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Performance of Grid connected system based on Voltage Modulated Direct Power Control and Series Voltage Regulator

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Abstract- The concept of a novel Series Voltage Regulator (SVR) for controlling dc bus voltage of a radial dc Microgrid is presented . In this paper, we design a voltage modulated direct power control (VM-DPC) for a three-phase voltage source inverter (VSI) connected to a weak grid, where the PLL system may make the system unstable if the conventional vector current control (VCC) method is applied. Compared with the conventional VCC method, the main advantage of the proposed VM-DPC method is that the PLL system is eliminated. Moreover, in order to inject the rated real power to the weak grid, the VSI system should generate some certain amount of reactive power as well. An Eigen values based analysis shows the system with the proposed method tracks its desired dynamics in the certain operating range. The proposed SVR uses a dual active bridge dc-dc converter followed by a full-bridge dc-dc converter. It injects dynamic voltage in series with the dc grid to compensate resistive drop over the network. As a result, the voltage level at the different points of the grid becomes independent of load variation and stays within the specified limit. Note that the required power rating of the SVR is very low compared to the load demand considering 5% voltage regulation. The simulation has performed on the MATLAB software.

Keywords- vector current control, weak grid, SVR etc.

I. INTRODUCTION

In recent years, the adverse impact of the PLL on the small-signal stability of VSIs has been reported. It is found out that the PLL may deteriorate the stability of VSIs by introducing the negative incremental resistance at low frequencies. The frequency coupling dynamics of VSIs introduced by the PLL have also been explicitly revealed.

The frequency range of the negative resistance is determined by the bandwidth of the PLL. Therefore, the low bandwidth PLL is usually adopted in order to improve the stability robustness of VSIs, which jeopardizes the dynamic performance of the system significantly. Moreover, even though the PLL is designed with a very low bandwidth, it is still very difficult for VSIs to remain stable under the very weak grid condition, in which the grid impedance is approaching 1:3 pu. Recently, Wang summarized the harmonic stability caused by the grid-connected VSIs in modern power grids, where the small-signal dynamics of VSIs tend to introduce a negative damping, which may be in different frequency ranges, depending on both the specific controllers of the converters and power system conditions.

Therefore, in order to guarantee stable operation of VSIs under the weak grid condition, the control strategy without the PLL is needed. Another control method, direct power control (DPC), has been researched for grid-connected VSIs to control the instantaneous real and reactive powers directly without using neither inner-loop current regulator nor PLL system. However, these methods have a main disadvantage as a variable switching frequency based on the switching state, which results in an unexpected broadband harmonic spectrum, i.e., it is not easy to design a line filter properly. To achieve a constant switching frequency, various DPC strategies have been proposed.

Some of them are using space vector modulation or calculating the required converter voltage vector in each switching period. Moreover, with the consideration of the robustness, a sliding mode control is applied to the DPC method in order to guarantee a fast tracking performance of the real and reactive powers, and a passivity-based control via DPC is proposed by considering the system's intrinsic dissipative nature.

Voltage source converters (VSCs) are widely used in the application of smart grid, flexible AC transmission systems, and renewable energy sources (e.g., wind and solar) in the modern power grids. One of the key devices in VSCs is grid-connected voltage source inverter (VSI), which is normally controlled as a current source injecting current into the grid.

For grid-connected VSIs, the conventional vector current control strategy is typically used to provide satisfactory control performance. However, it has been reported that a weak grid-connected VSI with the standard vector current control strategy suffers from stability and performance issues.

In addition, with the increasing penetration of renewable energy resources in modern power grids, it becomes more and more important to sustain stability and high power quality induced by grid-connected VSIs. A widely used control scheme for VSIs is the vector current control, where the phase-locked loop (PLL) is used for the purpose of grid synchronization [1-3].

II. RELATED WORK

The power to switch to renewable resources is to switch energy production to distributed nodes, so Pulse Width Modulation (PWM) voltage source inverter (VSI) becomes a widely used interface circuit between renewable resources and power grid [4].

The widespread use of PWM inverters in the power grid makes the stability analysis of grid connected VSIs the primary concern of electrical engineers. Several studies have shown that the stability of the network connected VSI is influenced by the control and filter parameters .In addition to filters and control parameters, a weak power grid will also affect the stability of the network connected VSI .Weak lattice is usually defined as a low short circuit (SCR) lattice, that is, high impedance and low inertia constant (H), which is a typical feature of micro grids.

As a result, voltage and frequency will be distorted in the weak grid. Furthermore, if the voltage at the common switching point (PCC) has harmonic components at the natural frequencies of LCL filters the network connected VSI may become unstable. If the voltage supply path is used to reduce the response time of the closed circuit system, the situation will be more complicated. Similarly, the coupling path in the control plane may cause the system to tend to be unstable in the lattice with current harmonics.

Therefore, the stability analysis of the inverter in the weak current network is a complicated problem which requires a detailed dynamic model. Root locus state space and Nyquist impedance based techniques have been reported for stability analysis of grid connected VSI .Impedance-based techniques use bulky equivalent circuits, so it is not possible to simply investigate the effect of individual circuits and control parameters on system stability.

In the dynamic analysis of network connected VSI through the state space method, a simplified model is usually considered for the system (circuit) or regulator. If you need to investigate the effects of simultaneous changes in circuits and control parameters, this simplification makes the stability The whole system is difficult to analyze. [5-8]

III. PROPOSED SYSTEM

The configuration of a typical radial dc Micro grid where various sources are connected at bus-0 and loads are connected at remaining buses. This system is widely used due to its simplicity and cost effectiveness [9]. Also, the expansion of load branches is easy for such configuration.

The bus voltage variation with loading is the main limitation which is already explained in Section I. The voltage at the buses which are far away from generation (e.g. bus-3 and bus- 4 here) may fall below the specified limits due to loading.

The proposed SVR need to be connected at the right place such that all node voltages remain within _5% deviation. The input side of the SVR is connected across the grid with terminals A and B. The output side is connected in series with the grid (in between the bus-2 and bus-3).

According to the connection, the output of SVR experiences lower voltage (Vsvro) associated to line-drop and up to rated line current (Isvro), whereas the input of SVR handles rated dc grid voltage (V1) and lower current (Iin). In this work, a new design method is proposed to ensure sufficient gain margin and phase margin at sudden change of real power at the load to achieve stable operation.

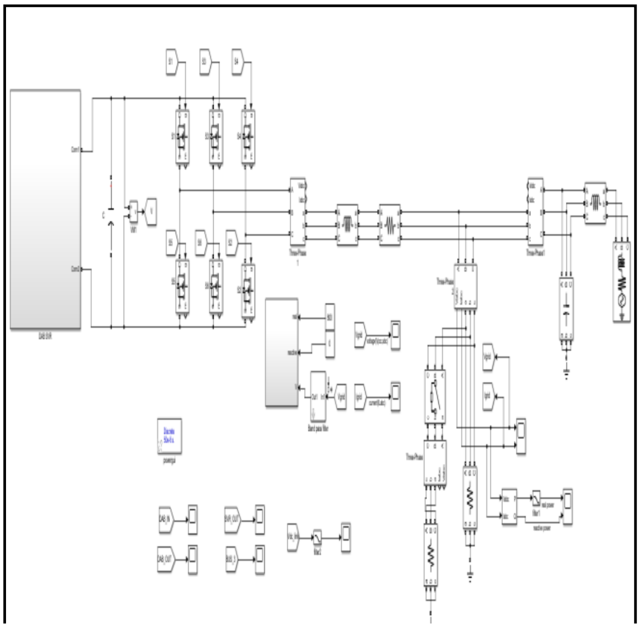

Fig 1. Proposed Simulink model.

1. Topology:

The proposed topology of SVR is shown in Fig.1. The SVR comprises of a DAB followed by a full-bridge dc-dc converter. The two bridges (primary and secondary) in DAB are operated to generate high-frequency square-wave voltage at the transformer terminals.

The phase shift between two square-waves can be adjusted to control power flow from V1 to V2 or vice versa. Power flow always happens from the bridge generating leading square-wave to the other bridge Note that the DAB is operated in power control mode. The output voltage of DAB (V2) is always maintained to its reference value under the variation of output current (Iinb) and input voltage (V1).

The constant output voltage of DAB is connected to the input of the full bridge dc-dc converter.

The full bridge is operated in voltage control mode with unipolar modulation [10] to generate an adjustable dc voltage (Vsvro). So, under steady state, as well as transient conditions, the required amount of voltage with suitable polarity can be added in series with the dc grid. In this proposed configuration, the SVR regulates the voltage at bus-3 by adding controlled series voltage with appropriate polarity.

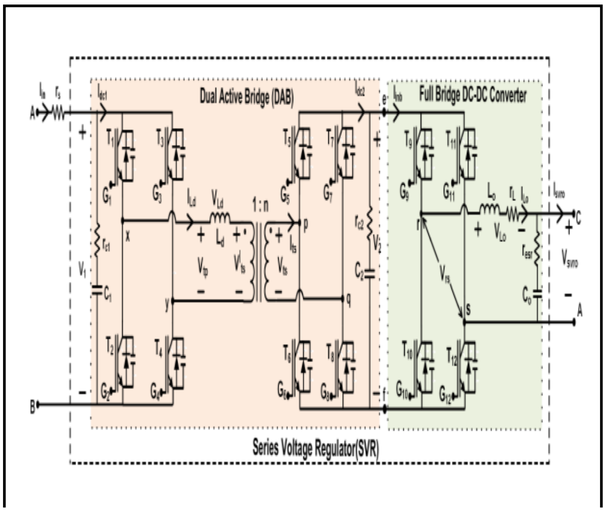

Fig 2. Control scheme for SVR.

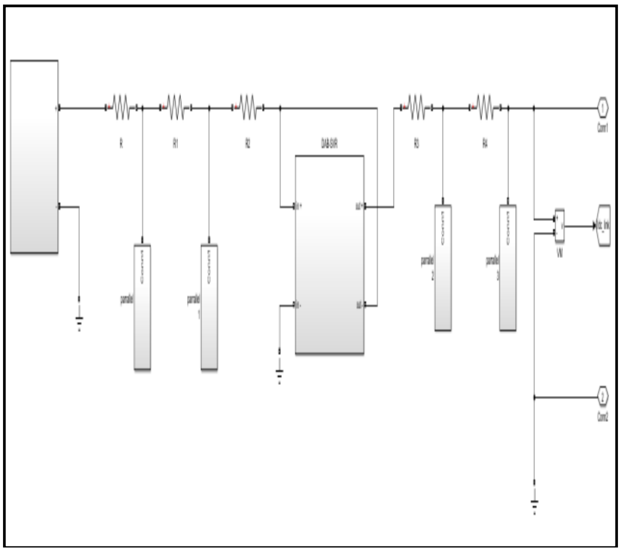

Fig 3. DAB Subsystem.

One of the key devices in VSCs is grid-connected voltage source inverter (VSI), which is normally controlled as a current source injecting current into the grid. For grid-connected VSIs, the conventional vector current control strategy is typically used to provide satisfactory control performance. However, it has been reported that a weak grid-connected VSI with the standard vector current control strategy suffers from stability and performance issues.

Fig.2 shows the overall control scheme for SVR. The proposed scheme consists of two control-blocks to ensure bus-3 voltage within a specified limit at different loading conditions. The Block-I performs power flow control and maintains a constant voltage at the output of DAB. The Block-II shows the control for full-bridge dc-dc converter, which is operated in voltage control mode.

Voltage Control; The control of full-bridge dc-dc converter to adjust output voltage of SVR (Vsvro) is shown in Fig.4. The voltage drop across the line (up to bus-3) is given as the reference to the controller. The voltage reference is generated through the following equation.

$$\mathbf{V^{*}_{suro} = V^{*}_{grid} - V_{1}}$$

The error is formed in between the reference and actual output which is fed to a PI controller.

voltage (i.e $V^{*}_{suro} = V^{*}_{suro}$) svro,Vsvro)

The PI controller provides the control signal (i.e., Vc) to generate PWM signals for switches T9 to T12. The gains of the PI controller are chosen in such a way that the bandwidth of this voltage loop is 10 times lower than switching frequency.

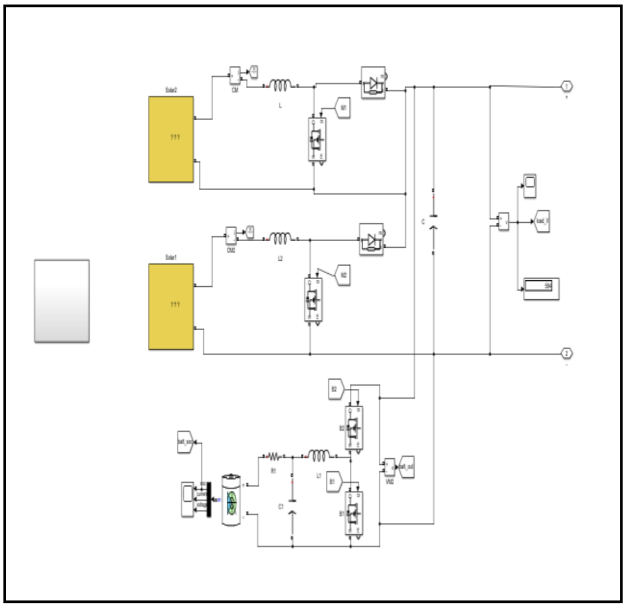

Fig 4. Solar sub system.

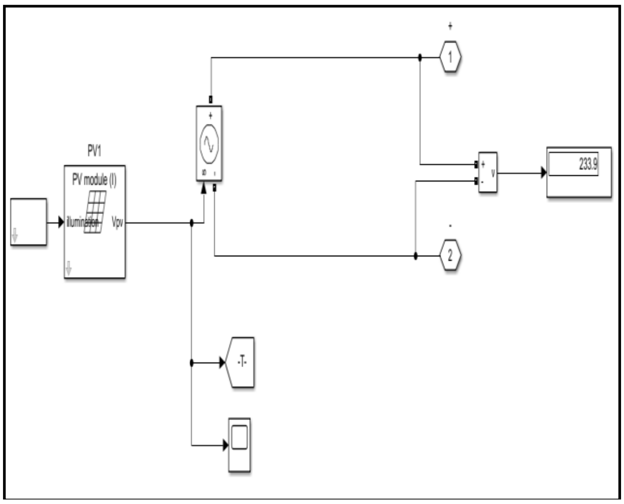

Fig 5. PV Panel Sub System.

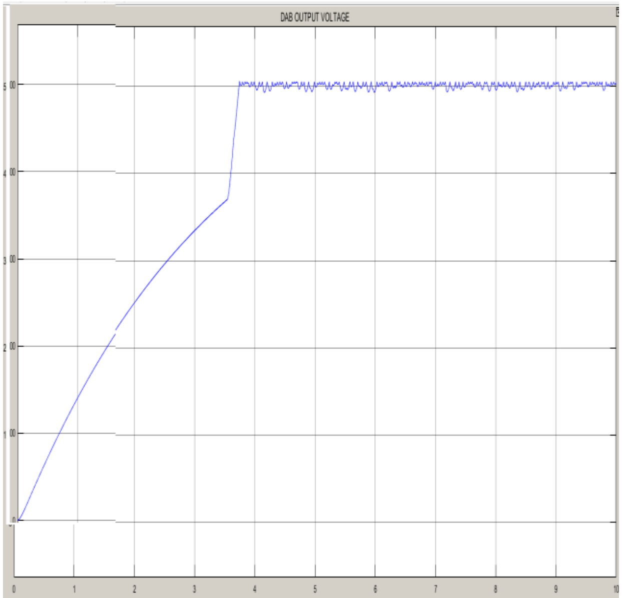

Fig 6. DAB output voltage.

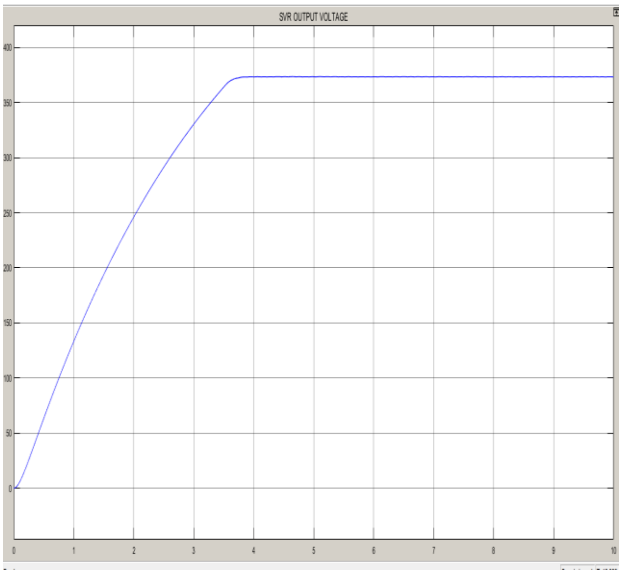

Fig 7. SVR Output Voltage

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Therefore is capable of handling forward and reverse power flow during voltage sag and swell respectively. The turn-on of switching devices in DAB occurs at zero voltage which reduces switching losses of the converter. The SVR dynamically regulates bus voltages of the dc Micro grid for various loading conditions.

The response time of SVR during transient is decided by the voltage controller (i.e. second stage of the power circuit) and the capacitor which is connected across the output of SVR. Here, SVR adds the appropriate series voltage with proper polarity to compensate drop across line resistance. The output and input voltages of the SVR, respectively. It is also noticed that the DAB output voltage.

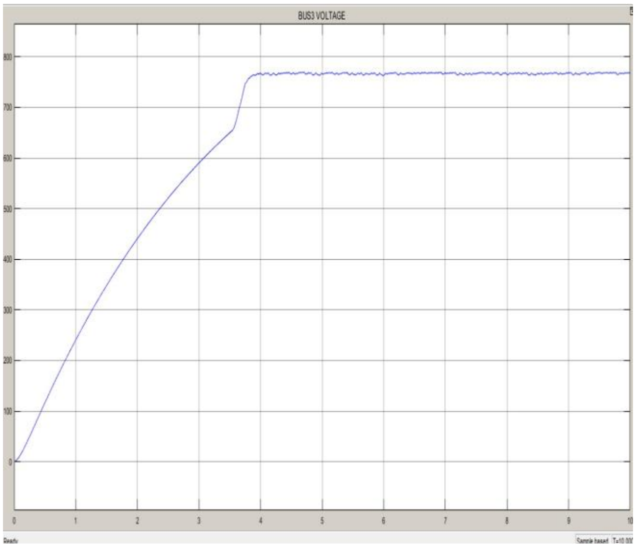

Fig 8. Bus Voltage.

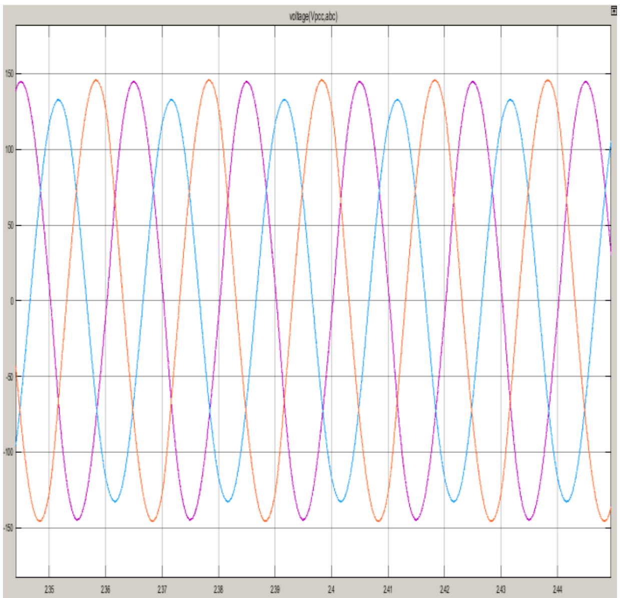

Fig 9. Constant Power.

The dc bus voltage is relative to the peak voltage of the mains input. What to look for: dc bus voltage is ~1.414 x the RMS line voltage. The total shunt admittance at the bus i and $y_{ii}v_i$ is the shunt current flowing from bus i to ground. Where V_R is the (n−1)×1-dimensional reference voltage vector containing in each element the slack bus voltage.

Fig 9. shows the output of solar power generation and daily load power curve when receiving a constant amount of power from the utility power system .Constant power circuit work by measuring the voltage across and current drawn by the load. The curve representing the power limit for the load for the range of current and voltage magnitudes in which the load circuit may safely operate.

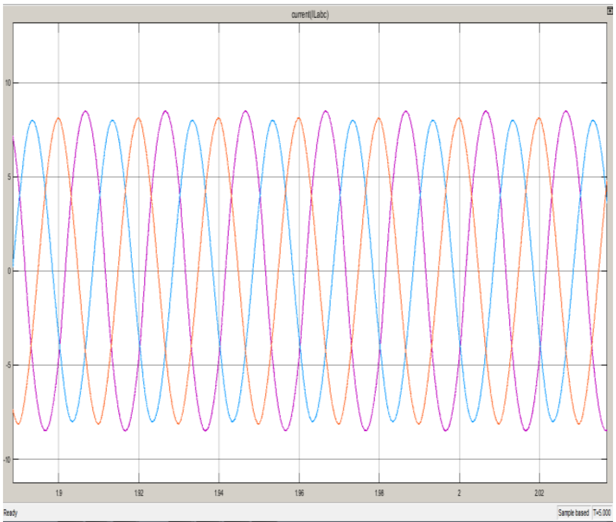

Fig 10. Voltage ($V_{pcc, abc}$) Current ($I_{L, abc}$).

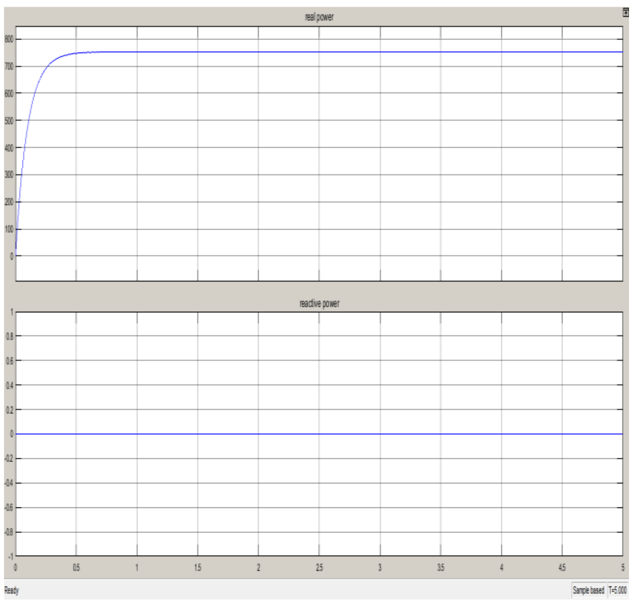

Fig 11. Real And Reactive Power (P,Q) Vary Power AT 2.5 Second.

Moreover, at 0.8 s, a converter load is connected at PCC and consumes 1.0 kW real power when the VSI regulates 3:5 kW real power and 2:0 kvar reactive power, as shown in Fig. 11. shows the low voltage ride through capability of the proposed control method when the VSI regulates real and reactive powers to 0:5 kW and 2:0 kvar, respectively.

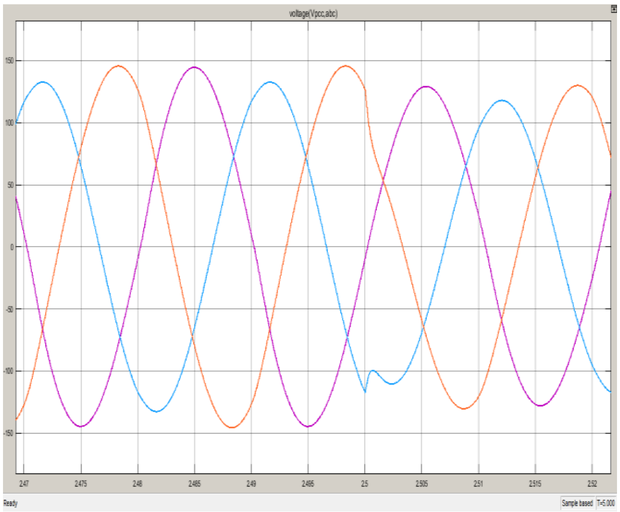

Fig 12. Voltage ($V_{pcc,\ Iabc}$).

Dynamics of the current varies according to the voltage level in Vpcc with respect to Iabc , As a consequence, the desired imposed dynamics should be chosen such as to obtain a suitable operation region for the DC Micro grid.

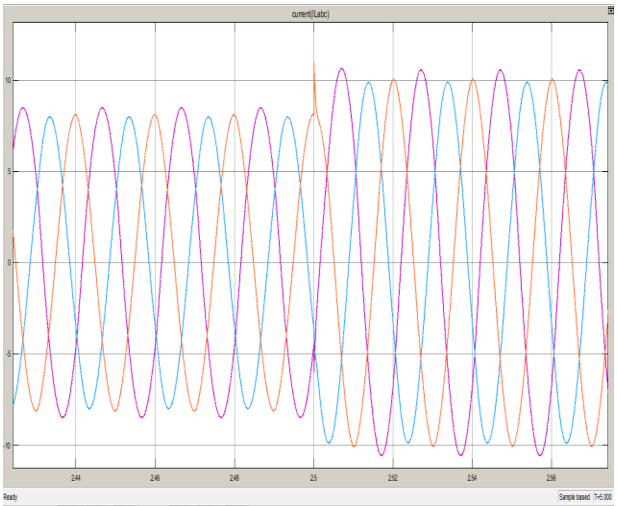

Fig 13. Current ($\mathbf{I_{L,\ abc}}$)

We also test the effect of the variation of the grid frequency. As shown in Fig. 15(a), the frequency is changed from 48 :5 Hz to 50 Hz at 0:8 s, and goes back to 49:5 Hz at 0:85 s. From Fig. 14, the VSI synchronizes the new frequency of the grid quickly. Hence, we can conclude that the proposed control method is robust to the variation of the grid frequency. In this case, we also use the different BPF parameter (i.e., = 0:3.) It can be observed that the real and reactive powers have offset when the grid frequency changes.

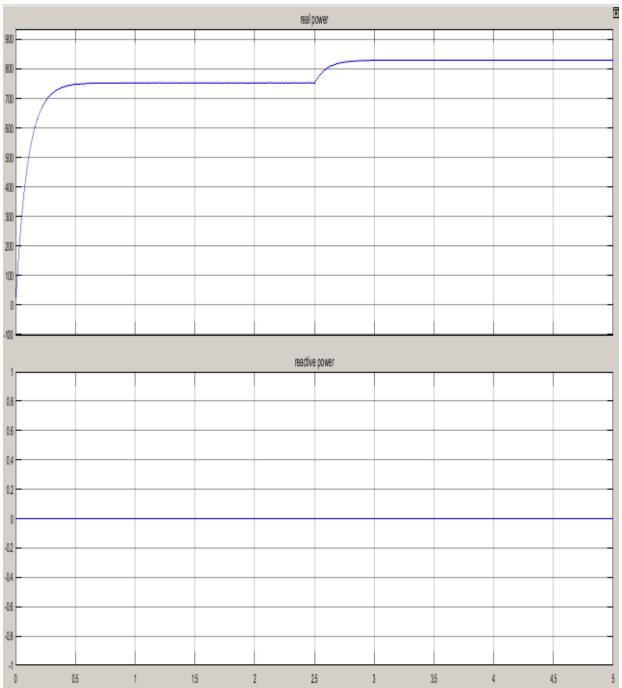

Fig 14. Real And Reactive Power (P,Q).

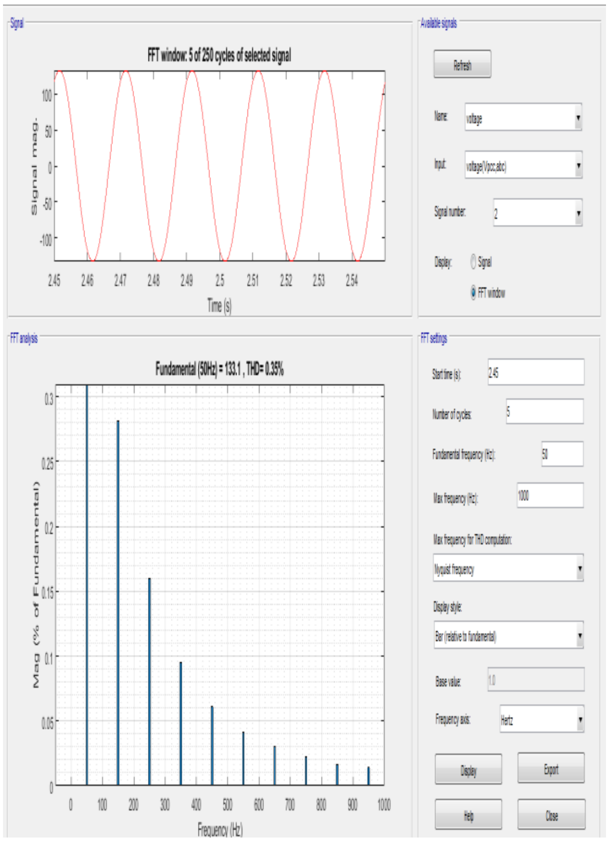

Fig 15. Total Harmonic Distortion (THD).

IV. CONCLUSIONS

The SVR dynamically regulates bus voltages of the dc Micro grid for various loading conditions. Optimal placement of the SVR keeps the dc distribution system regulated. In this paper, we have introduced a VM-DPC strategy for the three-phase VSI connected to a weak grid, where the PLL system may make the system unstable. We use a BPF for the weak grid connected VSI system to apply the concept of the GVM-DPC. From the comprehensive analysis based on the Eigen values, the system is always stable in this operating range. In addition, in order to inject the rated real power to the weak grid, the system should generate some certain amount of reactive power to support the voltages at PCC as well.

Finally, simulation and experimental results show that the proposed method is working well in the weak grid. In the proposed method, we tested with DC link we have to improvise into multiple output This system can be used in the application of renewable energy source solar, wind, fuel cell This system can also implemented in the single phase home applications .This paper presents the concept of a novel series voltage regulator for dc micro grid.

Topologically, this is a cascading of Dual Active Bridge (DAB) and a full bridge dc/dc converter connected in input-parallel and output-series mode. The dc/dc converter can generate both positive and negative voltages and therefore is capable of handling forward and reverse power flow during voltage sag and swell respectively. The turn-on of switching devices in DAB occurs at zero voltage which reduces switching losses of the converter.

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