Coordination Power Flow Control Method Of Multi Power Electronic Devices For A Hybrid Ac-Dc Micro Grid Operated In Islanding Model

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Abstract: In this paper, a hybrid ac/dc micro grid to reduce the processes of multiple dc–ac–dc or ac–dc–ac conversions in an individual ac or dc grid. The hybrid grid consists of both ac and dc networks connected together by multi-bidirectional converters. The proposed model is in such a way that the reliability of power can be maintained during the whole day. This is obtained by connecting the PV system. The proposed hybrid grid can operate in grid-tied or autonomous mode. The coordination control algorithms are proposed for smooth power transfer between ac and dc links and for stable system operation under various generation and load conditions. This micro grid works in islanding mode with a synchronous generator and PV farm supplying power to the system's AC and DC sides, respectively. A bidirectional AC-DC inverter is used to link the AC and DC sides by controlling the active and reactive power flow between them. The PV farm is connected to the DC bus through a DC-DC boost converter with maximum power point tracking (MPPT) functionality. A Battery bank is connected to the DC bus through a bidirectional DC-DC converter. The system is tested with a pulse load connected to the AC side. Simulation results verify that the proposed topology is coordinated for power management in both the AC and DC sides under critical loads with high efficiency, reliability and robustness in islanding modes. A small hybrid grid has been modeled and simulated using the Simulink in the MATLAB. The simulation results show that the system can maintain stable operation under the proposed coordination control schemes when the grid is switched from one operating condition to another.

Keywords- AC-DC inverters, DC - DC boost converter, Photovoltaic system (PV system), maximum power point tracking (MPPT), critical loads.

I. INTRODUCTION

Even though three phase ac power systems have existed for over 100 years due to their efficient transformation of ac power at different voltage levels, keeping in mind the environmental issues such as global warming, pollution, depletion of fossil fuels time had come to concentrate on renewable to concentrate on renewable sources of energy. More and more dc loads such as light-emitting diode (LED) lights and electric vehicles (EVs) are connected to ac power systems to save energy and reduce CO2 emission. When power can be fully supplied by local renewable power sources, long distance high voltage transmission is no longer necessary. A hybrid AC/DC micro grid has been proposed to facilitate the connection of renewable power sources to conventional ac systems. However, dc power from the renewable photovoltaic (PV) panels or fuel cells has to be converted into ac using dc/dc boosters and dc/ac inverters in order to connect to an ac grid. In an ac grid, embedded 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.

A. General information regarding micro grid

As electric distribution technology steps into the next century, many trends are becoming noticeable that will change the requirements of energy delivery. These modifications are being driven from both the demand side where higher energy availability and efficiency are desired and from the supply side where the integration of distributed generation and peak-shaving technologies must be accommodated [1].

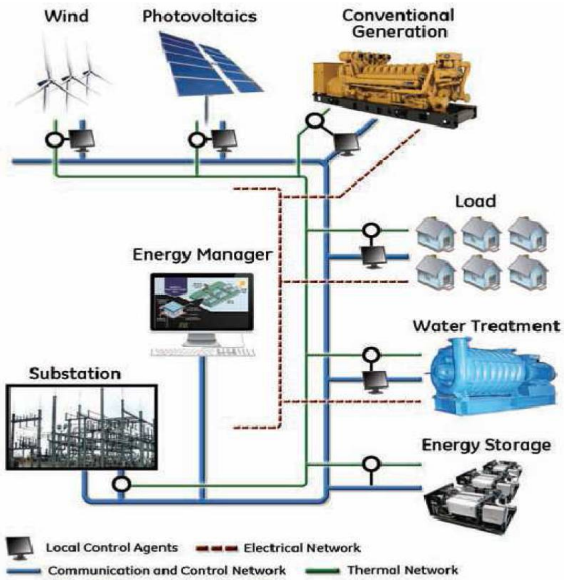

Fig1: Micro grid power system

Power systems currently undergo considerable change in operating requirements mainly as a result of deregulation and due to an increasing amount of distributed energy resources (DER). In many cases DERs include different technologies that allow generation in small scale (micro sources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having micro sources close to the load has the advantage of reducing transmission losses as well as preventing network congestions.

Moreover, the possibility of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (in Europe 230 V and in the USA 110 V) is diminished since adjacent micro sources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances.

This is identified nowadays as a micro grid. Figure 1.1 depicts a typical micro grid. The distinctive micro grid has the similar size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographic span of 1 km. Generally more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The micro grid often supplies both electricity and heat to the customers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels [2].The storing device in the micro grid is equivalent to the rotating reserve of large generators in the conventional grid which ensures the balance between energy generation and consumption especially during rapid changes in load or generation [3].

There are various advantages offered by micro grids to end-consumers, utilities and society, such as: improved energy efficiency, minimized overall energy consumption, reduced greenhouse gases and pollutant emissions, improved service quality and reliability, cost efficient electricity infrastructure replacement [2]. Technical challenges linked with the operation and controls of micro grids are immense.

Ensuring stable operation during network disturbances, maintaining stability and power quality in the islanding mode of operation necessitates the improvement of sophisticated control strategies for micro grid's inverters in order to provide stable frequency and voltage in the presence of arbitrarily varying loads [4].

II. LITERATURE SURVEY

The popularity of distributed generation systems is growing faster from last few years because of their higher operating efficiency and low emission levels. Distributed generators make use of several microsources for their operation like photovoltaic cells, batteries, micro turbines and fuel cells. During peak load hours DGs provide peak generation when the energy cost is high and stand by generation during system outages. Microgrid is built up by combining cluster of loads and parallel distributed generation systems in a certain local area. Microgrids have large power capacity and more control flexibility which accomplishes the reliability of the system as well as the requirement of power quality. Operation of microgrid needs implementation of high performance power control and voltage regulation algorithm [1]-[5].

To realize the emerging potential of distributed generation, a system approach i.e. microgrid is proposed which considers generation and associated loads as a subsystem. This approach involves local control of distributed generation and hence reduces the need for central dispatch. During disturbances by islanding generation and loads, local reliability can be higher in microgrid than the whole power system. This application makes the system efficiency double. The current implementation of microgrid incorporates sources with loads, permits for intentional islanding and use available waste heat of power generation systems [6].

Microgrid operates as a single controllable system which offers both power and heat to its local area. This concept offers a new prototype for the operation of distributed generation. To the utility microgrid can be regarded as a controllable cell of power system. In case of faults in microgrid, the main utility should be isolated from the distribution section as fast as necessary to protect loads. The isolation depends on customer's load on the microgrid. Sag compensation can be used in some cases with isolation from the distribution system to protect the critical loads [2].

The microgrid concept lowers the cost and improves the reliability of small scale distributed generators. The main purpose of this concept is to accelerate the recognition of the advantage offered by small scale distributed generators like ability to supply waste heat during the time of need. From a grid point of view, microgrid is an attractive option as it recognizes that the nation's distribution system is extensive, old and will change very slowly. This concept permits high penetration of distribution generation without requiring redesign of the distribution system itself [7].

The microgrid concept acts as solution to the problem of integrating large amount of micro generation without interrupting the utility network's operation. The microgrid or distribution network subsystem will create less trouble to the utility network than the conventional micro generation if there is proper and intelligent coordination of micro generation and loads. In case of disturbances on the main network, microgrid could potentially disconnect and continue to operate individually, which helps in improving power quality to the consumer [8].

With advancement in DGs and micro grids there is development of various essential power conditioning interfaces and their associated control for tying multiple microsources to the microgrid, and then tying the micro grids to the traditional power systems. Microgrid operation becomes highly flexible, with such interconnection and can be operated freely in the grid connected or islanded mode of operation. Each micro source can be operated like a current source with maximum power transferred to the grid for the former case. The islanded mode of operation with more balancing requirements of supply-demand would be triggered when the main grid is not comparatively larger or is simply disconnected due to the occurrence of a fault. Without a strong grid and a firm system voltage, each micro source must now regulate its own terminal voltage within an allowed range, determined by its internally generated reference. The micro source thus appears as a controlled voltage source, whose output should rightfully share the load demand with the other sources. The sharing should preferably be in proportion to their power ratings, so as not to overstress any individual entity [9].

III. PROPOSED METHODOLOGY

A hybrid AC-DC micro grid with solar energy, energy storage, and a pulse load is proposed. This micro grid can be viewed as a PEV parking garage power system or a ship's power system that utilizes sustainable energy and is influenced by a pulse load. The battery banks inject or absorb energy on the DC bus to regulate the DC side voltage. The frequency and voltage of the AC side are regulated by a bidirectional AC-DC inverter.The power flow control of these devices serves to increase the system's stability and robustness.

Fig. 2 shows the hybrid micro grid configuration where the synchronous generator, PV farm, and loads are connected to its corresponding AC and DC sides. The AC and DC sides are linked through a bidirectional three phase AC-DC inverter and transformer. The ac bus of the hybrid grid is tied to the utility grid. A compact hybrid grid as shown in Fig. 2 is modeled using the Simulink in the MATLAB to simulate system operations and controls. The proposed system works in islanding mode but can operate in grid connected mode if the AC bus is tied to the utility grid.

A 10 kW PV farm is connected to the DC bus as the DC source through a DC-DC boost converter with MPPT functionality. A 50 Ah lithium-ion battery with 108V terminal voltage is connected to the DC bus through a bidirectional DC-DC boost converter to regulate the DC bus voltage. A synchronous three phase generator with 13.8 kVA and 208V phase to phase rms terminal voltage is connected to the AC side. The rated voltages for DC and AC sides are 340 V and 208V phase to phase rms, respectively. A 15 kW pulse load is connected to AC and DC sides, respectively.

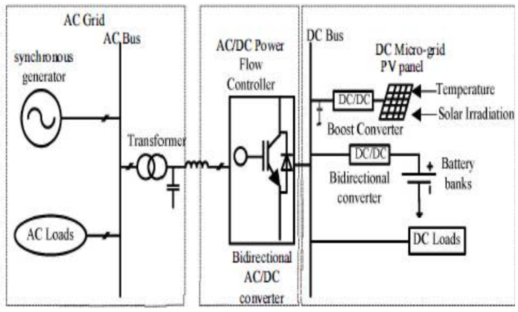

Fig 2: Hybrid AC-DC microgrid power system.

A. Grid Operation:

The hybrid grid can operate in two modes. In grid-tied mode, the main converter is to provide stable dc bus voltage and required reactive power and to exchange power between the ac and dc buses. When the output power of the dc sources is greater than the dc loads, the converter acts as an inverter and injects power from dc to ac side. When the total power generation is less than the total load at the dc side, the converter injects power from the ac to dc side. When the total power generation is greater than the total load in the hybrid grid, it will inject power to the utility grid.

Otherwise, the hybrid grid will receive power from the utility grid. In the grid tied mode, the battery converter is not very important in system operation because power is balanced by the utility grid. In autonomous mode, the battery plays a very important role for both power balance and voltage stability. DC bus voltage is maintained stable by a battery converter or boost converter according to different operating conditions. The main converter is controlled to provide a stable and high quality ac bus voltage. The PV system can operate on maximum power point tracking (MPPT).

B. PV System:

A mathematical model was developed in order to simulate a PV array. Fig. 1 gives the equivalent circuit of a single solar cell, where *IPV* and *VPV* are the PV array’s current and voltage, respectively, *Iph* is the cell’s photocurrent, *Rj* represents the nonlinear resistance of the p-n junction, and *Rsh* and *Rs* are the intrinsic shunt and series resistances of the cell.

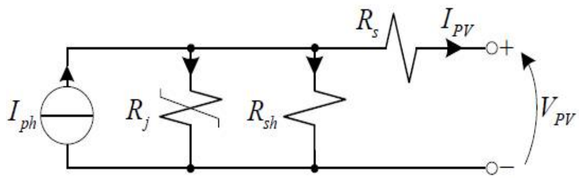

Fig 3: Equivalent circuit of PV cell

Since *Rsh* is very large and *Rs* is very small, these terms can be neglected in order to simplify the electrical model. The following equation then describes the PV panel [6]:

$$I_{PV} = n_p \cdot I_{ph} - n_p \cdot I_{rs} \cdot \left[\exp\left(\frac{q}{k \cdot T \cdot A} \cdot \frac{V_{PV}}{n_s} \right) - 1 \right] \quad (1)$$

where *ns* and *np* are the number of cells connected in series and the in parallel, q=1.602·10-19 C is the electron charge, k=1.3806·10-23 J·K-1 is Boltzman's constant, A=2 is the p-n junction's ideality factor, T is the cell's temperature (K), *Iph* is the cell's photocurrent (it depends on the solar irradiation and temperature), and *Irs* is the cell's reverse saturation current (it depends on temperature).

The PV panel here considered is a typical 50W PV module composed by *ns*=36 series-connected polycrystalline cells (*np*=1). Its main specifications are shown in Table 1. The PV array is composed of three strings in parallel, each string consisting of 31 PV panels in series. The total power is 4650W.

Table 1. Electrical characteristics of PV Panel with an irradiance level of 1000 W/m2

Symbol	Quantity	Value
P_{MPP}	Maximum Power	50 W
V_{MPP}	Voltage at P_{MPP}	17.3 V
I_{MPP}	Voltage at I_{MPP}	2.89 A
I_{sc}	Short-Circuit Current	3.17 A
V_{ov}	Open-Circuit Voltage	21.8 V
T_{SC}	Temperature coefficient of I_{SC}	(0.065±0.015)%/°C
T_{OC}	Temperature coefficient of V_{OC}	-(80±10) mV/°C

C. Boost Converter

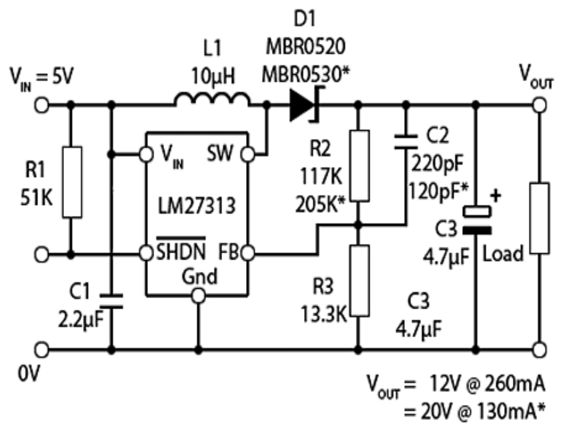

Fig 4: Typical I.C. Boost Converter (LM27313)

Because of the ease with which boost converters can supply large over voltages, they will almost always include some regulation to control the output voltage, and there are many I.Cs. manufactured for this purpose A typical example of an I.C. boost converter is shown in Fig. 3.2.6, in this example theLM27313 from Texas Instruments. This chip is designed for use in low power systems such as PDAs, cameras, mobile phones, and GPS devices.

In this circuit, an appropriate fraction of the output voltage (V_{OUT}), dependent on the ratio of R2:R3 is used as a sample and compared with a reference voltage within the I.C. This produces an error voltage that is used to alter the duty cycle of the switching oscillator, enabling a range of automatically regulated boost voltages between 5V and 28V to be obtained.

The LM27313 contains an internal oscillator operating at a fixed frequency of about 1.6MHz. The FET switching transistor is also internal and switches the current through L1 via the SW terminal. Notice also that a Schottky diode with an appropriate voltage and current rating is used for D1 to keep losses due to the forward voltage drop of the diode as small as possible, and to enable high switching speeds to be achieved. The I.C. also has a shut down (SHDN) facility, operated by external logic, by which the boost converter may be disabled when not required, to save battery power.

IV. SIMULATION RESULTS

Simulation was done on MATLAB R2013a, the results was shown that the system can maintain stable operation under the proposed coordination control schemes when the grid is switched from one operating condition to another.

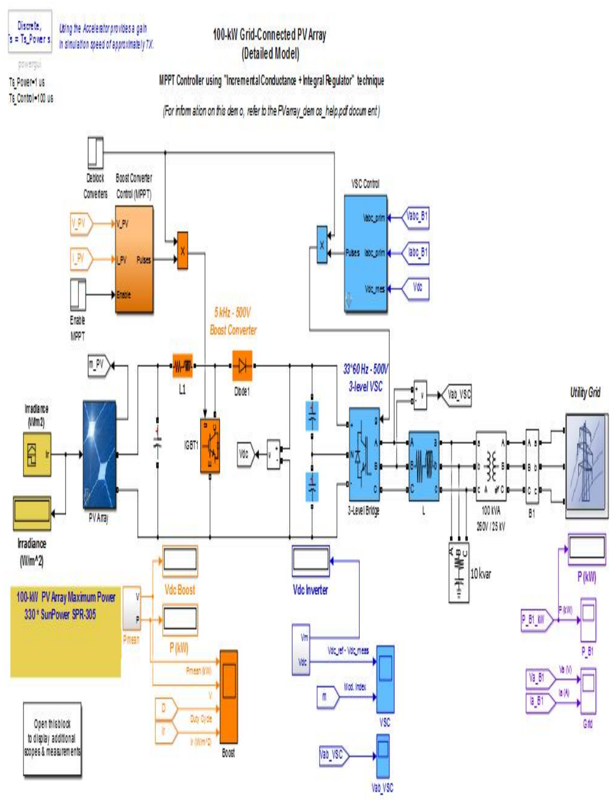

Fig 5: Matlab/Simulink diagram of proposed AC-DC converter.

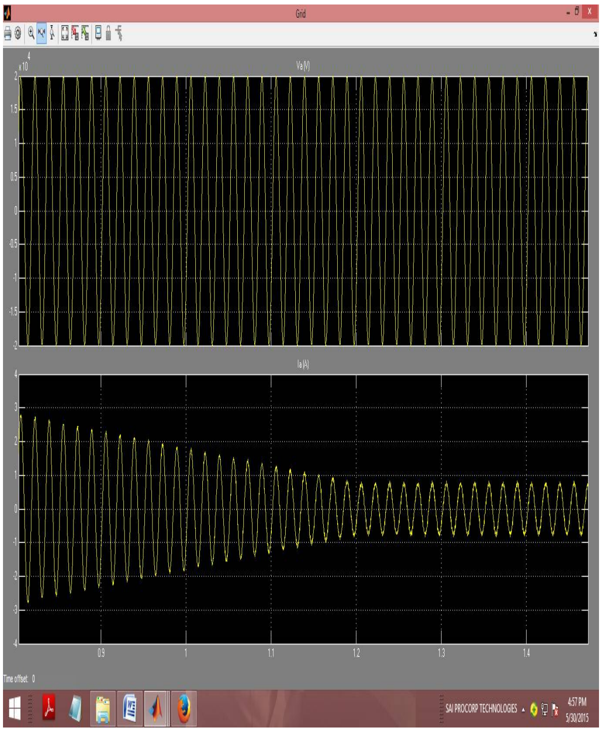

Fig 6: grid output

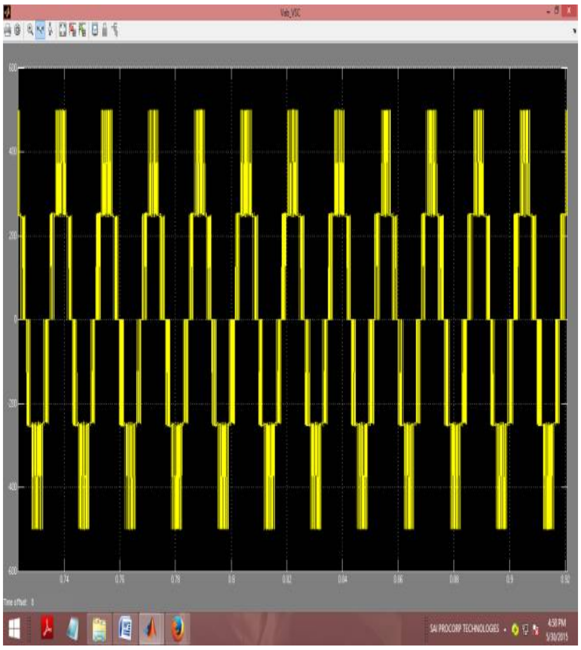

Fig 7: Vdc inverter output

V. CONCLUSION

A hybrid ac/dc microgrid is proposed and comprehensively studied in this paper. The models and coordination control schemes are proposed for the all the converters to maintain stable system operation under various load and resource conditions. The coordinated control strategies are verified by Matlab/Simulink.. Various control methods have been incorporated to harness the maximum power from dc and ac sources and to coordinate the power exchange between dc and ac grid. 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 when load condition changes. It is also difficult for companies to redesign their home and office products without the embedded ac/dc rectifiers although it is theoretically possible. Therefore, the hybrid grids may be implemented when some small customers want to install their own PV systems on the roofs and are willing to use LED lighting systems and EV charging systems.

VI. REFERENCES

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