Operation and control of Hybrid Microgrid

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Abstract – In recent years, hybrid microgrid comprises of dc and ac subgrids interconnected by power electronic interfaces unlike in existing microgrids which are purely ac or dc. The main objective is to manage the power flow among all sources distributed throughout the different types of subgrids. The hybrid grid reduces the process of multiple dc-ac-dc or ac-dc-ac conversions in an individual grid and reduces the number of converter stations for converting ac to dc or dc to ac power. This hybrid can operate in both grid connected and standalone mode. The proposed grid can operate in both standalone and grid connected mode. Proportional integral controller is used for smooth power transfer.

Keywords – hybrid microgrid, proportional integral controller, converter station, standalone, grid connected mode.

I. INTRODUCTION

The increasing number of Renewable Energy Sources and Distributed Generation (DG) requires new technique for the operation and management of the electricity grid to enhance proper power sharing. In the present power scenarios, when distributed generations are mentioned for small scale generations to meet the various customer demand. The coordination of these small scale generations may consist of photovoltaic, batteries, wind and fuel cells which are formed as Micro-grid [1],[2]. Interest on microgrid is rapidly increasing as it is based on the renewable energy sources, which connects to utility grid and various types of loads. In the grid tied mode, it is connected with utility whereas in case of autonomous mode it is totally disconnected. In case of autonomous mode it becomes totally independent and fulfills the demands of customers from the renewable energy sources [3],[4]. By using renewable energy sources we can get pollution less environment and it is available enormously in nature. The distributed generation and in integration of Renewable Energy Sources into the grid provides power quality problems.

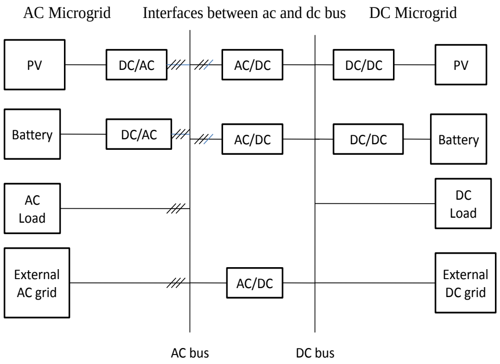

Fig. 1 Representation of ac dc hybrid microgrid

The main objective of constructing a micro grid is to provide reliable, high quality electric power to digit a societies with an environmentally friendly and sustainable way. Recently the most important and advanced futures of a smart grid is the advanced structure which can smooth the progress of the connections of various ac and dc generation systems, energy storage options, and various ac and dc loads with the most advantageous and benefit utilization and operation efficiency [5]. In microgrid the power electronics technology plays a most important role for interfacing different sources and loads to a grid to achieve the goal.

AC micro grids have been proposed to assist to tie the renewable power sources to conventional ac systems. On the other hand, dc output power from photovoltaic (PV) panels must be converted into ac for using ac loads. This can be made using dc/dc boosters and dc/ac inverters. In an ac grid, for various home and office facilities embedded ac/dc and dc/dc converters are necessary for supplying different dc voltages. AC/DC/AC [6],[7] converters are commonly used as drives for speed control of ac motors in various industrial plants. In recent times, dc grids are resurging due to the development of renewable dc power sources and their inbuilt benefit for dc loads in industrial, commercial, and residential applications. The dc micro-grid has been proposed to integrate various distributed generators [8]. Conversely, ac sources have to be converted into dc before connecting it to a dc grid. For conventional ac loads dc/ac inverters are mandatory. [9].

In individual AC or DC grids, multiple reverse conversions AC to DC and then DC to AC, and/or vice versa are essential, which may add extra loss to the system operation and it will make the system more complex. In proposed hybrid AC/DC microgrid multiple reverse conversions are reduced

by various AC and DC distributed generators (DGs) and loads than in an individual AC or DC microgrid. In micro-grids the voltage and frequency control is also one of the most significant issues. The control schemes are considered in order to manage the voltage and frequency of the microgrid.

2. SYSTEM CONFIGURATION AND DESIGN

A simple hybrid microgrid as shown in Fig.4 is modeled using the Simulink in the MATLAB to simulate system operations and controls. Forty kW PV arrays are associated to dc bus through a dc/dc boost converter to simulate dc sources. A capacitor C is to smother high frequency ripples of the PV output voltage.

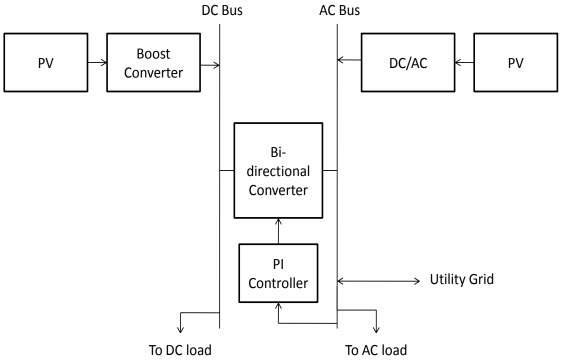

Fig. 2 Block diagram for proposed system

A hybrid microgrid system arrangement consist a mixture of ac and dc sources and loads which are connected to the equivalent dc and ac networks. The dc and ac links are connected together through bi-directional converters and two transformers. The dc loads are connected to dc bus and ac loads are connected to ac bus. The utility grid is connected to ac network of hybrid microgrid system. The hybrid microgrid can operate in two different modes standalone mode and grid connected mode.

Grid connected mode

In grid connected mode, the main converter is to afford stable dc bus voltage and to switch over power between the ac and dc buses which also provide the required reactive power. The maximum power is maintained by a boost converter. When the total load at dc side is greater than a power generation at the dc side, the converter injects power from the ac to dc side. When the output power of the dc loads is less than the dc source, the converter acts as an inverter and injects power from dc to ac side. When the total load is less than the total power generation in the hybrid grid, power is injected into the utility grid. Or else, the hybrid grid will receive power from the utility grid. In the grid tied mode, the battery converter is not essential in system operation as the power is balanced by the utility grid. In standalone mode, both power balance and voltage stability mainly depend on battery. According to different operating conditions battery converter or boost converter maintains the DC bus voltage stable. The main converter is controlled to provide a stable and high quality ac bus voltage. Based on system operating necessities, PV can operate in both on MPPT or off-MPPT mode. Variable solar irradiation is applied to the arrays correspondingly to simulate variation of power of ac and dc sources and test the MPPT control algorithm.

Standalone mode

In autonomous mode, hybrid microgrid becomes electrically cut off from the rest of the utility grid. The battery plays a very vital role for balancing the power and to obtain the voltage stability. Battery or boost converter is implemented to maintain DC bus voltage stable, according to different operating conditions. By controlling the main converter a stable and high quality ac bus voltage is provided.

3. MODELING OF SOLAR PANEL

In a grid-connected PV system, PV power varies with operational conditions such as irradiance, temperature, light incident angle, reduction of sunlight transmittance on glass of module, and shading. A photovoltaic array is an interconnection of modules which in turn is made up of many PV cells in series or parallel. The power produced by single module is not enough hence the modules in a PV array are generally first connected in series to attain the desired voltages then the individual modules are connected in parallel to allow the system to produce more current.

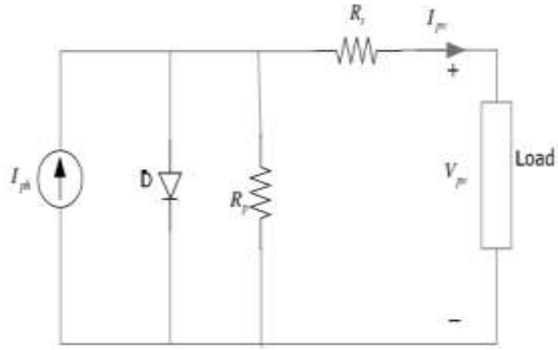

Fig. 3 Equivalent circuit of pv cell

Generally the equivalent circuit of a general PV model consists of a photocurrent, a diode, a parallel resistor which expresses a leakage current, and a series resistor which describes an internal resistance to the current flow [10]. The current output equation of a solar cell is given as

$$Ipv = npIph - npIsat * [\exp((q/AkT)(Vpv/ns + IpvRs)) - 1]$$

$$Iph = \left(Isso + ki(T - Tr)\right).\frac{S}{1000}$$

$$Isat = Irr\left(\frac{T}{Tr}\right)3\exp\left(\left(\frac{qEgap}{kA}\right).\left(\frac{1}{Tr} - \frac{1}{T}\right)\right)$$

4. MODELING OF BOOST CONVERTER

The dc-dc boost converter is a step up converter that steps up the input voltage by storing energy in an inductor for a certain time period, and then uses this energy to boost the input voltage to a higher value.

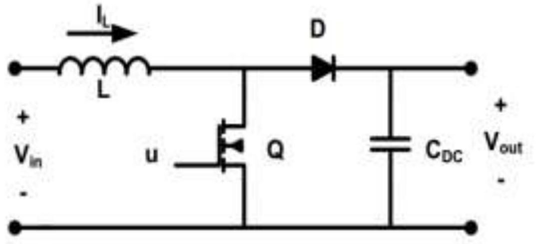

Fig. 4 Circuit diagram of Boost Converter

The relationship between the input and output voltages is given by

$$V_{in}t_{on} + (V_{in} – V_{out})\, t_{off} = 0$$

$$\frac{V_{out}}{V_{in}} = \frac{t_{on} + t_{off}}{t_{off}} = \frac{1}{1-d}$$

The boost converter is average model type meaning that switching action is absent. This model uses controlled current and voltage sources, whose input is reference signals, instead of power electronic devices to generate boosted voltage across output terminal. The output of boost converter is the input to the dc/ac inverter.

5. MODELING OF BATTERY

Terminal voltage Vb and state of charge (SOC) are the two important factors to describe the state of a battery.

$$Vb = Vo + Rb.ib - K.\frac{Q}{Q + \int ibdt} + A.\exp\left(B\int ibdt\right)$$

$$SOC = 100\,(1 + \int ib\,dt$$

6. PI CONTROLLER

In various industrial applications, proportional integral (PI) controller is one of the famous controllers used in a wide range. The PI controller output is in time domain and is defined by the following equation:

$$Vc(t) = Kp(t) + Ki\int_0^t e(t)\,dt$$

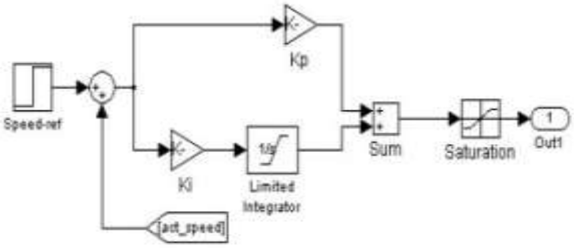

Fig 5: Block diagram of PI control system

Adding the integral part to the proportional controller is one of the major advantages to eradicate the steady state error in the controller variable. On the other hand, one of the main drawback of the integral controller is if the error does not change its direction subsequently it gets saturated after a while. By introducing a limiter in the circuit this incident can be avoided at the integral part of the controller ahead of adding its output to the output of the proportional controller. The input to the PI controller is the speed error (e), while the output of the PI controller is used as the input of reference current block as shown in fig 5.

7. THE CONTROL STRATEGY

The different sources and converters have to be coordinately controlled with the utility grid to obtain a continuous, high efficiency, and high quality power to variable ac and dc loads under variable solar irradiation when the hybrid grid operates in both grid tied and standalone modes. This section presents the various control algorithms for those converters.

A. Grid-Connected Mode

When the hybrid microgrid operates in grid connected mode, the main purpose of the boost converter is to track the MPPT of the PV array by regulating its terminal voltage. The bidirectional converter is controlled to regulate flow of current to achieve MPPT and to coordinate with ac grid. The excess energy of the hybrid grid can be sent to the utility system. The excess energy is stored in battery but the utility grid balances the excess power hence battery is less sufficient in this hybrid microgrid. The main purpose of battery is to eradicate regular power transfer between the ac and dc link. The dc/dc converter of the battery can be controlled as the energy buffer using the technique. The main converter is designed to operate as bidirectional converter to integrate harmonizing characteristic of solar sources. The main control objectives of the bidirectional converter is for variable load conditions a stable dc-link voltage must be maintained and to synchronize with the ac link and utility system [11],[12].

The power flow equations at the dc and ac links are,

$$P_{pv} + P_{ac} = P_{dcL} + P_b$$

$$P_s = P_w - P_{acL} - P_{ac}$$

B. Standalone mode

In isolated mode, the bidirectional dc to dc converter operates either in charging or discharging mode based on power balance in the system [13]. By using either battery or boost converter the dc-link voltage is maintained based on different system operating conditions.

$$P_{pv} + P_w = P_{dcL} + P_{loss} + P_b$$

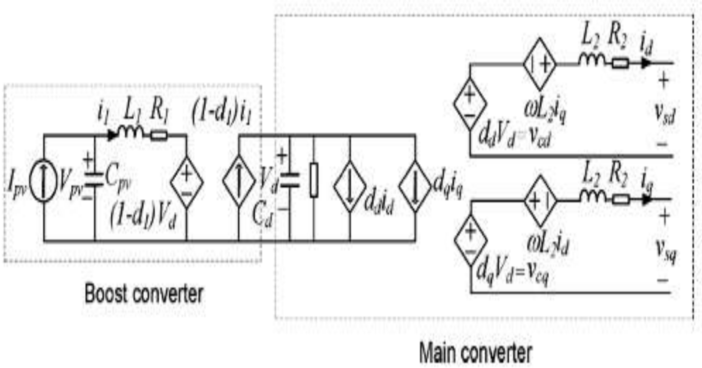

Fig.6 Control diagram for boost and main converter

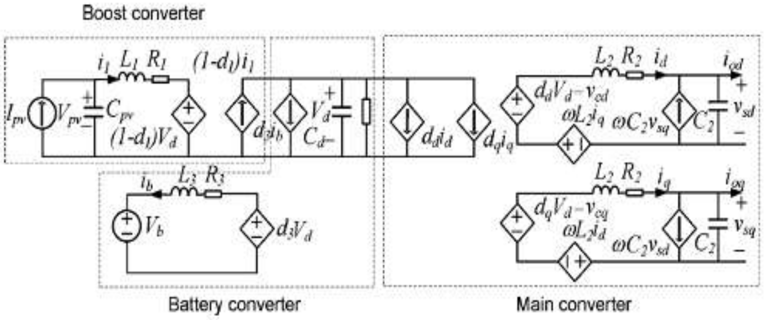

Fig.7 Equivalent circuit representation for the three converters.

The time average equivalent circuit representation of the booster and main converter is shown in Fig. 6 based on the basic principles and descriptions for booster and inverter respectively [16].

8. SIMULATION RESULT

This section presents the simulation results of the conventional and the proposed methods in order to certify the performance of the control scheme. Software simulation has been done using MATLAB/SIMULINK simulation package. The full diagram of the control methodology and the modulation is shown.

The Fig. 8 shows the terminal voltage of solar panel. The Fig. 9 shows that the voltage drops at 0.25 s and recovers quickly by the controller. Fig.11 shows the voltage (voltage times 0.2 for comparison) and current responses at the ac side of the main converter under variable solar radiation. Fig12. Shows the voltage and current response when the dc load increases from 20 kW to 40 kW at 0.25 s with a fixed irradiation level 750 W/m^2 . It can be seen from the current direction that power is injected from dc to ac grid before 0.25s and reversed after 0.25 s. Fig. 13 shows the voltage response at dc side of the bidirectional converter under the same conditions.

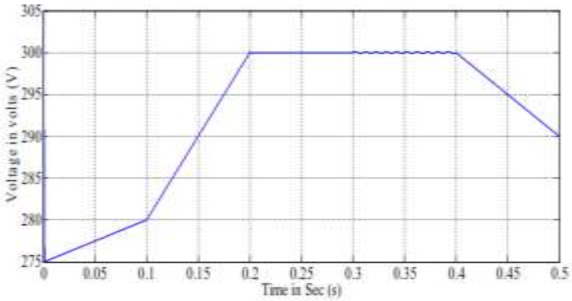

Fig.8 The terminal voltage of the solar panel

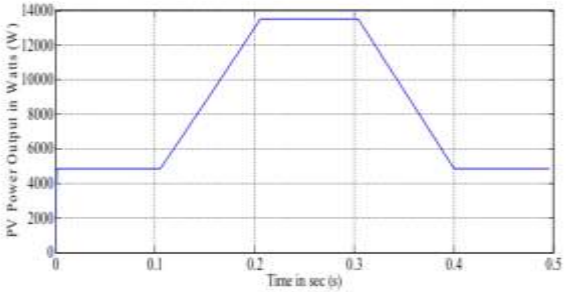

Fig.9 PV output power

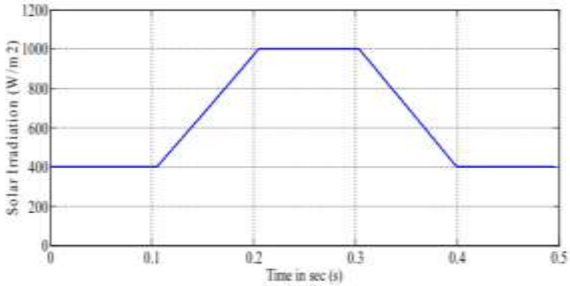

Fig. 10 Solar radiation

Different resource conditions and load capacities are tested to validate the control methods. The simulation results show that the hybrid grid can operate stably in the grid-tied or isolated mode. Stable ac and dc bus voltage can be guaranteed when the operating conditions or load capacities change in the two modes. The power is smoothly transferred.

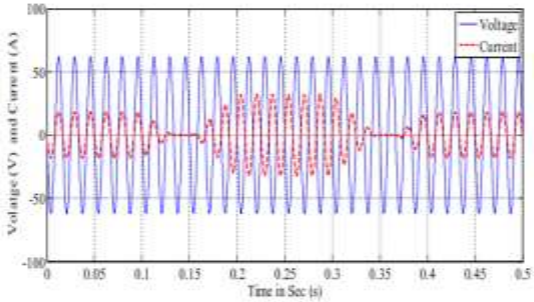

Fig.11. AC side voltage and current of the main converter with variable solar radiation

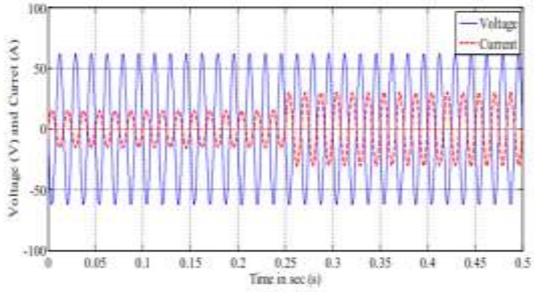

Fig.12. AC side voltage and current of the main converter with constant solar radiation

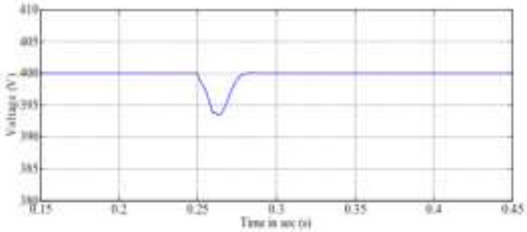

Fig.12 Voltage transient response.

9. CONCLUSION

A hybrid microgrid is proposed and briefly studied. The hybrid microgrid can decrease the processes of dc/ac and ac/dc conversions in an individual ac or dc grid. The efficient models and control schemes are proposed for the converters to maintain stable system operation under various load and resource conditions. Various control methods have been incorporated to manage the maximum power from dc and ac sources and to harmonize the power exchange between dc and ac grid. From the simulation results it is known that the hybrid grid can be stable in both the grid-tied and standalone mode. When there is a change in the operating conditions it is assured to have stable ac and dc bus voltage in both the modes. When the load condition changes, smooth power transfer is obtained.

There are some sensible problems in implementing the hybrid grid based on the current ac subjugated infrastructure. Mainly the total system efficiency depends on the reduction in various conversion losses and the increase in an additional dc link. The hybrid grid is mainly implemented where some small customers need to install their own PV systems on the roofs and are wish to use LED lighting systems. The hybrid microgrid is practicable for some isolated industrial plants with PV system as their major power supply.

REFERENCE:

[1] Y. Ito, Z. Yang and H. Akagi,"DC micro-grid based distribution power generation system," in Proc. IEEE Int. Power Electron. Motion Control Conf., Aug. 2004, Vol. 3, pp. 1740-1745.

[2] H. Zhou, T. Bhattacharya, D. Tran, T. S. T. Siew, and A. M. Khambadkone, "Composite energy storage system involving battery and ultracapacitor with dynamic energy management in microgrid applications," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 923–930, Mar. 2011.

[3] T.L.Vandoorn, B.Renders, L.Degroote, B.Meersman, and L.Vandevelde, "Active load control in islanded microgrids based on the grid voltage," *IEEE Trans. Smart Grid*, vol. 2, pp. 139–151, Mar. 2011.

[4] A. Ghazanfari, M. Hamzeh, and H. Mokhtari, "A control method for integrating hybrid power source into an islanded microgrid through CHB multilevel inverter," in Proc. IEEE Power Electron., Drive Syst. Technol. Conf., Feb. 2013, pp. 495–500.

[5] D. J. Hammerstrom, "AC versus DC distribution systems-did we get it right?," in *Proc. IEEE PowerEng. Soc. Gen. Meet.*, Jun. 2007, pp. 15.

[6] Y. Ito, Z.Yang, and H. Akagi,"DC micro-grid based distribution power generation system," in *Proc. IEEE Int. Power Electron. Motion Control Conf.*, Aug. 2004, vol. 3, pp. 1740–1745.

[7] A. Sannino, G. Postiglione, and M. H. J. Bollen, "Feasibility of a DC network for commercial facilities," *IEEE Trans. Ind. Appl.*, vol. 39, no. 5, pp. 1409–1507, Sep. 2003.

[8] A. Sannino, G. Postiglione, and M. H. J. Bollen, "Feasibility of a DC network for commercial facilities," *IEEE Trans. Ind. Appl.*, vol. 39, no. 5, pp. 1409–1507, Sep. 2003.

[9] X. Liu, P. Wang and P.C. Loh, "A hybrid AC/DC microgrid and its coordination control," *IEEE Trans. Smart Grid*, vol. 2, no. 2, pp. 278–286, 2011.

[10] V. Madhavi, J. V. R. Vithal "Modeling and Coordination Control of Hybrid AC/DC Microgrid" International Journal of Emerging Technology and Advanced Engineering Volume 4, Issue 8, August 2014

[11] S. A. Daniel and N. Ammasai Gounden, "A novel hybrid isolated generating system based on PV fed inverter-assisted wind-driven induction generators," IEEE Trans. Energy Conv., vol. 19, no. 2, pp. 416–422, Jun. 2004.

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

[13] L. A. C. Lopes and H. Sun, "Performance assessment of active frequency drifting islanding detection methods," IEEE Trans. Energy Conv., vol. 21, no. 1, pp. 171–180, Mar. 2006.

[14] L. Jong-Lick and C. Chin-Hua,"Small-signal modeling and control ZVT-PWM boost converters," IEEE Trans. Power Electron., vol. 18, no. 1, pp. 2–10, Jan. 2003.

[15]Y. Sozer and D. A. Torrey, "Modeling and control of utility interactive inverters," IEEE Trans. Power Electron., vol. 24, no. 11, pp. 2475–2483, Nov. 2009