Analysis the Performance of Three Phase Inverter Using Hierarchical Control Methods in Microgrid

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Abstract— Microgrids (MGs) consists of Voltage Source Inverters (VSIs) which are parallel connected. In this paper the steps towards the stability of these MGs have been achieved. With this situation, this system is assured of two control levels using hierarchical control scheme for the parallel operated VSI system. In order to enhance the stability of voltage and frequency of microgrid, several control methods are used. The droop method pursues the virtual impedance loops composed of primary control. The unified Phase Shift Modulation (PSM) technique renovates the frequency and amplitude deviations twisted by the droop method composed of secondary control. This technique regulates the phase and magnitude of voltage which can be analyzed based on zero crossings of the voltage and also available for connecting the main grid to the MG. Simulation results are provided not only to be acquainted with the good frequency as well as enhancing the voltage amplitude which enhances the stability of the Microgrid (MG) control system. Comparative results between the synchronization algorithm and Unified Phase Shift Modulation (PSM) technique shows which technique which attains the stable frequency quickly by comparing the two techniques.

Keywords— Voltage Source Inverters (VSIs), Distributed Generation System (DGS), droop method, virtual impedance concepts, hierarchical control, Microgrid (MG), Unified Phase Shift Modulation (UPSM) Technique.

I. INTRODUCTION

With the raise of usage of electrical areas curiosity in Microgrids (MGs) is enhanced. Because of smart grid system novel power electronic equipment will preside over the electrical grid in the next decades. Consistently Voltage Source Inverters (VSIs) are born as interface of power electronics; consequently, the formation of MG can be achieved by controlling the parallel operated VSIs has been analysed in the last few years [1]–[9]. This is due to the facts, the hierarchical control systems are predictable, which are capable to contrive both in Island mode and grid connected mode.

Renewable energy resources are hastily escalating due to the facts that larger power plants are economically unfeasible in many regions because of increasing system, fuel costs and stricter environmental regulations. These DGS are often connected to the utility grid or Microgrid through a power electronic interface converter. Microgrid is a local grid consisting of generation, transmission system and dispersed loads which may operate in grid connected or islanded mode.

The DC source worn out at this juncture is solar panel to augment the better economic as well as eco friendly environmental fact.

Electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It is composed of generating stations that produce electrical power, high voltage transmission lines that carry power from distant sources to demand centers and distribution lines that connect customers. A Microgrid is a small scale power grid that can operate independently or in conjunction with the area’s main electrical grid. Any small scale localized station with its own power resources, generation and loads and definable boundaries qualifies as a Microgrid. Microgrids can be intended as backup power or to strengthen the main power grid during periods of heavy demand. Often, Microgrids involve multiple energy sources as a way of incorporating renewable power. Other purposes include reducing costs and enhancing reliability.

In order to improve the consistency and performances of the droop controlled VSIs the virtual impedance loop have been developed, providing to the inverters with harmonic power sharing, hot swap operation, etc [10]. The focal predicament to be completed in such work is the frequency control of the system. Nevertheless, voltage stability and synchronization issues are additionally of the essence to get done adequate suppleness to manoeuvre in both mode.

Based on dynamically changing loads the frequency droop control is used for allowing multiple generating units to automatically change their power outputs. If the system remains stable, all the other units would pick up the slack, but the droop characteristic allows the frequency to settle at a steady state value below its nominal value (for example, 49.7Hz or 59.7hz). Other controllers are therefore necessary to bring the frequency back to its nominal value (i.e.50Hz or 60Hz), which is called secondary control. It is mandatory to concern for communication systems to propel information among the DG units to utilize such a category of multilevel control algorithm [17]–[20]. In order to eliminate the negative aspects of droop controlled VSIs, some implications were done by combination of low bandwidth communications with average power sharing, droop control and extra harmonic compensation control loops [18], [19].

A distributed synchronization control loop is unavoidable [1] in order to connect the main grid to the MG. At the point of common coupling, it is inevitable to control the active and reactive power flows after the transfer process between grid connected and islanded mode is refined. Gain over this system is if one inverter trips, another can competent to distribute the supply to the non linear load, the system will still stay behind stable [21]. These all specifics point up the consistency and the excellent performance of the MG control system.

The Multilevel inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations. Nowadays many industrial applications have begun to require high power. Two inverters are used in order to provide the uninterrupted supply to the load. Diode clamped inverters are preferable.
among the various types of inverters since it is plausible to weaken the stress on other electrical devices and provide the multiple voltage level.

The synthesized output waveform has more steps which provide a staircase wave that approaches a desired waveform as number of levels increases and also the harmonic distortion of the output wave decreases. Several control modulation methods are implemented in order to maintain the stability of frequency. This modulation technique achieves faster transmission of signals and also makes the system to attain the frequency stable and voltage amplitude of the Microgrid control system.

This paper is prearranged as follows. In Section II describes the primary control consist of droop method and virtual impedance concepts. Section III illustrates the secondary control for frequency and voltage amplitude restoration using synchronization technique and Unified Phase Shift Modulation (PSM) technique. Section IV clarifies the comparison of simulation results between synchronization technique and Unified PSM technique. Finally, Section V shows the conclusion of this paper.

II. PRIMARY CONTROL

The control proposed for the parallel operated VSI system is based on the droop control framework, which contains the voltage and current control loops, the virtual impedance loop and the droop control methods. These control methods are used inorder to regulate the frequency and amplitude of the voltage reference with the inner current and voltage control loops. By droop functions the reference voltage $V_{ref}$, frequency and amplitude will be controlled, which is generated in abc and transformed to αβ coordinates using the well known Clarke transformation. In addition currents and voltages are transformed to αβ coordinates using the same transformation. The above statement can be combined in VSIs using the P/Q droop method as follows,

$$\omega = \omega^* - G_\omega(s)(P - P^*)$$

$$E = E^* - G_\alpha(s)(Q - Q^*)$$

Where $\omega^*$ and $E^*$ corresponds to their references, P and Q are the active and reactive power, $\omega$ and E specifies the reference output voltage of the frequency and amplitude, $P^*$ and $Q^*$ are their references and $G_\omega(S)$ and $G_\alpha(S)$ are their transfer functions.

A. Droop Control and Virtual Impedance Loop

The droop method combined of subtracting relative parts of the output standard active and reactive powers from the frequency and amplitude of each section for imitate the virtual inertias in parallel connected inverters. For sharing active and the reactive power this control is used. These control modules have been applied for paralleled inverters with UPS systems to evade mutual control wires while obtaining good power sharing [4].

This control method is used in this level to emulate physical behaviours to avoid circulating currents among the converters without using any critical communication between them that makes the system stable and more damped. With the subsequent correlation [16], this method calculates $P$ and $Q$ in the αβ coordinates from power block computation as,

$$p = v_{ca}i_{oc} + v_{c\beta}i_{c\beta}$$

$$q = v_{c\beta}i_{oc} - v_{ca}i_{c\beta}$$

With p and q represents the instantaneous active and reactive powers and $i_{oc}$ and $V_{oc}$ represents the output current and the capacitor voltage respectively. The implementation of the droop control and the virtual output impedance is shown in Fig.1. Inorder to avoid the negative aspect of droop control method virtual impedance method is used. The block diagram of two VSIs forming an MG is shown in fig.2. The droop characteristic allows multiple units to share load without the units fighting each other to control the load. To restore the initial frequency of the inverters using an integrator and also to avoid frequency deviation by shifting the droop function various methods are implemented.

![Fig.1. Block Diagram of the Droop Control and the Virtual Output Impedance in αβ Co-ordinates.](http://www.ijre.org)

![Fig.2. Block Diagram of Two VSIs forming an MG.](http://www.ijre.org)
eradicate any steady state error pioneered by the primary control [15], [16]. This control is also called Automatic Generation Control (AGC), the use of frequency data is appropriate for low bandwidth communications as an alternative of using phase or time domain information, which would be crucial for critical high speed communication.

A. Using Synchronization Algorithm

The secondary be in charge of be supposed to exact the frequency deviation contained by the tolerable limit with enchanting the grid constraint [22].

i) Frequency Restoration

To investigate the system stability as well as to regulate the parameters of the frequency secondary control, a model has been proposed as shown in fig 3. It allocates for regulating the

Fig.3. Block Diagram of the Frequency Secondary Control control parameters of the secondary control as well as to cram the inadequacy of the communication delay. It comprises the droop control of the system, the simplified PLL first order transfer function used to extort the frequency of the MG and the secondary control $G_{f, sec}(s)$, pursued by a delay $G_d(\tau)$ for the communication lines.

ii) Amplitude Restoration

Similar process has been applied for designing the voltage secondary controller as well as for obtaining the closed loop voltage dynamic model. Fig.4 represents the block diagram of the amplitude secondary control. To renovate the deviations twisted by the primary control, this control will be implemented using an external centralized controller.

Fig.4. Block Diagram of the Amplitude Secondary Control

B. Using Unified PSM Technique

The novel technique called Unified PSM technique is proposed which can unconventionally standardize the phase and magnitude of the voltage. The controllers of phase and magnitude incorporated by this modulation can accomplish optimized output synchronization. This technique is easily related for parallel operation of inverters and also it is simple while comparing frequency modulation techniques. This technique can probable to acquire the reference voltage which accomplish the fast renovation of frequency and the voltage amplitude of the microgrid when grid failure occurs. The flowchart for Unified PSM technique is shown in fig.5.

Advantages over Unified PSM technique is easy matched against frequency modulation.

Fig.5. Flowchart for unified PSM technique

This technique achieves the faster transmission of signals results in decreasing the raising time of the system, thus improves the stability of the frequency.

IV. COMPARISON OF SIMULATION RESULTS

Some simulation results from a 3ϕ inverter MG are accessible. The comparative simulation result identifies the technique which attains the stable frequency quickly by comparing the two algorithms. The selected control parameters and the data are listed in Table1 for simulation.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Simulation parameters</th>
<th>Values</th>
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<tbody>
<tr>
<td>1</td>
<td>Nominal DC source voltage</td>
<td>500 V</td>
</tr>
<tr>
<td>2</td>
<td>Solar Panel</td>
<td>63 kW</td>
</tr>
<tr>
<td>3</td>
<td>DC source current rating</td>
<td>200 A</td>
</tr>
<tr>
<td>4</td>
<td>Inverter voltage</td>
<td>440 V</td>
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<td></td>
<td></td>
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<tr>
<td>---</td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td>Inverter current rating</td>
<td>100A</td>
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<tr>
<td>6</td>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>7</td>
<td>Nonlinear load</td>
<td>180 KW</td>
</tr>
<tr>
<td>8</td>
<td>Grid Load</td>
<td>40W</td>
</tr>
</tbody>
</table>

### A. Synchronization Algorithm

At first, both inverters were connected and provided supply to the load. Later, at $t = 1.2s$, some interruption occurred and the inverter 1 was disjointed from the MG.

**Fig.6.** Output Voltage Waveform of Inverter 1

After $t = 1.2s$, inverter 2 is supplying all the required power. The primary control produces frequency and amplitude deviations, which can be remunerated by the secondary control loops. These control loops avoid the inherent steady state error produced by the primary control.

**Fig.7.** Output Voltage Waveform of Inverter 2

The output voltage of inverter 1 is 440V. After $t=1s$ it gets turned off, its voltage is 0V as shown in fig. 6. The output voltage of inverter 2 is 440V as shown in fig. 7. The resultant output voltage for inverter 1 and 2 are shown in fig. 8, where voltage of inverter 1 is 440V. After 1s it gets turned down, its voltage value is 0V. The output voltage of inverter 2 is 440V. At $t=0.16s$, the voltage (amplitude) gets unbalanced and it regains to normal amplitude after 0.2s.

**Fig.8.** Resultant Output Voltage Waveform of Inverter 1 and Inverter 2

**Fig.9.** Frequency Restoration of Inverter 1 and Inverter 2

The frequency and amplitude restoration waveform for the secondary control are shown in fig.8 and 9 respectively. At start, the frequency gets deviated and it is restored after 0.4s. After $t=1s$ the inverter 1 gets turned off, its frequency attains 0 Hz and the frequency of inverter 2 withstand the same value. Fig. 9 shows the frequency restoration waveform of inverter 1 and 2. Advantage over this system is if one inverter trips and another can able to supply the load, the system will still remain stable. These all facts highlight the reliability and the good performance of the MG control system.

### B. Unified PSM Technique

The output voltage of both inverters is 440V. Afterward, at $t=0.2s$, the voltage (amplitude) of inverter 2 gets unbalanced which can be managed by inverter 1. At $t=0.96s$, some disruption occurs in inverter 1, it gets removed from the MG, its voltage value is 0V. The inverter 2 provides all the required power, finally the output voltage of inverter 2 is 440V. The output voltage for inverter 1 and 2 are shown in fig.10, with blue and pink color represents the output voltage of inverter 1 and 2 respectively.

**Fig.10.** Output Voltage Waveform of Inverter 1 and Inverter 2

**Fig.11.** Frequency Restoration of Inverter 1 and Inverter 2

The frequency and amplitude renovation waveform for the secondary control using Unified PSM technique are shown in fig. 10 and 11 respectively. At start by $t=0.05s$, the frequency gets diverged and it regains to normal frequency after 0.5s. Later at $t=0.2s$, the frequency gets unstable and it reclaims to normal frequency after 0.5s pursued by deviation at 0.3s and also regained at 0.34s. At $t=0.9s$, some interruption occurs in inverter 1, it gets isolated from the
MG, it gets turned off; the first inverter frequency attains 0Hz and the frequency of inverter 2 sustained in the same value. Thus by comparing the two techniques, unified PSM techniques attains the faster stability by decreasing the raising time.

V. CONCLUSION

In this paper the steps towards the stability of these MGs have been proposed. This system is assured of two control levels using hierarchical control scheme for the parallel operated VSI system. In order to enhance the stability of voltage and frequency of microgrid, several control methods are used. The droop method followed by the virtual impedance loops composed of primary control. Pursued by this, the confined centralized controller known as the secondary control is responsible for power sharing for renovating the frequency and amplitude deviations using unified PSM technique. It regulates the phase and magnitude of voltage which can be analyzed based on zero crossings of the voltage and also available for connecting the main grid to the MG. Comparative simulation result shows that the unified PSM technique attains the stable frequency and voltage amplitude of MG control system. Thus by comparing both techniques, unified PSM techniques attains the faster stability by decreasing the raising time.

REFERENCES