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Dynamic Behavior Investigation of a Power Source Inverter for Drive Applications

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ABSTRACT

This work examines the vigorous performance of a PWM voltage source inverter based voltage generator with the aid of an output LC filter. This converter plays a vital role in bringing about proper frequency modulation both in affixed mode and in isolated mode with slight alterations in the control algorithm. In detached state, the converter generates ample voltage source. A scheme of islanding detection is elaborated in this survey. This strategy relies on the rate of Change of Frequency (ROCOF). An authentic observation using Power Hardware in the real-time simulation is recognized in order to substantiate the conceptual interpretation.

KEY WORDS: Distributed Generation, Droop Control, LC Filter, Voltage Source Inverter (VSI), Primary Frequency Control.

1. INTRODUCTION

In recent years, environmental factors have led to a sea change in the field of electricity. There is a swift advancement of distributed generation in the scenario of electricity market. This quick progress is chiefly dependent on the accessibility of modern, economical and well- organized miniature generators.

The harmonization of distributed generation becomes very essential. 'Micro Grids' play a vital role in harmonizing distributed generation. 'Micro Grids' are nothing but the sum total of numerous distributed sources of energy that has the capacity to feed their associated loads irrespective of the absence of the principal grid. Micro grids possess the capability to operate in two modes. Initially, the micro grid can function side by side fastened to a utility grid. In this position, the main grid binds the voltage to micro grid generators. Owing to this fact, inverter based generators basically act as current injectors in this grid connected operation mode. Secondly, micro grid can work in a standalone mode creating an islanded grid. In this mode, the loads in a micro grid can just receive power from the local sources, depending on the customer's situation.

The current exploration is carried out by categorizing the work into four portions. The rudimentary part gives a detailed description of the droop control scheme devised in the manipulation of PWM voltage source inverter based generator. The succeeding section conducts a survey of the dynamic behaviour of the above said machine. The third portion displays ROCOF relay model that is installed to spot out the switching that occurs between the two positions of the micro grid and provides a brief explanation of the same. The final section deals with the principle of power hardware in the loop and real time simulation which vividly makes us clear. How the control and islanding detecting strategies are put into operation.

1.1. Droop control of PWM voltage source inverter: There are three levels in the control system of the voltage generator. They are as follows:

- LC filters voltage and current control.
- Active Power control.
- Primary frequency control.

1.2. LC Filter Voltage and Current Control: Fig.1.sums up the general sketch of the voltage source inverter based generator.

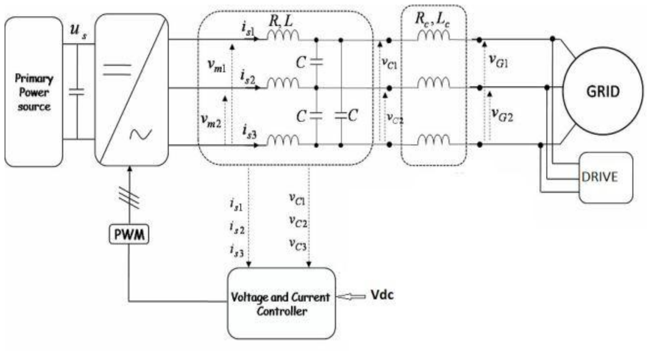

Fig.1.Sketch of the voltage source inverter based generator

1.3. Active Power Controller: As far as a conventional current source connection is concerned, the power offered to the grid is restrained by the phase and the magnitude of the current. In this operation, the restricted quantities are the voltages. The implementation of a different procedure becomes essential in order to curb the flow of power to the grid. This novel scheme relies on the usual pattern of power transmission between two voltage sources. Fig. 2(a) and Fig. 2(b) illustrates how power flows from one voltage source to the other. In a three-phase non resistive line, the active and reactive power is subordinate to the transmission angle δ between both voltage sources.

The above figure exhibits the complete procedure of control recommended for the inverter together with its output LC filter. The principal focus of this control scheme is to produce quasi-sinusoidal three-phase voltages (Vc_1, Vc_2, and Vc3). In order to achieve this aim, a band of three voltage references (Vc1REF, Vc2REF, and Vc3REF) is designated. The average of a resonant algorithm manifests the control of the instantaneous voltage value.

The control strategy is established on a state feedback for state variables. A unique technique is applied in the designation of the controller parameters. This technique is known as Pole Placement Technique (PPT). Synchronization of the above mentioned three-phase voltage source to the network voltage becomes indispensable. To fulfill this necessity, a classical Phase Lock Loop (PLL) is accomplished and enforced on the grid voltage (vG1, vG2, vG3). It is observed that this PLL created the instantaneous grid angle θ.

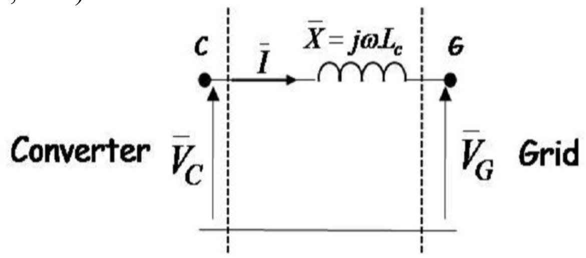

Fig.2(a).Power through a line

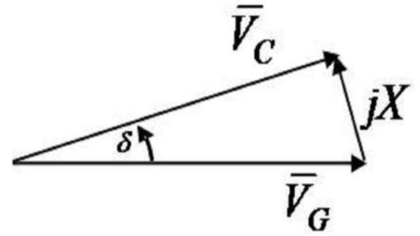

Fig.2(b).Phase diagram

1.4. Primary Frequency Control: The primary frequency control is much the same as that normally made use of in synchronous generators. A decline in frequency signifies an unstable power between production and consumption. The rotational speed of the synchronous machine is directly proportional to the frequency. A simple proportional speed regulator is employed to adapt the generated power to the frequency. It is a well-known fact that this method of frequency constraint contributes to a reasonable sharing of the load between generators.

Fig.3 displays the droop control for the active power. Per unit value of the active power is transfigured into an authentic value by way of multiplication with a base value of the converter power P base. The value similar to the nominal value of the converter active power is selected as the base value. There are two principal sources through which power is transmitted to the load. One of the sources is "Voltage Source Inverter" and the other is "Asynchronous Machine". In order to procure the primary frequency control, a droop (KMS) is administered on the control of synchronous machine power.

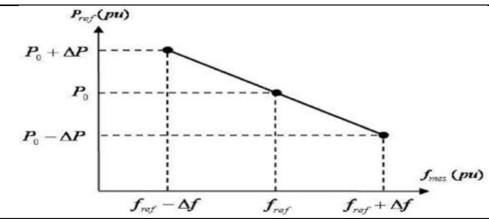

Fig.3.Frequency-power characteristic

1.5. Dynamic performance in islanded mode: The phenomenon of micro grid islanding or Loss of Grid takes place in the event of an incidental happening. It also occurs when switching is planned in advance. The PWM voltage source inverter which prevails in the islanded mode enables the disconnected part of the system to remain vitalized. When islanding occurs, this generator should inevitably gratify the load requirements. Besides, it must also stay ready for action in an autonomous mode. Suitable alteration with regard to the control of the LC filter becomes imperative in view of this different setting. The most important adjustment lies in the calculation of voltage reference angle.

In grid tied position, it is the PLL that computes the grid angle. On the other hand, in islanded state, the grid angle is instituted by the source and generated by the incorporation of the micro grid frequency reference.

1.6. Switching between connected and islanded mode: In order to make out the changeover between connected and islanded mode, a well-defined methodology becomes an essential prerequisite. There are, of course, a number of islanding detection modes. In this work, relay ROCOF (Rate of Change of Frequency) is employed to identify the islanding mode. As soon as the grid is tripped, the voltage source inverter must transfer all the load power then and there. Owing to the application of "P Control Algorithm", the instantaneous frequency Δf increases promptly. Besides, there is an augmentation in the level of rate of change of frequency. This stratum is utilized to discern the islanded manipulation. Giving due consideration to the natural frequency variation resulting from measures noise, a mock- up of the ROCOF relay is demonstrated.

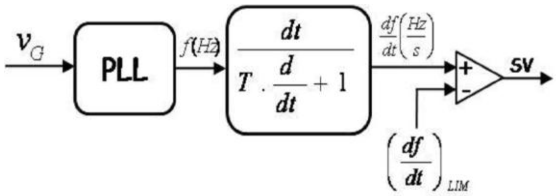

Fig.4: ROCOF relay implemented model

Fig. 4 sets forth the accomplished model of the rate of change of frequency measurement. This computation necessitates the selection of two parameters:

- T: the time constant of the filter: 0.12s
- $\frac{df}{dt}$ lim the rate of change of frequency limit : 0.5 Hz/s

The ROCOF relay output signal validates the switching phenomenon. This signal is therefore known as Switching Validation (SV).

1.7. Observational scrutiny and recognition: It becomes indispensable to justify the theoretical findings of the whole novel set-up. This requirement is achieved by putting into operation the principle of PHIL, the expansion of which is Power Hardware in the Loop. This very same procedure is until now playing a vital role in assessing the appropriate control system associated with real- time simulation.

Fig. 5 exhibits the Power Hardware in the Loop. PHIL demands the use of a high bandwidth power amplifier between the real-time simulator and the device itself because a power device is evaluated. This power amplifier brings into being a three-phase voltage source whose magnitudes are distributed by the simulator.

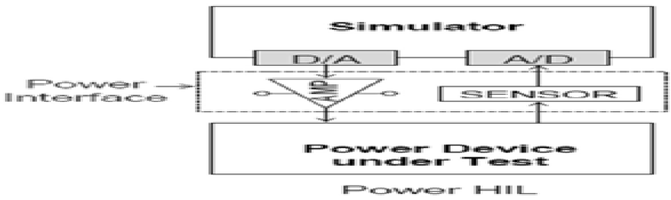

Fig.5.Power hardware in the loop (PHIL) scheme simulation

By reason of Analog Digital Converters, the sensors that are rested on the Power Device under Test contribute certain facts on the subject of current, voltage etc.

1.8. Outcome and Review

Grid Tied Operation Mode (Power Sharing Tests):

The performance of the entire process while the voltage source inverter and the synchronous machine are both simultaneously fastened to the same grid is as follows:

Let't' be 22.9s and an 8.8kW load be provided. In this case, there seems to be no active power generations at all on account of a fixed zero active power reference value. The frequency descends to 46.55Hz due to the frequency primary controller.

Just as't' becomes 46.85s, there is an addition of 1kW active power reference value Fig. 7 brings to our noticethat the time response is 1.4s. This result almost matches with that of hypothetical observation (1.3s). The already liberated power of 1kW value causes a rise in frequency level. The frequency increase is found to be 47.1Hz. However, this generated power in turn is minimized by the synchronous machine. As't' equals 61s, the approval of primary frequency control occurs, thereby paving the way for load distribution by both the voltage sources. The power is shared between the two sources in appropriate ratio with the droop value. As a result of the inverter's primary frequency regulation, the power reference value augments to 3.8kW along with boost of frequency to 48.1Hz.

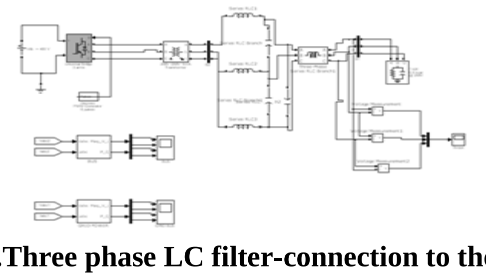

Fig.6.Three phase LC filter-connection to the grid

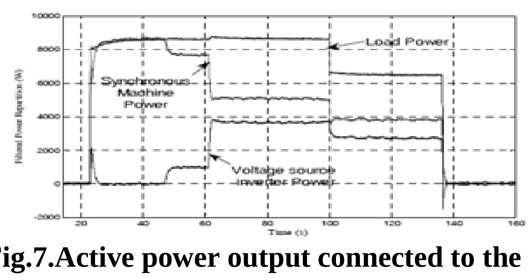

Fig.7.Active power output connected to the drive

1.9. Islanding Assessment: The course of islanding demands exact evaluation. ROCOF principle relay turns out to be the matchless procedure for the same. This code shifts the control to function in independent standalone mode. Prior to the switching occurrence, the two generators seem to share 1.3kW load by virtue of the primary frequency control system. At 94.7s, the synchronous machine is tripped. This induces a decrease in f which stands for the rate of change of frequency at the islanding juncture. SV signal is hooked and eyed exactly at the spot where the curvature extends across the ROCOF level limit (0.5Hz/s). As is already mentioned, in Fig.6 the frequency turns to a stable value.

1.10. Islanded Operation Mode: The best performance of a system in an islanded mode can very well be substantiated by subjecting it to load variation. This can be enhanced by applying a 8.8kW load. Fig. 8 delineates the power generated by the voltage source inverter in the islanded operation mode. "P control" algorithm that exists on hand culminates in a slight frequency variation. In the event of load variation, the voltage appears to be restricted in the islanded operation mode.

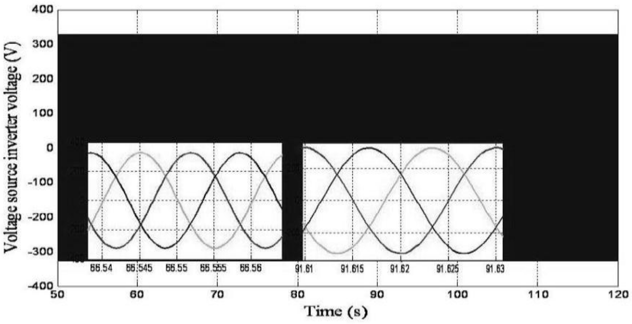

Fig.8.Voltage source inverter

2. CONCLUSION

An analysis of the dynamic behavior of voltage source inverter implanted on a distribution system has been made in this paper. A primary frequency control strategy based on assistance of ROCOF relay principle. The suggested control algorithm relies on islanding detection via ROCOF thereby leading the control to operate under an imposed frequency. This work includes three operational stages in which the control strategy is examined and analyzed. First and foremost, it is tested in a grid connected operation mode. Secondly, the verification is undertaken during islanding operation. Finally, the validation is done in the islanded mode. Experimental implementation for the control strategy is accomplished on a real time simulator.

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