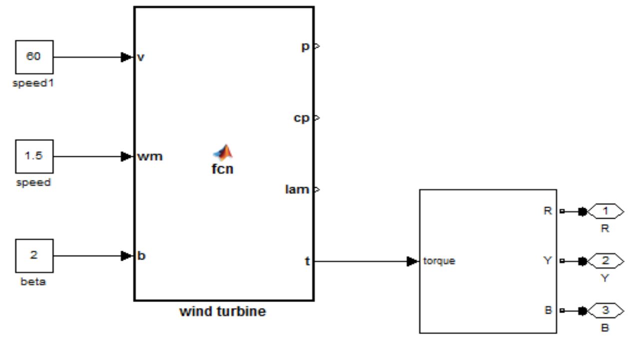

Fig 2.Wind Turbine Modelling

And the specification of the wind turbine model is given in table 1

Parameter	Value	Unit
Rated power	3.5	Kw
Rated wind speed	12	m/s
Rated rotor speed	27.54	Rad/s
Blade radius	2.5	M
Blade pitch angle	0	Degree
Air density	1.225	Kg/m^3

Tab 1 specification of wind turbine model

2.2 PHOTOVOLTAIC MODEL

P.V model used in this study is shown in Fig3 and it was proposed in [18] This P.V model is suitable for simulating practically. Which composed are composed of numerous P.V cell and it require few parameter for simulation. Such as number of P.V modules, PV array open circuit voltage and short circuit current.

Generally PV power production depending on solar radiation and temperature change. It generates maximum electrical energy during the time of cold weather and cloudy days. The detailed discussion of this PV model is given in reference [18] a reader may refer it for model derivations. Rated power of PV model is 500w. The simulated PV system configuration is an array of 5×10 models and its voltage and current at the MPP with the solar radiation of 1KW, 220v, 10.7 amps.

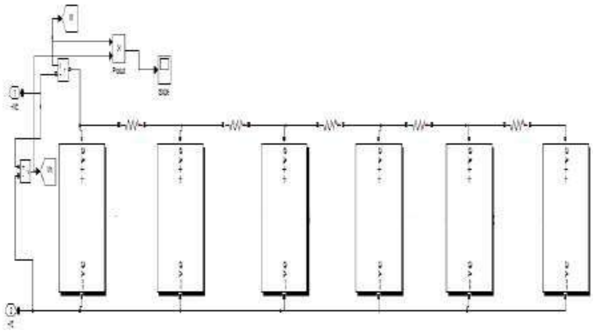

Fig 3.PV Panel Model

2.3 ENERGY STORAGE SYSTEM MODEL.

The proposed system use battery as energy storage device to store the electrical energy. However it requires a dc – dc converter for charge the extra energy and also can discharge the energy to load.

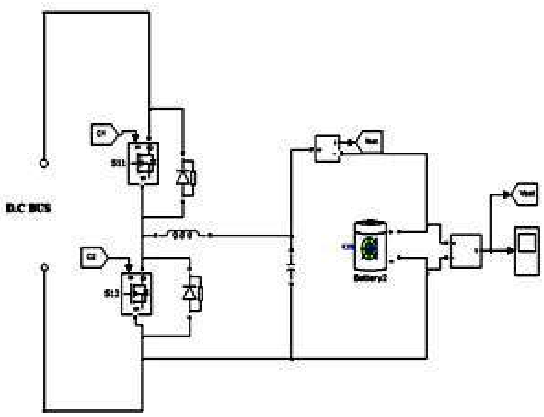

Fig 4 Battery energy storage system.

In the paper use lead acid battery to store energy and its capacity are given below 50Ah,180V ,ESS is typically connected to the dc bus through a bidirectional dc – dc converter, as shown in Fig 4. The utility grid is considered as a backup source and the battery bank serves as a short duration power source to meet the load demands which cannot be fully met by the PV System, particularly during fluctuations of the solar or transient periods.

The primary objective of the battery converter is to maintain the common dc link voltage constant. In this way, no matter the battery is charging and discharging, the voltage of the dc can be stable and thus the ripple in the capacitor voltage is much less. When charging, switch s11 is activated and the converter work as a boost circuit, otherwise, when discharging switch s12 is activated and the converter work as a buck circuit.

When the voltage at dc link is lower than the voltage reference, switch s12 is activated, when the voltage at dc link is higher than the voltage reference, switch s11 is activated.

2.4 MI CONVERTER MODEL

Among different MI converter topologies [11] a CSI MI cuk converter used in this micro grid for integrating the renewable energy sources to the micro grid. The main advantages of using this converter is not require any additional filter to remove the harmonic content percent in the output of the converter and converter simulation model is shown in Fig5.

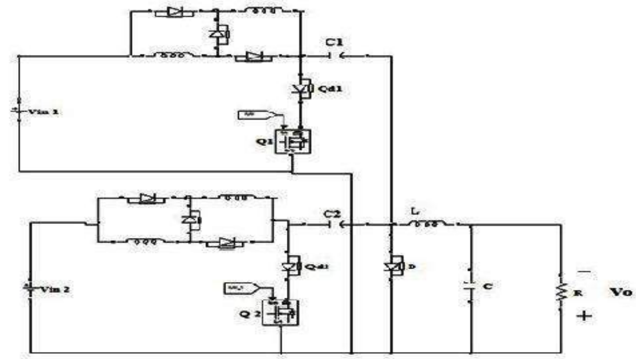

Fig 5 MI cuk converter arrangement

In this modified converter model use high step up switching concept implemented in front end of the source side to increase the output of the converter Fig 6 shows the switching diagram of the proposed converter it act under three modes.

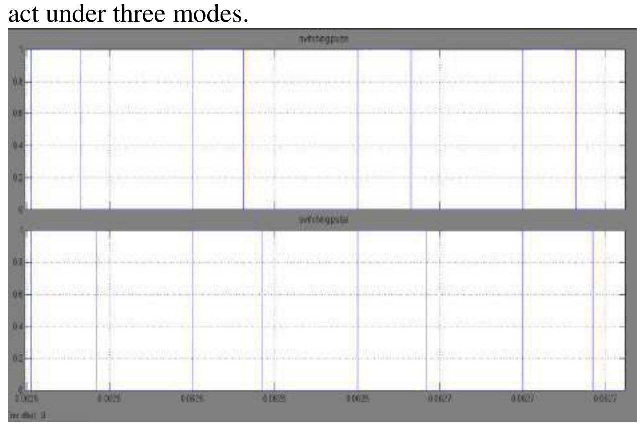

Fig 6 Switching diagram of converters

Mode1

Assume wind system output voltage (Vin1) is greater than the second source solar (Vin2). In this case both switch Q1 and Q2 are activated but only Q1 is on because Qd2 diode is reverse bias and diode D at the common output stage is also reverse bias.

Mode2

Only active switch Q2 is on and conducts current in this mode. The diode at the output stage is still reverse bias.

Mode3

All switch are turned off expect diode D. So the diode only conducts current. The output voltage equitation is given below.

$$V_0 = \frac{V_1 * D_1(1+D_1)+V_2 * D_2(1+D_2)}{1-D_2} \quad (5)$$

3 CONTROL STRATEGIES

This section deals about different control strategies of micro grid such as MPPT controller battery charging controller, and inverter control. Each and every controller is explained in the following section.

3.1 WIND TURBINE CONTROLLER

In existing system use variable speed control method is used to control the wind turbine but this paper use MPPT controller for captures the maximum power according to the variation in the input Fig 7 shows mechanical power captured by wind turbine at each rotor speed (W_m) and varies with wind speed. The optimal power line can obtain by connecting MPP at each wind speed.

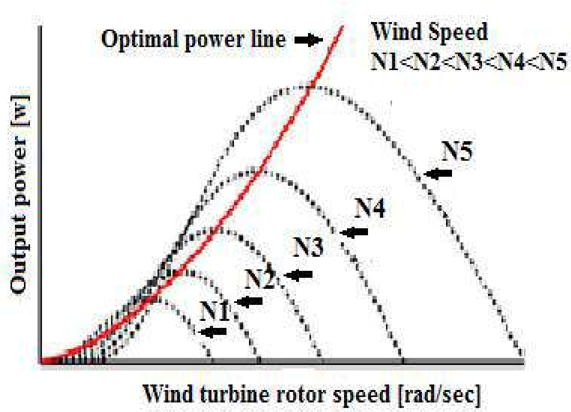

Fig 7 Characteristics of wind turbine

So maximum output power is obtained by controlling the converter switching period with different wind turbine rotor speed (W_m).optimal mechanical power of wind turbine is [4]given below.

$$P_{opt} = \frac{C_{p\max}\rho\pi R^5}{2\lambda_{opt}^3}\omega_m^3 \quad (6)$$

Wind turbine output power is converted to dc by using rectifier and the output of the rectifier is given to the converter. Real power of the rectifier is given by.

$$P_r = V_r I_r \quad (7)$$

Wind turbine MPPT controller is shown in Fig 8. It senses the output voltage and current and the product of this to power it will be compare to previews power if error is present during the time of comparison of power means again it will compare with voltage. Correspondingly the PWM pulse is generated and it will give to the converter section for generating the maximum output power.PWM pulse generation varies with wind speed.

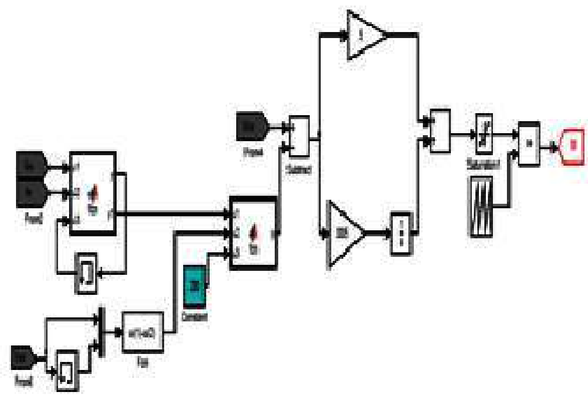

Fig 8 MPPT controller for wind

3.2 PV MODULE MPP TRACKING

Photovoltaic system is controlled with the help of MPP for obtaining maximum power from the PV model. Maximum Power Pointe Tracking aims at using some control algorithms to ensure the PV array to operate at the maximum power Pointe. There are different many different MPPT methods, perturbation and observation method (p&o) is used most widely since it is much simpler and needs fewer measured variables. P&O algorithm operates by constantly measuring the terminal voltage and current of the PV array, then constantly perturbing the voltage by adding a small disturbance, and then observing the changes of the output power to determine the next control signal. If the power increases, the perturbation will continue in the same direction in the following step, otherwise the perturbation direction will be inversed. Flow chart of MPPT is shown in Fig 9

For the P&O algorithm, if the perturbation is large, the maximum power Pointe can be tracked fast, but the accuracy is low. If the perturbation is small, the algorithm can have high accuracy, but it will cost a long time to track the maximum power Pointe in order to improve both of the tracking speed and algorithm accuracy. MPPT controller of the PV system is shown in Fig 10

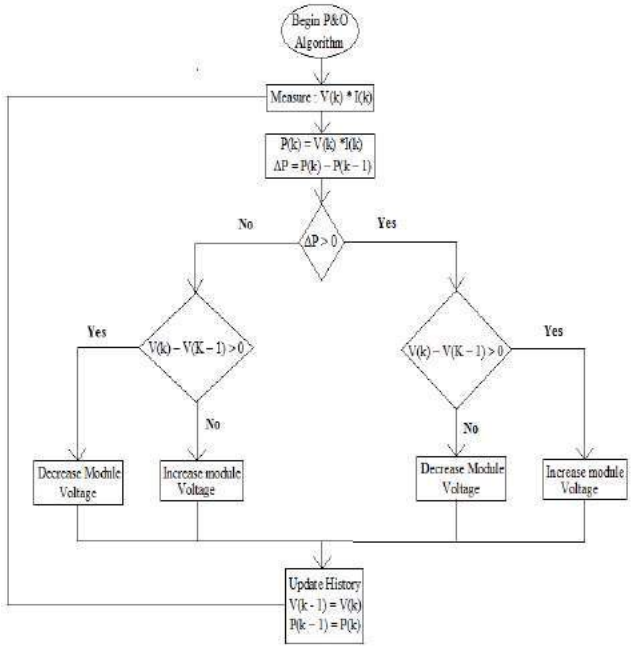

Fig 9 Flow chart for MPPT

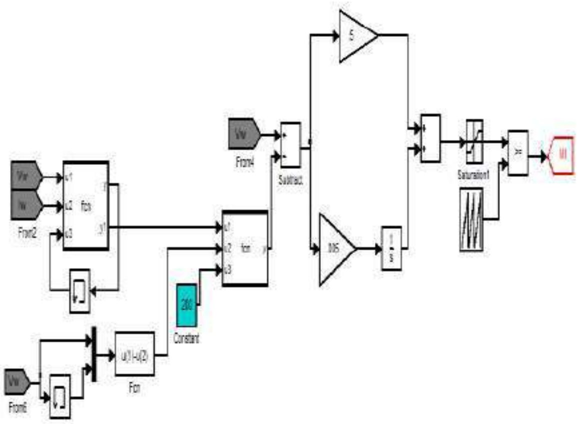

Fig 10 MPPT controller for PV

It will work same as explained in section 3.1. The main aim of the controller is to get the maximum power from the solar panel.

3.3 ENERGY STORAGE SYSTEM CONTROLLERS

Energy storage system controller use Bi–directional converter for controlling the charging and discharging of the battery it senses the dc bus voltage. if the dc bus voltage is greater than the reference voltage means c2 is on it give firing pulse to the bi directional converter in this time it act as buck mode to store the electrical energy to the battery.

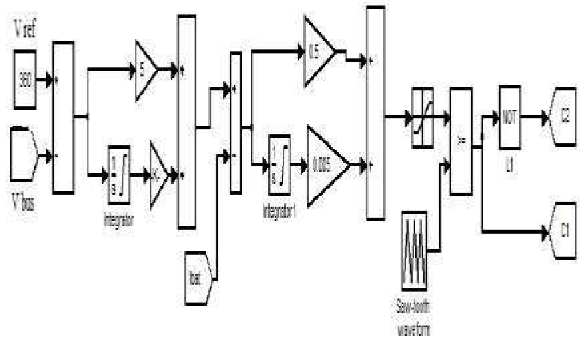

Fig 11 Energy storage system controller

The basic circuit diagram of the ESS controller is shown in Fig 11. In cause the dc bus voltage is low compare to reference value means in this time c1 switch is turn on so the bi directional converter works under the boost mode to deliver the energy to grid for maintains constant voltage at dc bus.

3.4 INVERTER CONTROLLER

Inverter controller is used to control the local A.C bus voltage and frequency in the micro grid and deliver the active power to the distribution grid. In this paper use hysterics band current controller are used to perform control action. This controller is shown in Fig 12

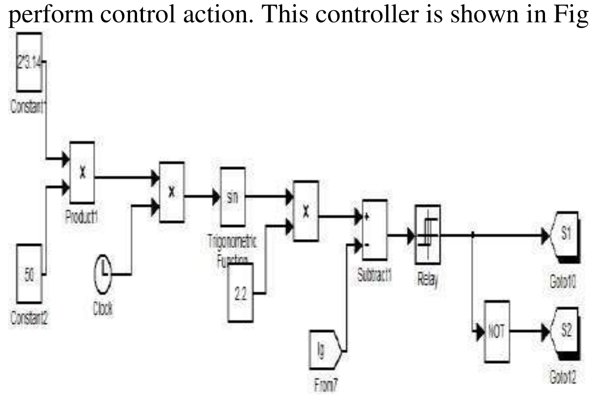

Fig 12 Inverter controller

Controller can generate the firing pulse for maintaining constant voltage at the load side.

4 RESULTS AND DISCUSSION

Overall configuration of the renewable energy generating system is shown in Fig1.the wind and photovoltaic system are modelled for generating electrical power and to reduce electrical energy demanded and also reduce global warming.

Wind turbines are modelled with the help of equ (1) – (5) and detailed specification of wind turbine module is given in table 1. Mechanical power captured by wind turbine various with respect to wind speed so the MPPT technique is used to capture the maximum power according to the variation in wind speed. Wind turbine generating torque is directly connected to the Permanente magnet synchronous generator so it will generate the electrical energy and it will connect to D.C bus through converter output power of the wind turbine is shown in Fig 13.

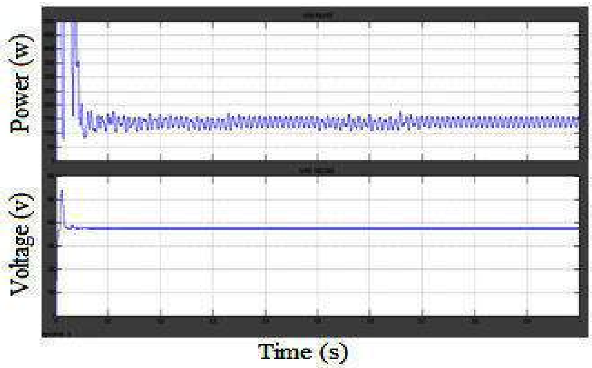

Fig 13 Voltage and power characteristics of wind system module

MPPT controller is used to change the duty cycle of the converter according to the variation in inputs. PV modules operating power points are well-followed toward the MPPs because $d_{p/}d_v$ described in (10) is almost zero even when the solar irradiance changes. This PV system controller tracks the MPPs of solar energy regardless of the rapidly changing solar radiation. Specifically, this PV system controller immediately locates the MPP since this PV system is independently controlled. Considering that the performances of this PV controller illustrated in Fig 14. and generated power are integrated to micro grid

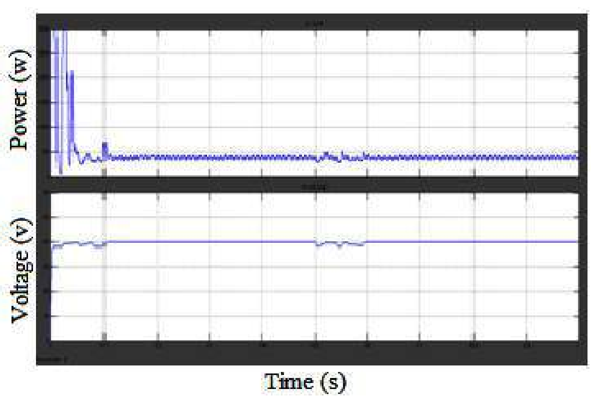

Fig 14. Voltage and Power Characteristics of PV Module.

In case the load demand is low compare to electric power generation ESS is used to store electrical energy by using bi directional converters. Operated under the buck mode and it performance characteristics are shown in Fig 15.

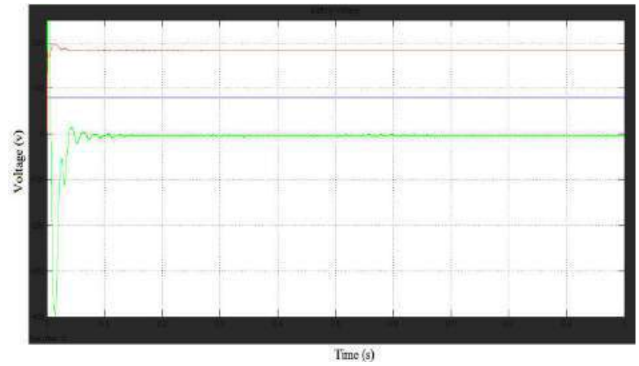

Fig 15 Battery charging characteristics

Also it will deliver power to micro grid operating under boost mode to compensate the required power level of micro grid it shown in Fig 16

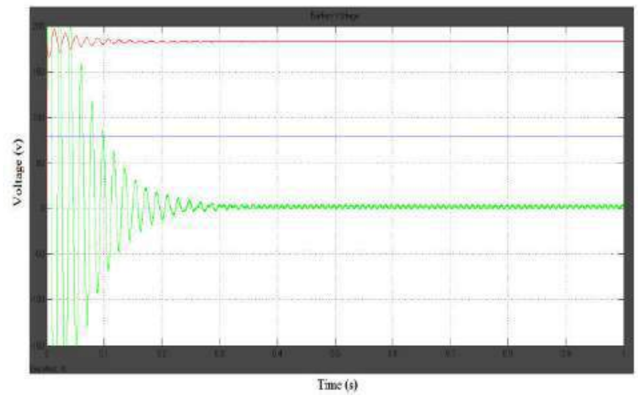

Fig 16 Battery discharging characteristics

The grid-side PWM inverter generates enough power required for the variable local ac load and dispatch power to the grid. Depict that the ESS is also well-controlled because it is discharged and regulates the main dc link voltage (Vdc) toward (Vdc low) (i.e., 370 V) when the renewable power production is insufficient compared to demand power, and vice versa. Moreover, Fig 17. shows that this micro grid inverter well regulates

The local ac voltage level of 240v and frequency in 50 Hz despite source and load power variations.

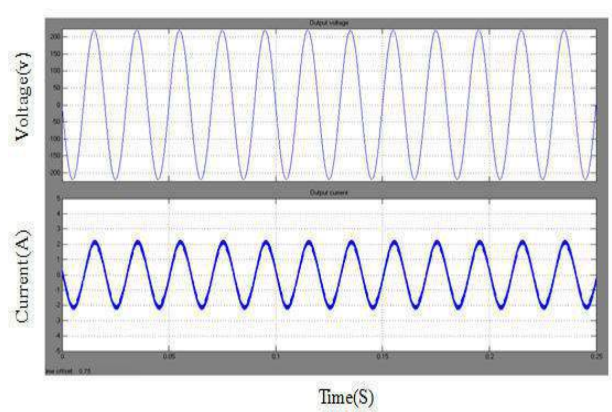

Fig 17. Performance Characteristics of Micro Grid.

The proposed micro grid was implemented by using following circuitry having power converter circuit, battery charging circuit, inverter control circuit and MPPT tracking controller. Proto type model of proposed system is shown in Fig 18.

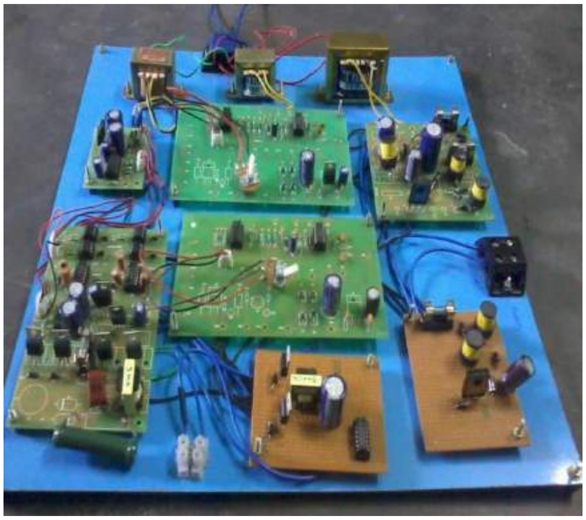

Fig 18 Hardware model

In this proto type instead of using wind system source 12 V supply act as one source and 17 V solar panel act as another sources. These two sources are connected to D.C bus through MI cuk converter.

Output of the converter is connected to grid by using inverter. So that we can get the constant output voltage and current at the grid side. The performance characteristics of hardware prototype model is shown in Fig 19. So we can get 40v at the grid side.

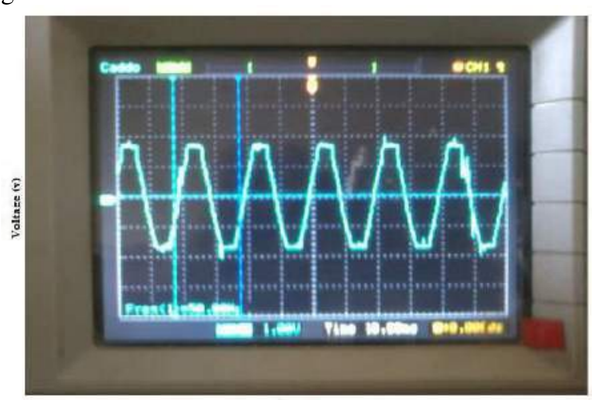

Fig 19 Output voltage waveform for hardware

VI. CONCLUSION

Thus this paper presents the dynamic modelling and operational strategy of a sustainable micro grid primarily powered by wind and solar energy. These renewable sources are integrated into the main dc bus through an MI dc-dc converter. In this proposed converter we use high step up switching concept to increase the output of the converter. Wind energy variations and rapidly changing solar irradiance were considered in order to reduce the micro grid variations. In addition, the proposed micro grid is equipped with an ESS and is connected with the distribution grid. These diverse micro-energy resources can improve the micro grid performance and reduce power generation variation and balance the power at grid side. Its power converter can also be designed in a smaller size with low production costs because MICs can remove unnecessary redundant components.

A wind/solar hybrid micro grid dynamic model was developed with MATLAB Simulink/SimPower systems. For this purpose, this paper focused on the MPP tracking of the renewable micro-energy source power variations under the local ac demand changes and the variable dispatch power to the distribution grid.

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