International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:268
Vol.2, No.3, March 2013 DOI:10.15693/ijaist/2013.v2i3.12-16

Modeling And Control Of Hybrid Microgrid

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***Abstract*—In the hybrid microgrid , processes of multiple dc-ac-dc or ac-dc-ac conversions are reduced in an individual ac or dc grid. The hybrid grid consists of both ac and dc networks connected together by multi directional converters. In this micro grid network , it is especially difficult to support the critical load without incessant power supply . the generated power can be extracted under varying wind speed , solar irradiation level and can be stored in batteries at low power demands. In this scheme, inverter control is executed with hysteresis current control mode to achieve the faster dynamic switch over for the support of critical load. The system provides rapid response to support the critical load. And can also operated as a stand alone system in case of grid failure like a incessant power supply. The system is simulated in MATLAB/SIMULINK.**

***Key words:* Hybrid microgrid, islanded mode operation, Hysteresis control mode, power quality,**

I. INTRODUCTION

Over 100 years the three phase AC power systems existing due to its different operating voltage levels and over long distance. Newly more renewable power conversion systems are connected in ac distribution systems due to environmental issues caused by fueled power plants. Nowadays, more DC loads like LED and Electric vehicles are connected to AC power systems to save energy and to reduce the pollution caused by the fossil fueled power plants. There is no longer necessary for long distance transmission if the power is supplied by the local renewable power sources. To connect the Conventional AC system to the renewable power sources, AC microgrid have been proposed and DC power from PV panel and Fuel cell are converted into AC in order to connect to an ac grids. Implanted ac/dc and dc/dc converters . In an ac grid, implanted ac/dc and dc/dc converters are required for various home and office facilities to supply different dc voltages. AC/DC/AC converters are commonly used as drives in order to control the speed of ac motors in industrial plants.

Recently, dc grids are resurging due to the development and deployment of renewable dc power sources and their inherent advantage for dc loads in commercial, industrial and residential applications. The dc microgrid has been proposed to incorporate various distributed generators and ac sources have to be converted into dc before connected to a dc grid and dc/ac inverters are required for conventional ac loads.

Multiple reverse conversions required in individual ac or dc grids may add additional loss to the system operation and will make the current home and office appliances more complicated.

The objective of constructing a smart grid is to provide reliable, high quality electric power to digital societies in an environmentally friendly and sustainable way. One of most important futures of a smart grid is the advanced structure which can facilitate the connections of various ac and dc generation systems, energy storage options, and various ac and dc loads with the optimal asset utilization and operation efficiency. Here in Smartgrid the power electronics technology plays a most important role to interface different sources and loads to a smart grid to achieve this goal.

A hybrid ac/dc microgrid is proposed in this paper to reduce processes of multiple reverse conversions in an individual ac or dc grid. Since energy management, control, and operation of a hybrid grid are more complicated than those of an individual ac or dc grid, different operating modes of a hybrid ac/dc grid have been investigated.

In order to verify the effectiveness of the proposed system, the current control mode of voltage source inverter is proposed into the distributed network. The proposed control system has the following objectives

- Unity power facto and power quality at point of common coupling bus
- Real and reactive power support from wind generator and batteries to load
- Stand alone operation in case of grid failure

II. CHARACTERISTICS OF HYBRID MICROGRID

Fig.1 represents the Hybrid microgrid configuration where various AC, DC sources and loads are connected to corresponding AC and DC networks. The various characteristics and the component used in the hybrid microgrid system is depend on the application. The characteristics and component of a hybrid microgrids system greatly depend on the application. The most important factor is to be considered whether the system is operated in islanded mode or grid tied mode.

A. Grid tied mode

If the hybrid system is connected to the utility grid as in Distributed generator application the system design will be simple with reduced no of components. Since the voltage and frequency are set by the utility system. In addition to this , the grid normally provides the reactive power . when the demand is more than the supplied power by the hybrid system, then the shortage is provided by the utility. similarly, any excess power produced by the hybrid system can be absorbed by the utility system . In such cases, the grid does not act as an infinite bus. However , it is then said to be weak , additional components and control may need to be added. The grid connected mode hybrid system will then come to more closely resemble an isolated one

B. Islanded mode

Islanded grid connected hybrid system is differs in many ways from central grid connected system. Initially the system must be able to provide all the energy that is required at any time on the grid . They must be able to set the grid frequency and control the voltage.

After that the system must be able to provide the reactive power required by the system. Under certain conditions , renewable generators may produce energy in excess of what is needed.

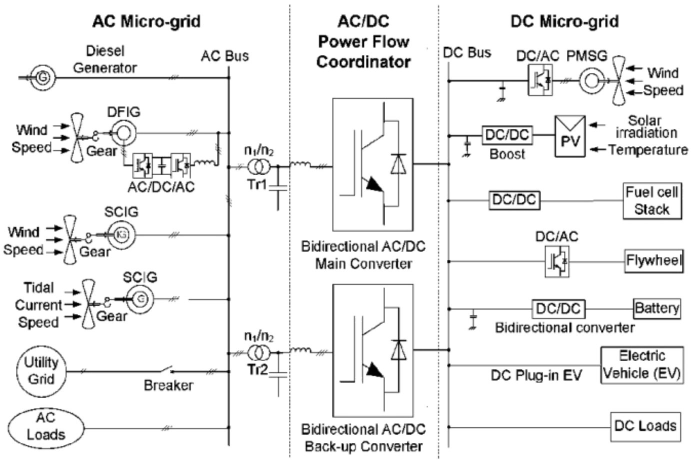

Fig. 1. Representation of Hybrid microgrid

III. SYSTEM MODELLING

A. PV panel Modeling

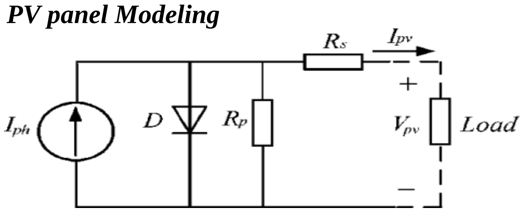

Fig. 2. Equivalent circuit of a solar cell

Fig.2 shows the equivalent circuit of a PV panel with a load. The current output of the PV panel is modeled by the following equations.

$$I_o = n_p I_{ph} - n_p I_{rs}[\exp(k_o v/n_s) - 1] \quad (1)$$

$$Ipv = npIph - npIsat * \left[\exp\left(\left(\frac{q}{Akt}\right)\left(\frac{Vpv}{ns} + IpvRs\right)\right) - 1\right] \quad (2)$$

$$Iph = (Isso + Ki(T - Yr)) * \frac{s}{1000} \quad (3)$$

$$Isat = Irr\left(\frac{T}{Tr}\right)\left(\frac{T}{Tr}\right)^3 \exp\left(\left(\frac{qEgap}{Ka}\right) * \left(\frac{1}{Tr} - \frac{1}{T}\right)\right) \quad (4)$$

B. Modeling of battery

Two important parameter to represent state of battery are terminal voltage Vb and the state of charge (SOC)

$$Vb = Vo + Rb * ib - K\frac{Q}{Q} + \int Ib\ dt + A\exp(B\int Ib\,dt) \quad (5)$$

$$SOC = 100(1 + \int Ib\frac{dt}{Q} \quad (6)$$

C. Modeling of wind generating system:

Wind generating system is connected with turbine , induction generator, interfacing transformer and AC-DC-AC converter.

The static characteristics of wind turbine can be described with the relationship in the wind as in

$$Pwind = \frac{1}{2}\rho\pi R^3 V^3 wind \quad (7)$$

It is not possible to extract all kinetic energy of wind and is called power co-efficient. This power co-efficient can be expressed as a function of tip speed ratio and pitch angle.

The mathematical power can be written as

$$Pmech = CpPwind \quad (8)$$

$$Pwind = \frac{1}{2}\rho\pi R^3 V^3 wind\ Cp \quad (9)$$

By using turbine rotational speed ,W_{tubine} mechanical torque is shown in

$$Tmech = \frac{Pmech}{Wturbine} \quad (10)$$

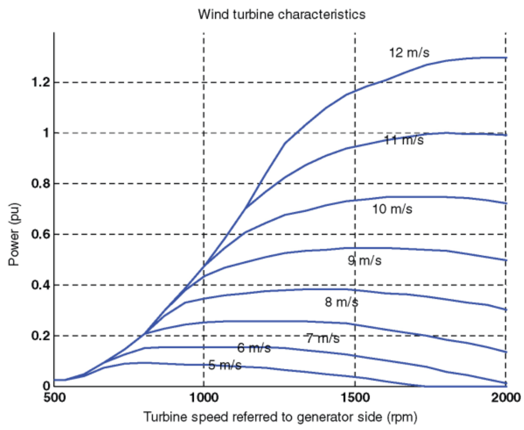

Fig. 3. Power-speed characteristic of turbine.

IV. CONTROL SCHEME OF THE SYSTEM

The control scheme of the proposed system is based on injecting the current into the grid using "hysteresis current controller." Using this techniques the controller will keeps the control system variables between the boundaries of hysteresis area and gives correct switching signals for inverter operation.

The control scheme for generating the switching signals to the inverter is shown in Fig.4.

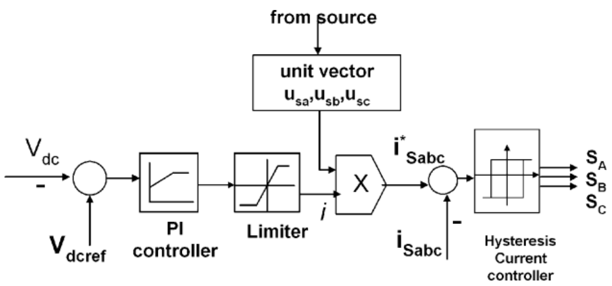

Fig. 4. Control scheme for switching the inverter circuit

The control algorithm desires the measurement of several variables such as three-phase source current i_{Sabc} for phases a, b, c, respectively, dc voltage V_{dc}, inverter current I_{abc} with the help of sensors. The current control block receives an input of reference current i^*_{Sabc} and actual current i_{Sabc} is measured from source phase a, b, c, respectively, and are subtracted so as to activate the operation of the inverter in current control mode.

In the three-phase balance system, the RMS voltage source amplitude is calculated at the sampling frequency from the source phase voltage (V_{sa}, V_b, V_{sc}) and is expressed as sample template V_{sm}, as in

$$V_{sm}=\{\frac{2}{3}(V_{sa}^2+V_{sb}^2+V_{sc}^2\}^{1/2} \quad (11)$$

The in-phase unit vectors are obtained from ac source-phase voltage and the RMS value of unit vector u_{sa}, u_{sb}, u_{sc} as shown in

$$u_{sa}=\frac{V_{sa}}{V_{sm}},\ u_{sb}=\frac{V_{sb}}{V_{sm}},\quad u_{sc}=\frac{V_{sc}}{V_{sm}} \quad (12)$$

The in-phase generated reference currents are derived using the in-phase unit voltage template as in

$$I^*_{sa}=i.\ u_{sa},\ I^*_{sb}=i.\ u_{sb},\ I^*_{sc}=i.\ u_{sc} \quad (13)$$

where i is proportional to the magnitude of filtered source voltage for respective phases. It is the output taken from proportional-integral controller. This ensures that the source current is controlled to be sinusoidal. The unit vector implements the important function in the grid for the synchronization of inverter. This method is simple, robust and favorable as compared with other methods.

When the grid voltage source fails, the hybrid microgrid system acts as a stand-alone power structure. Under such conditions the voltage sensors sense the condition and will transfer the micro-switches for the generation of reference voltage from Distributed generator. The above generated reference under no source supply gets switched to the stand-alone reference generator after voltage sensing at the point of common coupling. This is a unit voltage vector which can be realized by using microcontroller or DSP. Thus, the inverter maintains the continuous power for the critical load.

A. Hysteresis Based Current Controller

Hysteresis based current controller is implemented in the current control scheme. The reference current is generated as in and the actual current is detected by current sensors that are subtracted for obtaining current errors for a hysteresis based controller. The ON/OFF switching signals for IGBT of inverter are derived from hysteresis controller. When the actual (measured) current is higher than the reference current, it is necessary to commutate the corresponding switch to get negative inverter output voltage. This output voltage decreases the output current and reaches the reference current. On the other hand, if the measured current is less than the reference current, the switch commutated to obtain a positive inverter output voltage. Thus the output current increases and it goes to the reference current. As a result, the output current will be within a band around the reference one. The switching function S_A for phase a is expressed as follows:

$$i_{sa} > (i^*_{sa} + HB) \rightarrow S_A = 1 \quad (14)$$

$$i_{sa} < (i^*_{sa} - HB) \rightarrow S_A = 0 \quad (15)$$

where HB is a hysteresis current-band, similarly the switching function S_B, S_C can be derived for phases “b” and “c,” respectively. The current control mode of inverter injects the current into the grid in such a way that the source currents are harmonic free and their phase-angles are in-phase with respect to source voltage. Thus, the injected current will cancel out the reactive and harmonic part of load current. Thus, it improves the source current quality at the PCC. The power transfer takes place as soon as battery energy system is fully charged with the help of micro-wind generator.

To achieve this goal ,the source voltage is sensed and synchronized in generating the desired reference current command for the inverter operation. The implementation of the hysteresis band current control is not expensive. The control is excellent for a fast response of an inverter to rapid changes of reference current, since current control has negligible inertia and delay.

B. Performance of PI Controller

The proportional-integral type controller is used in the control system and its response is very fast. It corrects the error between measured variable and a desired set value. The K_p determine amplification to the current error and K_i process the corrected error.

The PI controller used to increase the overshoot increases the change in the settling time and eliminates the steady state error in the system. The increase in loop gain Kp improves the steady state tracking accuracy , disturbance signal rejection , the relative stability and also makes the system less sensitive to the parameter variation .

The integral controller reduces the steady state error without the need for manual reset. The performance of controller is used to stabilize the voltage in the distributed network.

Here the FFT analysis of waveform is expressed and the THD of the signal is obtained. Three power quality improvement is observes at the point of common coupling, when this controller is used.

V. SYSTEM PERFORMANCE:

The simulink diagram shows the simulation model of the hybrid microgrid system with solar and wind energy system. In this system, voltage is obtained from the solar panel , and this voltage is boosted by using booster circuit. Then this voltage is converted into AC by using inverter circuit and this voltage is directly applied to the load with the wind power

The Wind power is obtained from wind turbine with Induction generator. The produced power is rectified and boosted to a high value which will be synchronized with the power from DC source. Then this boosted voltage is converter to AC by means of inverter and given to load.

The various Output waveforms were taken from Solar and wind turbine and the output voltage across the load is indicated here under various conditions.

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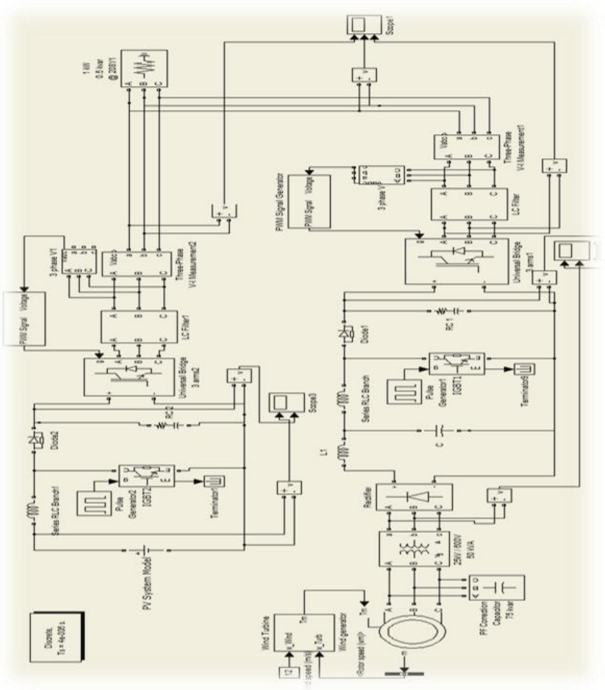

Fig.6 Simulation model of the Hybrid microgrid

The below waveform shows the output voltage of wind turbine after rectified with the increasing wind speed.

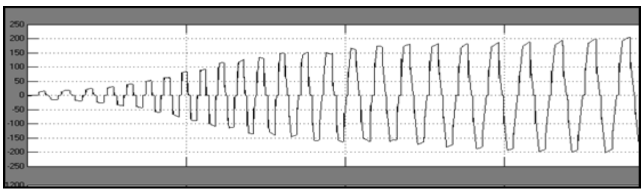

Fig.7 Rectified voltage waveform from the wind turbine.

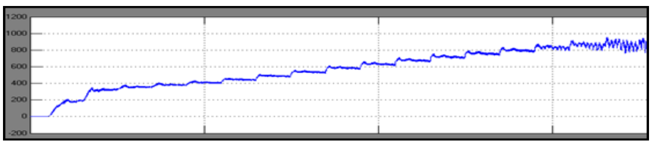

Fig.8 output voltage form the DC source.

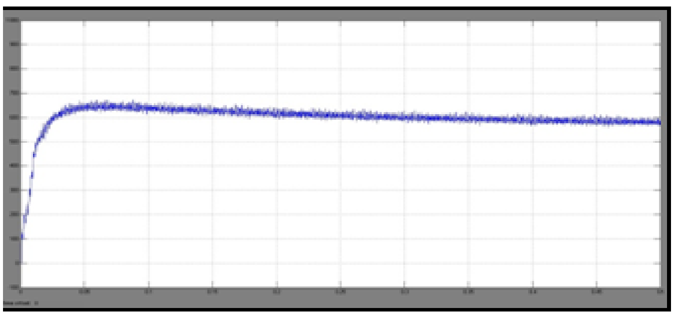

Fig.9 Boosted output voltage form the DC source.

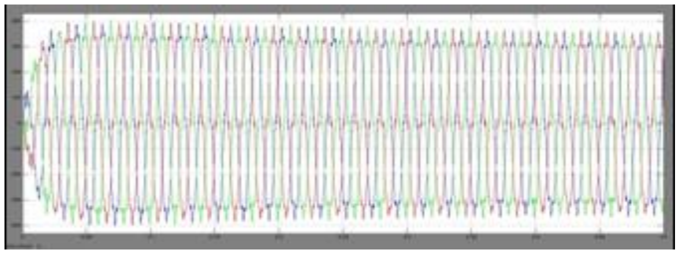

Fig.10 Output waveform across the load for varying input condition.

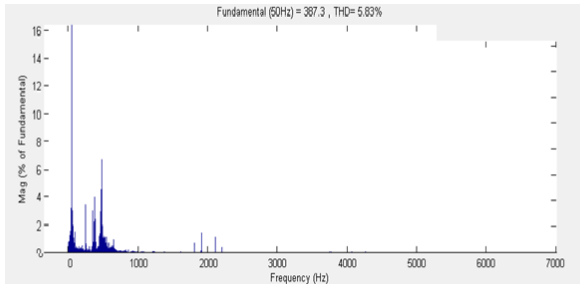

Fig.11 FFT Analysis of microgrid

The harmonic analysis of voltage applied to the load is shown here. And the different values of THD for various harmonic order are listed below.

Table-I

Performance of the controller operation

Harmonics order in source current	1	3	5	7	THD
With Controller	44.2	0.2	0.6	0.2	5.83%
With international Electro-Technical Standard					3.0%

The power quality improvement is observed at the point of common coupling, when the controller is in ON condition. The inverter is placed in the operation and source current waveform can be obtained with its FFT. It is shown that the THD has been improved considerably and nearer to the norms of its standard.

VI. CONCLUSION

The present work mainly includes the Islanded mode of operation of hybrid grid. The models are developed for all the converters to maintain stable system under various loads and resource conditions and also the control mechanism are studied the hybrid grid can diminish the processes of DC/AC and AC/DC conversions in an individual AC or DC grid, there are many practical problems for the implementation of the hybrid based on the current AC dominated infrastructure. The efficiency of the total system depends on the diminution of conversion losses and the increase for an extra DC link. The hysteresis current controller is used to generate the switching signal for inverter in such a way that it will cancel the harmonic current in the system. The scheme maintains unity power factor and also harmonic free source current at the point of common connection in the distributed network.

The hybrid grid can provide a reliable, high quality and more efficient power to consumer. The hybrid grid may be feasible for small isolated industrial plants with both PV systems and wind turbine generator as the major power supply.

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