IJCTA, 7(2) December 2014, pp. 191-199

Power Management Scheme for Photovoltaic/Battery Hybrid System in Microgrid

[*]Sathish Kumar Shanmugam, [**]Dhivya Bharathi Sundaramurthy, [**]Ayswarya Swami Nathan and [**]Sathya Priya Natrayan

ABSTRACT

In this paper a novel strategy of power management for hybrid systems in microgrids is proposed. To improve the effectiveness of the system control strategies such as adaptive droop control technique and voltage source control has been employed in the PV/battery unit to operate as voltage source. Internal power flow management and adaptive droop control is done to maintain the grid voltage and frequency that are considered to be the main feature of power management that is employed in this paper. This scheme is proposed to share the load with other sources while charging the battery. This in turn increases the efficiency of the overall system that is used to satisfy the needs of the microgrids. The employed PV/battery unit can not only track the maximum power like MPPT (Maximum Power Point Tracking) but also supply the maximum PV power to the microgrids as long as there is sufficient load that is to be supplied with the power generated by the hybrid system. The control strategy employed is also designed to modify the operating point of PV to autonomously whenever the available PV power is higher than the load and the battery is completely charged. Moreover, the battery can operates as separate storage unit that can regulate voltage and frequency and supply deficit power to the micro grid. The various strategies employed are the PI and MPPT (Maximum Power Point Tracking) along with Phase Locked Loop (PLL) is employed in the management of power in a hybrid system. The applied adaptive droop control does not depend on the communications and any state machines. The system performance is studied by using MATLAB software and the output is analysed.

Index Terms: Micro grid, droop control, PV, battery storage, Power management strategy.

I. INTRODUCTION

A large number of interconnected solar panels are used in PV array. These panels may be installed as stationary or with sun tracking mechanism. It is an important factor that the solar PV output and the load matching is done in an increased manner, hence Maximum Power Point Tracker (MPPT) is employed. The PV arrays which is given a most attractive option among the renewable energy resources.

It is employed in vast applications due to its high efficiency, increased reliability and low maintenance. Due to its advantages it is being widely employed in various applications through roof top supply source. The main advantage is that it can be located at the place of use and no distribution network is needed. Various applications of solar PV system are,

- Grid Interactive PV Power Generation
- Water Pumping
- Lighting
- Medical Refrigeration

[*] Assistant Professor Department of EEE, Jansons Institute of Technology, Coimbatore, Tamilnadu, India

[**] PG Scholars Department of EEE, VSB Engineering College, Karur, Tamilnadu, India

- Village Power
- Telecommunication And Signaling
- Solar Furnaces

One of the main drawbacks of the PV system is the reduction of energy generation which is due to the mismatching conditions and partial shading. To overcome the above drawback management techniques have been introduced to reduce the above problems. The grid connected PV system can be more efficient and reliable with an additional energy storage battery system.

In a grid connected system the battery storage is crucial in the operation of microgrids, which is used for the regulation of frequency and voltage when there is no alternate generation. It is also necessary to ensure that the load is supplied with sufficient power even in the absence of intermediate power. In such a case an energy storage unit is employed that is connected to microgrids through voltage source controller.

To avoid this problem power management strategy has been employed between PV and battery units. Normally the battery and the other sources connected to the grid is controlled by certain droop control strategies when there is an occurrence of insufficient from the PV to the micro grid. This droop control strategy is used to prevent the battery from depletion. The depletion of battery may cause damage in the loads connected to microgrids. The main purpose of battery is not only for the storage purpose but also used to supply or absorb power during fault conditions.In this scheme PV and battery units along with EMS (Energy Management System) which is used to measure the SOC (State Of Charge) of the battery is employed. To overcome this problem a hybrid system along with the PV and battery is employed which is called the DG hybrid unit. This hybrid unit cannot be connected directly to the grid, it requires certain droop control schemes. This control scheme is used to coordinate the features of the grid connected system with the micro grid system. This paper principally involves two basic power management strategies as shown below

- Internal Power Flow Management
- Voltage Control Scheme

Internal Power Flow Management manages the flow of power among the battery, PV array, DC link so that power balance is maintained among the hybrid system.

Voltage Control Scheme is responsible for the flow of power between the battery and the PV array which maintains the balance of power in the hybrid system.

II. SYSTEM DESCRIPTION

The proposed scheme is the system that combines the following features,

- The load is effectively shared between the hybrid unit and other available sources.
- The hybrid unit is capable of supplying the maximum power to the microgrids as long as there is sufficient load.
- The proposed condition has the efficiency to follow the load demand whenever the PV available is greater and the battery is charged completely.
- Efficient frequency regulation and voltage regulation is provided such that the deficient power in microgrids is supplied.

The method employs an adaptive multi-segment droop control method and a multi-loop control strategy without relying on the basic methods such as communications and machines to switch among the various operating modes that prevail in the system during operating condition.

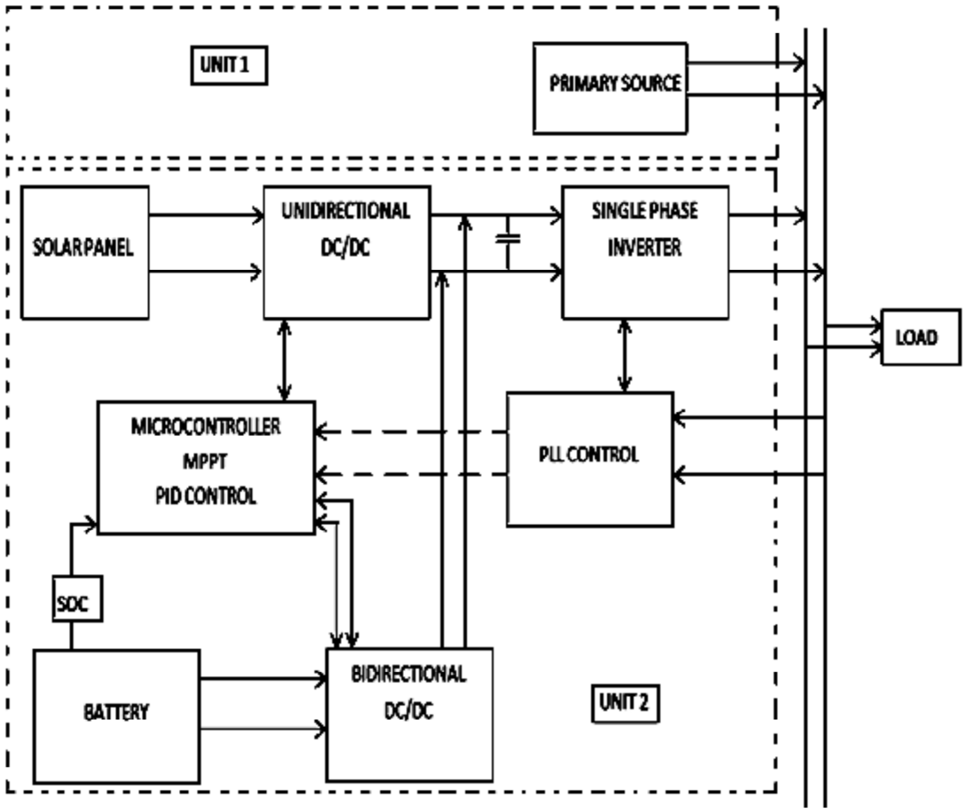

Figure 1: Schematic Diagram of PV/battery Hybrid System.

II. INTERNAL POWER FLOW MANAGEMENT

The internal power flow management is managed by using two main components such as MPPT (Maximum Power Point Tracking) and PID controller.

MPPT is an electronic DC-DC converter. It is a device where the grid connected inverters, battery and other devices so that it gets the maximum power from the photovoltaic devices. The MPPT samples the output of the cells and gives proper resistance during the solar irradiation and temperature in the solar cells for any given environmental conditions. MPPT are usually integrated with electric power converters so that it provides current conversion, voltage conversion, filtering purposes etc,

(a) Solar inverters convert AC-DC and incorporate MPPT and apply proper resistance so that the system obtains maximum power.

(b) MPP (Maximum Power Point)is the product of V_{MPP}(MPP voltage) and I_{MPP} (MPP current).MPPT is classified into various types based on its applications such as

- Perturb and Observe
- Incremental Conductance
- Current Sweep Method
- Constant Voltage

In a grid connected PV system the MPPT will always try to operate the PV panel at its maximum power. The MPPT controllers follow one of the above mentioned algorithm and switches between the operating conditions in the system.

Proportional– integral- derivative controller (PID Controller) is a loop control feedback mechanism, which is used to calculate the error values between the measured and desired values. There are three terms present in PID controller they are proportional term, integral term and a derivative term. The output from the above they are summed together. The block diagram of PID controller is shown below,

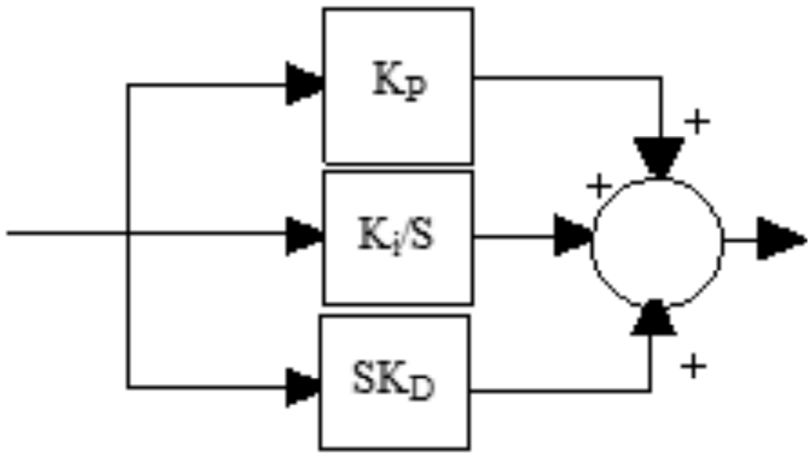

Figure 2: Schematic Diagram of PID Controller

The PID controller transfer function is given by,

$$PID(s) = K_p + K_i/s + sK_d \tag{1}$$

Thus by using a PID controller the overall performance is improved when compared with using a simple proportional or integral controller alone. PID controller operates on the error in the feedback system.

The power flow in the internal power flow management is categorized into two parts the MPPT and SOC (State of Charge). During the MPPT part the $V_{PV\text{-}REF}$ is generated by the MPPT algorithm, this assumes that the charge of the battery present in the system is always less than that of the maximum charge of the battery. When the SOC of the battery increases beyond the maximum value the PID control loop controls the PV power so that it is away from the maximum power point (MPP), thereby reducing the power extracted from the PV array, until the battery current drops to zero. At this point the SOC of the battery is maximum, in such a case the PID output disables the MPPT algorithm and forces it to stay at current V_{MPPT}, else it keeps searching for the maximum power from the PV. This is called the SOC strategy.

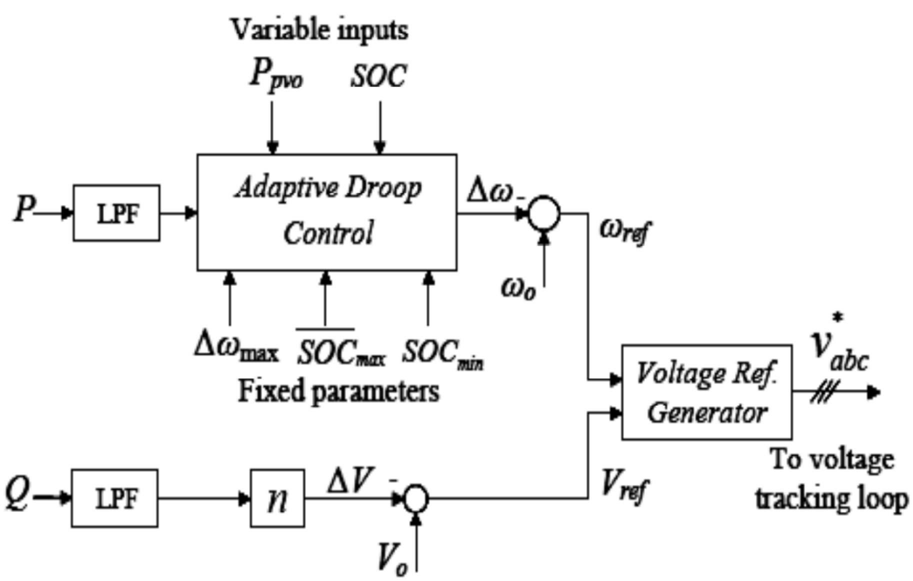

Figure 3: Voltage Source Control

III. VOLTAGE SOURCE CONTROL

In VSC the system is controlled as voltage source. Here the frequency and the reference voltage tracking are done. The reference frequency is generated with the help of the real power in the system by the adaptive droop control system. The LPF (Low Pass Filter) block present in the below diagram is a first order low pass filter. The main purpose of this LPF is to remove the harmonics in the output. The control strategy depends on the SOC of the battery.

When the SOC of the battery is below the minimum limit then the control strategy the first priority is given to the charge of the battery and next to the power sharing. On the other hand, when the SOC of the battery is between the minimum and maximum of the charge of the battery.

Else the micro grid is shared with the hybrid unit and the excess PV power is stored in the battery. If the SOC exceeds the maximum value the hybrid system will supply the power to the microgrid as long as there is sufficient load otherwise it will store the excess in the battery. There are certain cases where conditions from different criteria as mentioned above takes place. In such a case the internal power management loop control is performed which reduces the ability of PV to extract Maximum Power Point Tracking (MPPT). By reducing the power output of the PV the system can effectively follow the load change that occurs in the system.

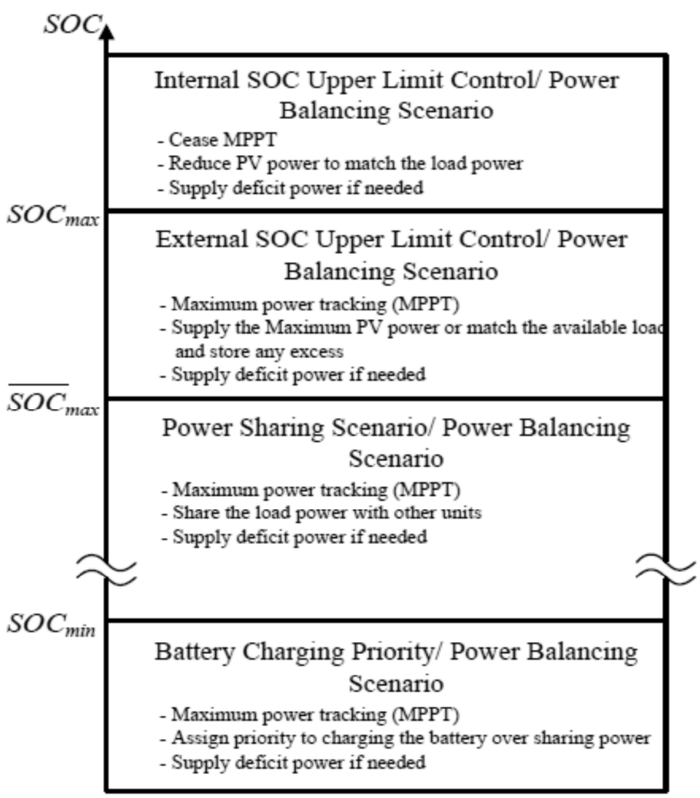

Figure 4: SOC Operating Scenario

Various operating scenario based on the SOC (State Of Charge) of the battery is described in Fig.(3).Space vector pulse width modulation technique is employed in the closed loop control scheme as one of the effective PWM(Pulse Width Modulation) technique.

Space Vector Pulse Width Modulation (SV-PWM) is actually just a modulation algorithm which translates phase voltage (phase to neutral) references, coming from the controller, into modulation times/duty-cycles to be applied to the PWM peripheral. It is a general technique for any three-phase load, although it has been developed for motor control. SV-PWM maximizes DC bus voltage exploitation and uses the “nearest” vectors, which translates into a minimization of the harmonic content. The classical application of SV-PWM is vector motor control, which is based on the control of currents' projection on two orthogonal coordinates (direct and quadrature, dq), called Field Oriented Control (FOC). The basic concept is that with a known motor and known voltage output pulses you can accurately determine rotor slip by monitoring current and phase shift. The controller can then modify the PWM "sine" wave shape, frequency or amplitude to achieve the desired result.

IV. POWER MANAGING SCENARIO

The major advantage of the power management scenario is that it overcomes the problem of black-outs. The shedding of load during the lack of power secures the equipments, by switching of the renewable sources. It reduces the electricity cost during the peak hours. During the low load periods the system automatically sheds away the low priority sources in the hybrid system. The power management shares the available active and reactive power that is available in the system. This power sharing scenario reduces the cable necessity to connect various sources to the load.

V. SIMULATION AND RESULT

The wind energy renewable source is employed along with the PV/Battery hybrid system in the proposed paper. The management of power is effectively carried out among the wind, solar power and the battery as shown in fig.5. The output Measurement block gives the signal to the flow control block that consists of ideal switches that operates as per as the signal from the output measurement. Based on the switching performance the sources act to follow the change in load conditions.

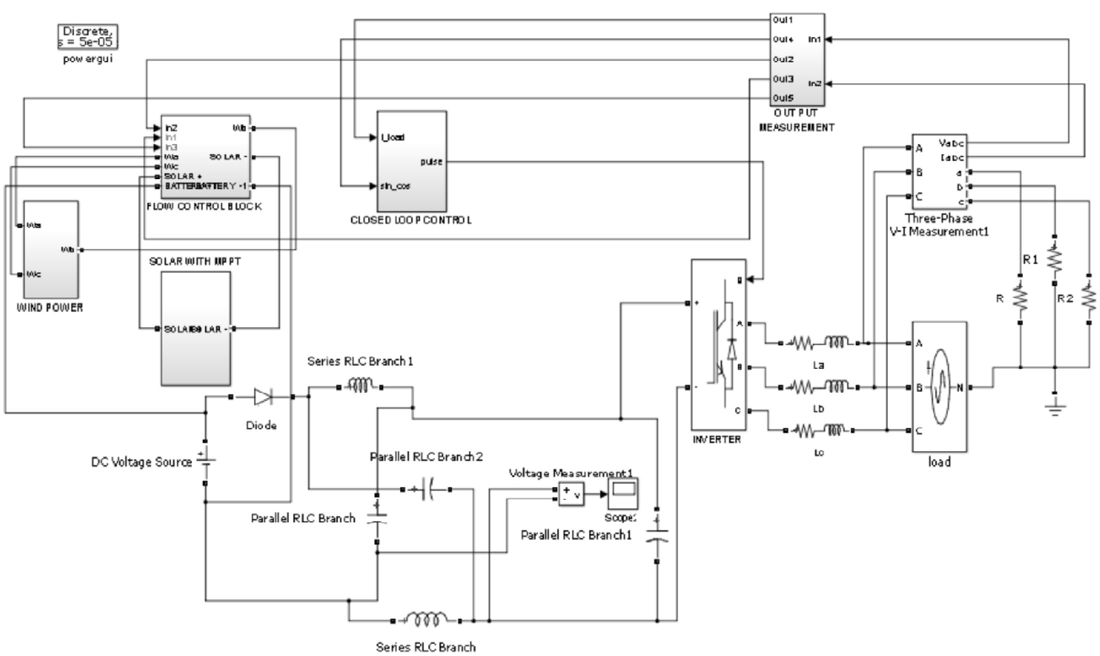

Figure 5: Simulation Diagram

Based on the load value the sources are given priorities according to the switching signals from the flow control block. During the off load period the battery that has been charged continues to deliver the power to the load. During the peak hours the renewable sources continues to deliver the power to the load.

The closed loop control with the help of the feedback obtained from the load settings converts the abc frame of the output to the dq reference frame such that the difference of the reference and the measured value can be calculated. This block performs the abc to dq0 transformation on a set of three-phase signals.

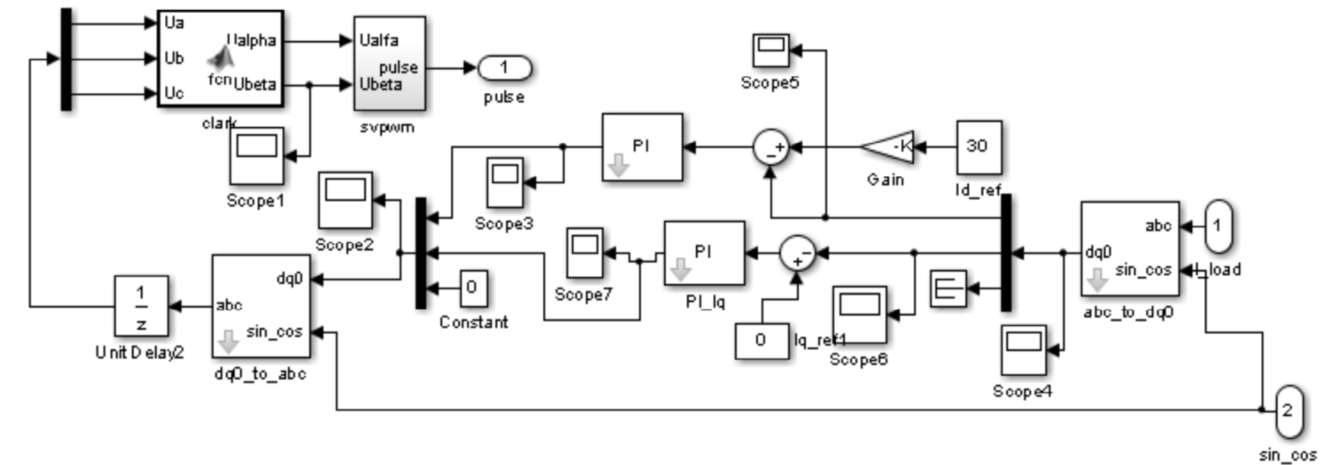

Figure 6: Closed Loop Control Block

In the closed loop control the abc to dq0 transformation is done on a set of three phase signals as given below :

$$Vd = 2/3*[Va*\sin(wt) + Vb*\sin(wt-2pi/3) + Vc*\sin(wt+2pi/3)] \tag{2}$$

$$Vq = 2/3*[Va*\cos(wt) + Vb*\cos(wt-2pi/3) + Vc*\cos(wt+2pi/3)] \tag{3}$$

$$V0 = 1/3*[Va + Vb + Vc] \tag{4}$$

It computes the direct axis Vd, quadratic axis Vq, and zero sequence V0 quantities in a two axis rotating reference frame. This transformation is commonly used in three-phase electric machine models where it is known as the Park transformation.

For the dq0 to abc transformation the block transforms three quantities (direct axis, quadature axis and zero-sequence components) expressed in a two axis reference frame back to phase quantities. The following transformation is used,

$$Va = [Vd*\sin(wt) + Vq*\cos(wt) + Vo] \tag{5}$$

$$Vb = [Vd*\sin(wt-2pi/3) + Vq*\cos(wt-2pi/3) + Vo) \tag{6}$$

$$Vc = [Vd*\sin(wt+2pi/3) + Vq*\cos(wt+2pi/3) + Vo) \tag{7}$$

where w = rotation speed (rad/s) of the rotating.Input1contains the vectorized signal of [Vd Vq V0] components. Input 2 must contain a [sin (wt) cos (wt)] two dimensional signal containing the three [Va Vb Vc] phase sinusoidal quantities.

$$Ualpha = 2/3*(Ua-0.5*Ub-0.5*Uc); \tag{8}$$

$$Ubeta=2/3*(sqrt(3)/2*Ub-sqrt(3)/2*Uc); \tag{9}$$

$$Ii=(3/2); \tag{10}$$

The unit delay block samples and hold with one sample period delay. The clark transformation is done with the following clark function.The output measurement block consists of Phase Locked Loop (PLL).this system can be used to synchronize on a set of variable frequency, three-phase sinusoidal signals. If the Automatic Gain Control is enabled, the input (phase error) of the PLL regulator is scaled according to the input signals magnitude. The RMS block employed computes the true RMS value of input signal. The RMS value is calculated over a running window of one cycle of the specified frequency. The numerical inputs that are given can be viewed from the display block. The simulated result during peak hour is generated and given in fig. 6.

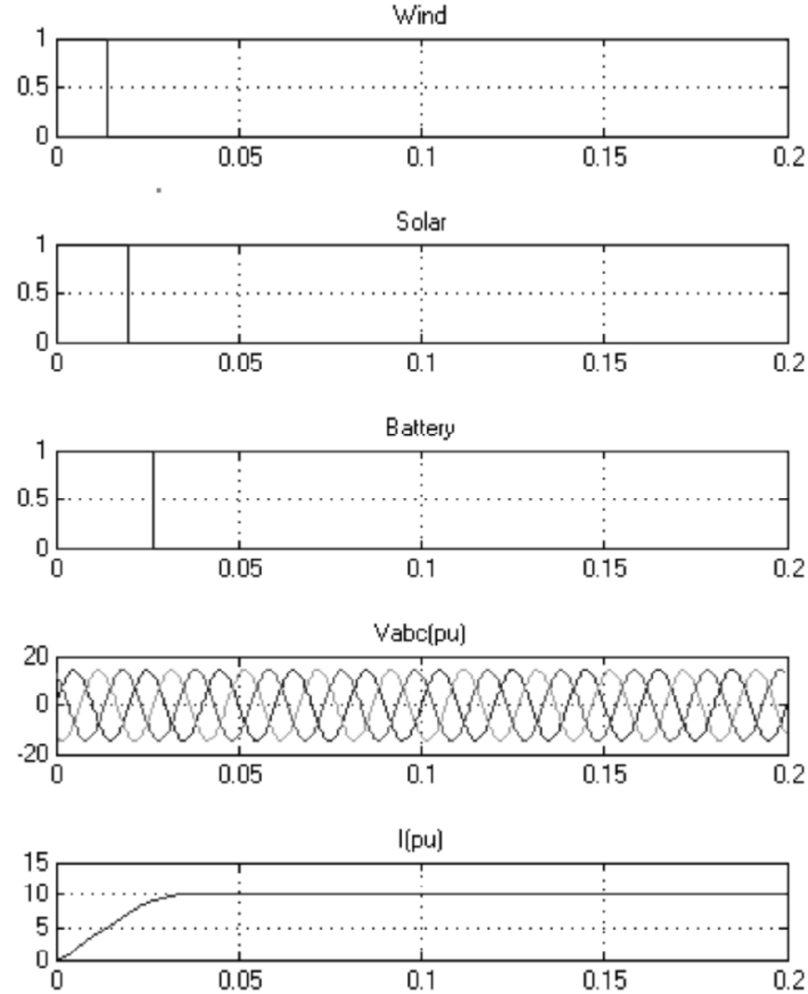

Figure 6: Simulation Result

The simulated result shows the priority of the renewable sources according to the load requirements. When the load current reaches the peak value the graph shows that the hybrid system effectively functions to follow the load change.

The major scope of the project is to employ effective power management in areas such as,

- Home appliances
- Portable power
- Power train
- Large industrial power generation

The major advantage of the power management scenario is that it overcomes the problem of black-outs. The shedding of load during the lack of power secures the equipments, by switching of the renewable sources. It reduces the electricity cost during the peak hours. During the low load periods the system automatically sheds away the low priority sources in the hybrid system. The power management shares the available active and reactive power that is available in the system. This power sharing scenario reduces the cable necessity to connect various sources to the load.

VI. CONCLUSION

In this paper a novel strategy for hybrid PV/battery in a utility grid has been proposed effectively. In this proposed scheme the PV unit is operated as voltage source which employs two control strategies such as internal power flow control and the voltage source control is employed. The control strategy employed is also designed to modify the operating point of PV to autonomously whenever the available PV power is higher than the load and the battery is completely charged. Moreover, the battery can operates as separate storage unit that can regulate voltage and frequency and supply deficit power to the micro grid.

REFERENCES

[1] N. Asano and T. Saga, "PV Technology trends and industry's role," in In Conf. Rec. IEEE International Electron Devices Meeting, 2008, pp.1–6.

[2] F. Ongaro, S. Saggini, and P. Mattavelli, "Li-ion battery supercapacitor hybrid storage system for a long lifetome,photovoltaic-based wireless sensor network," *IEEE Trans. Power Electron.*, Vol. 27, No. 9, pp. 3944–3952, Sep. 2012.

[3] H. Mahmood, D. Michaelson, and J. Jiang, "Control strategy for a standalone PV/battery hybrid system," in Conf. Proc. IEEE Industrial Electronics Conference, 2012, pp. 3412–3418.

[4] S. J. Chiang, H.-J. Shieh, and M.-C. Chen, "Modeling and control of a PV charger system with SEPIC converter," IEEE Trans. Ind. Electron., Vol. 56, No. 11, pp. 4344–4353, Nov. 2009.

[5] H. Fakham, D. Lu, and B. Francois, "Power control design of a battery charger in a hybrid active PV generator for load-following applications," IEEE Trans. Ind. Electron., Vol. 58, No. 1, pp. 85–94, Jan. 2011.

[6] B. I. Rani, G. S. Ilango, and C. Nagamani, "Control strategy for power flow management in a PV system supplying DC loads," IEEE Trans. Ind. Electron., Vol. 60, No. 8, pp. 3185–3194, Aug. 2013.

[7] C. Wang and M. H. Nehrir, "Power management of a stand-alone wind/photovoltaic/fuel cell energy system," IEEE Trans. Energy Con- vers., Vol. 23, No. 3, pp. 957–967, Sep. 2008.

[8] K. T. Tan, P. L. So, Y. C. Chu, and M. Z. Q. Chen, "Coordinated control and energy management of distributed generation inverters in a microgrid," IEEE Trans. Power Del., Vol. 28, No. 2, pp. 704–713, Apr. 2013.

[9] K. Brabandere, B. Bolsens, J. V. Keybus, A. Woyte, J. Driesen, and R. Belmans, "A voltage and frequency droop control method for parallel inverters," IEEE Trans. Power Electron., Vol. 22, No. 4, pp. 1107–1115, Jul. 2007.

[10] R. H. Lasseter and P. Piagi, "Providing premium power through dis- tributed resources," in In Conf. Rec. IEEE 33rd HICSS, 2000, pp. 1–9.

[11] S. Bae and A. Kwasinski, "Dynamic modeling and operation strategy for a microgrid with wind and photovoltaic resources," IEEE Trans. Smart Grid, Vol. 3, No. 4, pp. 1867–1876, Dec. 2014.