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Research Paper Engineering

Control of Islanded Mode of Micro Grid

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ABSTRACT

Micro grid is defined as the cluster of multiple distributed generators (DGs) such as renewable energy sources that supply electrical energy. The connection of micro grid is in parallel with the main grid. When micro grid is isolated from remainder of the utility system, it is said to be in intentional islanding mode. In this mode, DG inverter system operates in voltage control mode to provide constant voltage to the local load. The main contribution of this paper is summarized as , Design of a network based control scheme for inverter based sources, which provides proper current control during grid connected mode and voltage control during islanding mode. From the simulation results using Simulink dynamic models, it can be shown that these controllers provide the micro grid with a deterministic and reliable connection to the grid.

Keywords : Distributed generation (DG),dc-dc boost converter, intentional islanding operation and micro grid, voltage source converter, Pulse width modulation, simulation and result

I. INTRODUCTION

Around the world, conventional power system is facing the problems of gradual depletion of fossil fuel resources, poor energy efficiency and environmental pollution. These problems have led to a new trend of generating power locally at distribution voltage level by using non-conventional/renewable energy sources like natural gas, biogas, wind power, solar photovoltaic cells, fuel cells, combined heat and power (CHP) systems, micro turbines, and Sterling engines and their integration into the utility distribution network [1]-[2]. This type of power generation is termed as distributed generation (DG) and the energy sources are termed as distributed energy resources (DERs).

They can supply uninterruptible power, improve local reliability, reduce feeder losses and provide local voltage support. From environmental point of view, micro grids reduce environmental pollution and global warming through utilization of low-carbon technology. The typical micro grid structure is shown in Fig 1 In the Fig.1 it consists of three radial feeders (A, B and C) to supply the electrical and heat loads. It also has two CHP and two non-CHP micro sources and storage devices. Micro sources and storage devices are connected to feeders A and C through micro source controllers (MCs). Some loads on feeders A and C are assumed to be priority loads, while others are non-priority loads. Feeder B, however, contains only non-priority electrical loads. The micro grid is coupled with the main medium voltage (MV) utility grid through the PCC (point of common coupling) circuit breaker CB4 as per

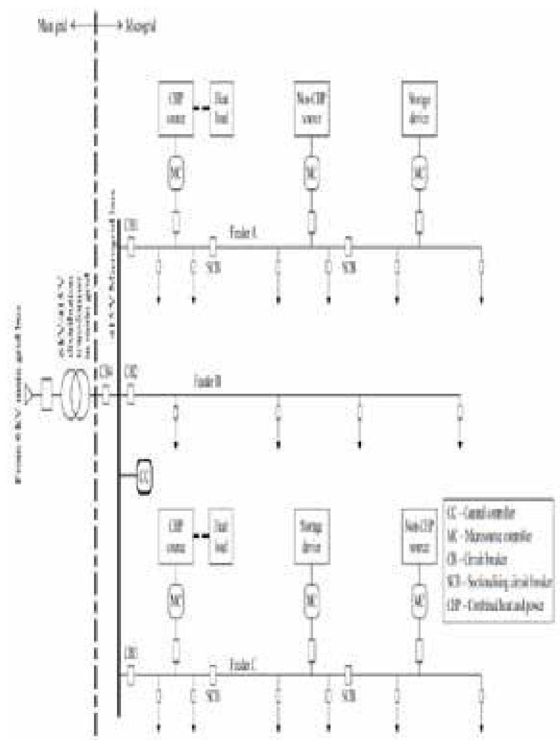

Fig.1 A Typical micro grid structure [3]

standard interface regulations. CB4 is operated to connect and disconnect the entire micro grid from the main grid as per the selected mode of operation. The micro sources on feeders A and C are placed quite apart from the micro grid bus to ensure reduction in line losses, good voltage profile and optimal use of waste heat..The micro grid is operated in two modes:

(1) Grid-connected
(2) Stand alone.

In grid-connected mode, the micro grid remains connected to the main grid either totally or partially, and imports or exports power from or to the main grid. In case of any disturbance in the main grid, the micro grid switches over to stand-alone mode while still feeding power to the priority loads

II. DC-DC BOOST CONVERTER

The circuit of the PWM boost dc–dc converter is shown in Fig.2 (a). Its output voltage Vo is always higher than the input voltage V1 for steady-state operation of the Converter. It 'boosts' the voltage to a higher level. The converter consists of an inductor L, a power MOSFET, a diode D, a filter capacitor C, and a load resistor RL. The switch S gets turned on and off at the switching frequency fs = 1/T with the ON duty ratio D = ton/T, where ton is the time interval when the switch S is ON. The boost converter can operate in either continuous or discontinuous conduction mode. It depends on the waveform of the inductor current. The boost converter in DCM cannot operate at RL =∞ because the filter capacitor has no path to discharge. The CCM operation will be considered here. Fig.2 (b)–(c) shows the equivalent circuits of the boost converter for CCM. When the switch S is ON and the diode is OFF, and when the switch is OFF and the diode is ON, respectively [8]. The analysis of the boost PWM converter shown in Fig.2 (a) begins with the following

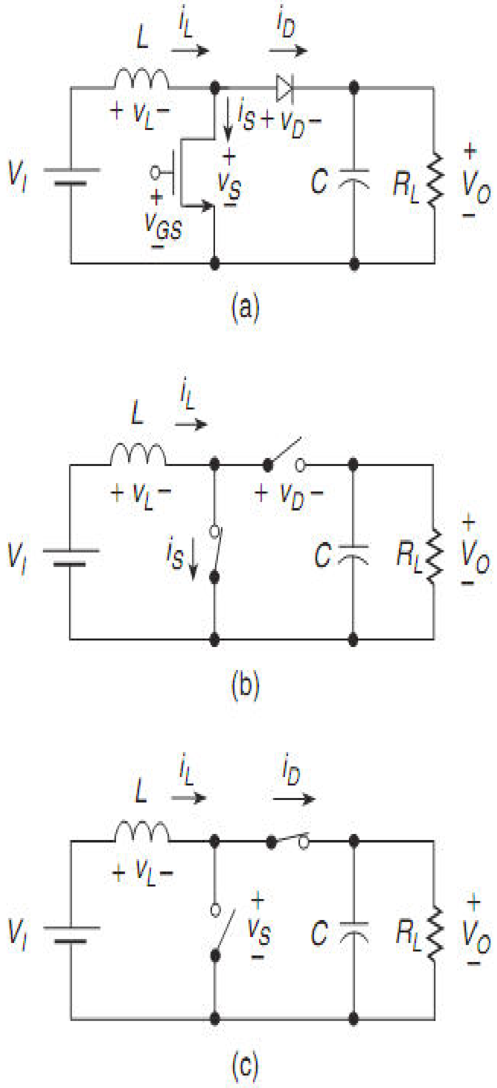

Fig.2 PWM boost converter and its ideal equivalent circuits for CCM. (a) Circuit.(b) Equivalent circuit when the switch is ON and the diode is OFF. (c) Equivalent circuit when the switch is OFF and the diode is ON [8]

III. DESIGN OF L-C FILTER

Use of power converters will also introduce undesirable harmonics that can affect nearby loads at the point of common coupling to the grid. Hence all such converters have a filter to eliminate these harmonics.. There are certain simplifying assumptions that are made to analyze the frequency characteristics of the grid connected as well as islanded low pass filter. The assumptions are made to keep the initial design simple. All filter elements are considered ideal, i.e. no winding resistance, inter-turn/inter winding capacitance in case of inductor, and no equivalent series resistance, parasitic inductance in case of capacitor. Grid is considered as an ideal voltage source, i.e. zero impedance, and supplying constant voltage/current at fundamental (50Hz) frequency. The filter design procedure is appropriate for grid connected PWM voltage-source inverters. Current source inverters are not considered.

IV. ISLANDED DISTRIBUTED ENERGY RESOURCES

In a distribution system, when a Utility grid is disconnected for any reason, the Distributed generation still supplies the required power to any section of local loads. Phenomenon is called "Islanding Phenomena"..

Islanding once again can be classified into two types namely:

(i) Unintentional Islanding
(ii) Intentional Islanding
(i) Unintentional islanding: As the name suggests is an undesirable islanding caused in a power grid. It occurs when a part of the distribution system becomes electrically isolated from the whole power grid and is still being energized by the distributed generators. The reason for such occurrence of islanding is due to several reasons such as inverter misinterpreting the voltage and frequency harmonics of utility grid, ground fault on the feeder from grid etc
(ii) Intentional Islanding: Intentional islanding can be explained as a purposeful islanding of a micro grid from the remaining power grid system. When there is a power outage, many distributed generators may go out of synchronous with one another and therefore it is required to have specific islands at points where there is a slight mismatch between load and generation. Circuit breaking operations are executed to develop islanded systems.

V. CONTROL OF DER UNIT IN ISLANDED MODE

A schematic diagram of a DER unit is shown in Fig. 3 , consisting of a current-controlled Voltage Source Inverter (VSI) and a three phase LC filter that supplies an isolated distribution network. Components L and C_f represent the inductance and capacitance of the filter. R Models the ohmic loss of filter inductor and also includes the effect of the on-state resistance of the VSI valves. The VSI DC side is paralleled with the DC-link capacitor C and a controlled voltage source.

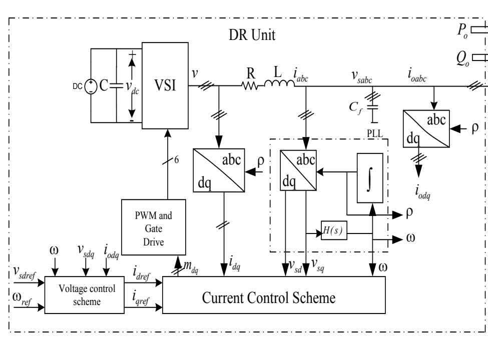

Fig.3 DER single unit in islanded mode

Fig.3 illustrates that the control is performed in a rotating $dq0$ reference frame whose *d* axis makes an angle ρ with respect to the the stationary a axis. ρ is obtained from a PLL which constitutes an essential part of a modern electronically-coupled DER unit. The PLL also provides ω, i.e. the frequency of v_{sabc} .In the grid connected mode of operation, v_{sabc} is dictated by the grid in which case ρ and ω represent the phase-angle of the PCC voltage and power system frequency, respectively. In, islanded mode, however, the switch S is open and the DER unit of Fig.3, solely supplies the load. Thus, the control objective is to regulate the amplitude and frequency of the PCC/load voltage, i.e. v_{sabc}.

VI. CONTROL OF ISLANDED DER UNIT

In the islanded mode, the control of DER unit involves regulation of PCC line to neutral voltage magnitude, i.e. $\hat{v}_s = \sqrt{v_{sd}^2 + v_{sq}^2}$ and the frequency ω. Therefore the regulation of the voltage magnitude boils down to that of v_{sd}. On the other hand, based on (11) the frequency cannot be controlled by v_{sq}. However, the control of v_{sd} and v_{sq} is not a straightforward task due to following reasons Based on (8) through , the open loop control plant is nonlinear. Based on (8) and (9), dynamics of v_{sd} and v_{sq} are coupled. Dynamics of the load are, in general, highly inter-coupled, of a high dynamic order, and nonlinear, even for a fairly simple load (e.g. RL load). Fig.4 illustrates a control scheme, capable of largely overcoming the foregoing issues, in which the compensators $k(s)$ are PI controllers for d and q axis control loops. Fig.4 shows that feed forward signals are used to eliminate the coupling between v_{sd} and v_{sq}. The decoupling mechanism used here is similar to that used to decouple i_d and i_q in the current control scheme. The control scheme of Fig.4 enables independent control of v_{sd} and v_{sq}, respectively, by i_{dref} and i_{qref}. Fig.4 shows that measures of i_{od} and i_{oq} are included in the control process as two other feed forward signals, to mitigate the impact of load dynamics on v_{sd} and v_{sq}. The reason for the effectiveness of the control scheme of Fig.4 can be understood based on the following equations

$$L\frac{di_d}{dt} = -\left(R-\left(K_{iiid}+\frac{K_i}{s}\right)\right)i - \left(K + \frac{K_i}{s}\right)i \quad (1)$$

$$L\frac{di_q}{dt} = -\left(R-\left(K_{iiid}+\frac{K_i}{s}\right)\right)i - \left(K + \frac{K_i}{s}\right)i \quad (2)$$

It is obvious that iq and id is decoupled. Fig.4 shows the structure of this current control strategy.

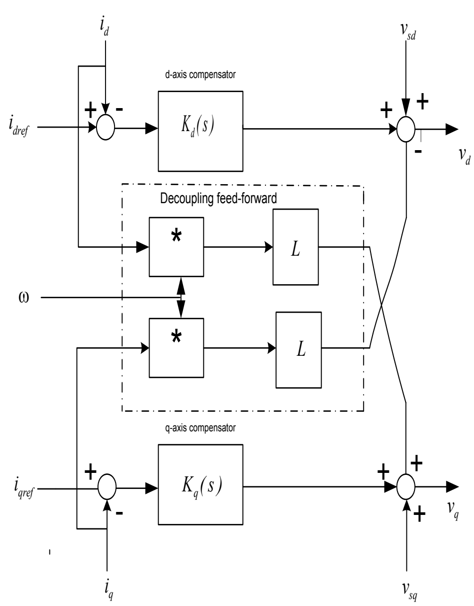

Fig.4 Block diagram of current control loop

VII.VOLTAGE SOURCE INVERTER TOPOLOGIE

The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable A three phase, three leg, voltage source inverter with input DC source and three phase AC output LC filters is shown in Fig.5 [13] and the eight valid switch states are given. The switches of any leg of the inverter cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. In order to generate a given voltage waveform, the inverter moves from one state to another. Thus the resulting ac output line voltages consist of discrete values of voltages that are Vi/2, and –Vi/2 for the topology shown . The LC filter eliminates harmonics and provides a near sinusoidal output voltage. In Fig. 5, v_{dc} is input dc source voltage and L_a, L_b, L_c and C_a, C_b, C_c are filter inductances and capacitances, respectively. The impedance z_{load} represents the load impedance. Voltages v_{la}, v_{lb}, v_{lc} are load voltages and i_{Labc}, i_{oabc} are three phase filter inductor currents and load (output) currents respectively. Switches S_a, S_b, S_c are top switches and switches S'_a, S'_b, S'_c are bottom switches.

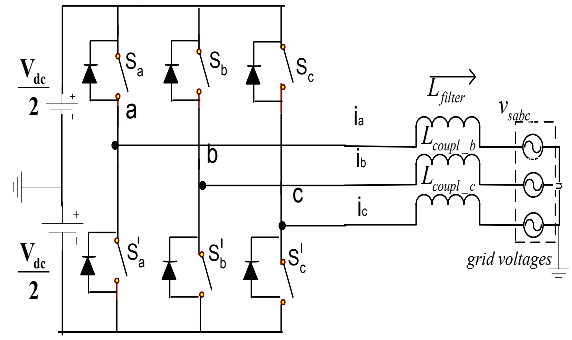

Fig.5 Neutral Clamped Voltage Source Inverter

VIII. PULSE WIDTH MODULATION TECHNIQUE

The pulse width modulator is used to generate the firing pulses. The pulses are generated by comparing a triangular carrier waveform to a reference modulating signal [14]. The amplitude, phase, and frequency of the reference signals are set to control the output voltage of three phase VSI.

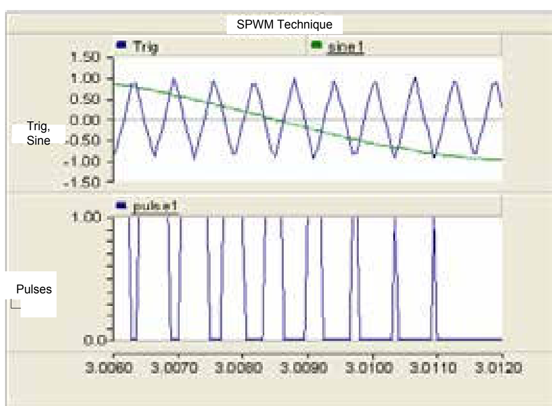

Fig.6 Sine-Triangle pulse width modulation

When the reference voltage signal at point a shown in Fig.6 is compared with carrier signal (triangular wave is used generally) and if reference signal is greater than carrier signal S_a is switched on (S_a=1), otherwise S'_a is on (S'_a=1). The peak value of per phase fundamental voltage obtained using SPWM technique is given by

$$v_o = m_a v_{DC}/2 \quad (3)$$

Where, m_a is amplitude modulation index, which is the ratio of peak value of reference signal to peak value of carrier signal.

IX. SIMULATION AND RESULT

A. PI controlled close loop dc-dc Converter

To verify the control structure presented for designed close loop dc-dc converter and showed the proper working of designed controller. simulation study is carried out in Matlab/Simulink.

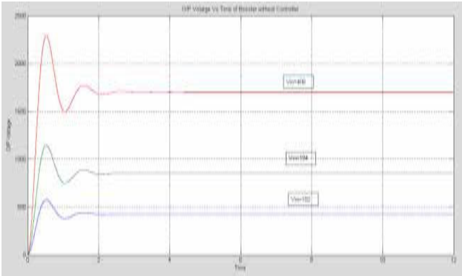

Fig.7 Output voltage of boost converter without controller

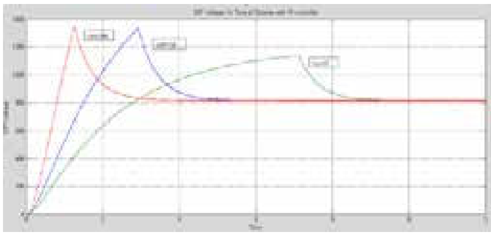

Fig. 7.1 Output voltage of boost converter without controller

Fig.7 shows the behavior of the output voltages of the dc-dc boost converter without having any control on its duty ratio. As we want to have constant dc bus voltage (814V) but from Fig.8 it can easily be observed that the output voltage gets changed as we change input voltage. Fig.7.1 shows that our controller is working nicely and a good range of control in variation of the input voltage is achieved, which can be seen in Fig.7.1 PI controller gives a controlled output of 814 V when the input voltage is 97 V and 388V. This is a range for a designed controller gives a proper output voltage with an acceptable transient period.

B. **Results of the Designed LC Filter**

A low pass filter is used to maintain the frequency of the inverter voltage to 50 Hz. A series inductor (L) and a parallel (C) is used to attenuate any frequency above 50 Hz. The designing of this filter has been explained.

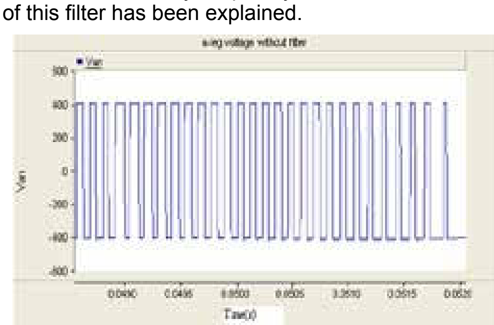

Fig.8 Inverter a- leg voltage before the filter

As seen in the above Fig.8, the inverter successfully converted the input direct current which is supplied by a DC source into an AC voltage. The inverter initially produces a PWM wave which develops due to the uni-polar switching of the IGBT diodes of inverter.

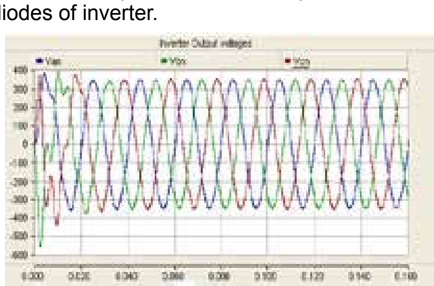

Fig.8.1 Inverter output voltages after filter

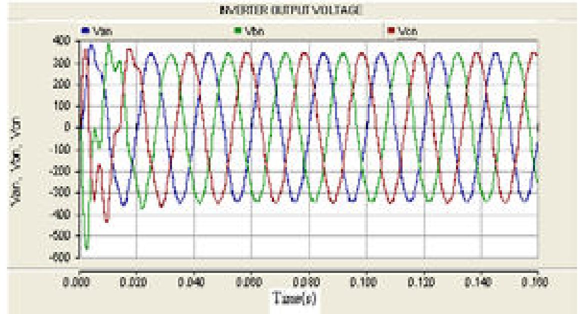

Fig. 8.2 Inverter output voltages at no load condition

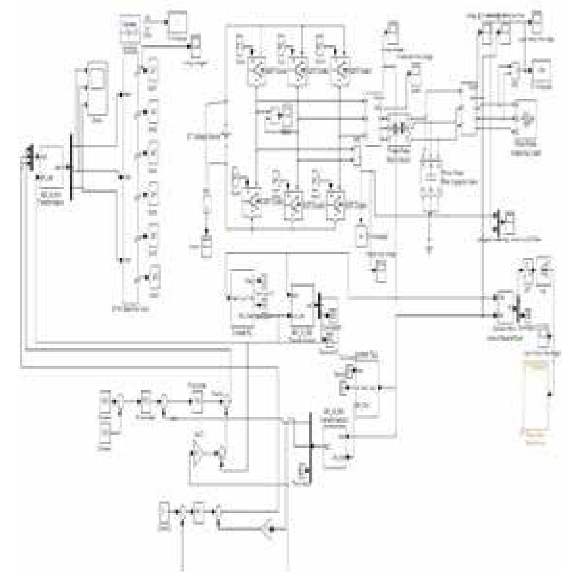

Fig.9 Model of islanded mode of MG with controller

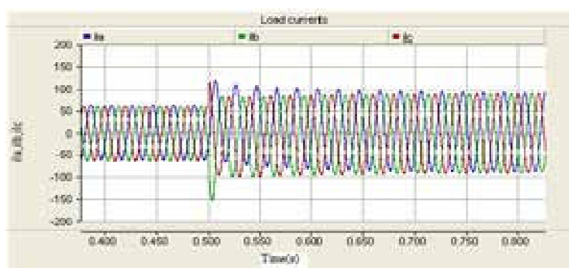

Fig. 9.1 Zoomed in load currents at 0.5 second

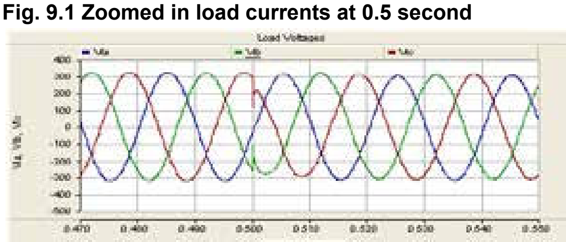

Fig. 9.2 Zoomed in load voltages at 0.5 second

X. ACKNOWLEDGMENT

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CONCLUSION:

At present there are two major issues with Micro grid structure. 1) Islanding and 2) Interfacing with the utility grid. In the islanded mode of operation critical or local load requires constant voltage with constant frequency. As load changes there is a sudden drop in voltage and frequency which are undesirable. Also by LC filter we can keep the frequency up to it's permissible limit, because output of inverter having harmonic, To reduced that harmonic contain and get sinusoidal waveform here we had design LC filter. Also we design SPWM for switching operation of Inverter, SPWM produced gate pulse by comparing carrier wave (Triangular wave) and reference wave (Sinusoidal wave).

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