Improvement of Power Quality in Island Mode Using VSI

A. Arikesh
Assistant Professor
Department of EEE
Hindustan University, Chennai, India

P. Thangamani
PG Student
Department of EEE
Hindustan University, Chennai, India

Abstract

Voltage Source Inverters (VSI's) places an important role in the voltage control of Distributed generation (DG) units interfaced to the grid. Implementation of effective control of the inverter allows improving the voltage and frequency in the load side if the main power grid is disturbed or disconnected. In this paper, a simple control technique is developed for a VSI working in island mode. The control technique consists of a voltage loop and PI controller. Voltage regulation under various loads is studied.

Index Terms- *Voltage Source Inverters (VSI's), Distributed generation (DG), PI controller*

I. INTRODUCTION

At present scenario there is a huge demand of power due to massive economic growth. In Tamil Nadu there is a huge shortage of power in spite of the rising prices of oil & other fossil fuel / depletion of fossil fuels. Recently, distributed generation (DG) units are increasingly being used because of their economic and environmental benefits compared to the use of large power plants which is depending on fossil fuels. Many distributed power sources, such as wind turbines, photovoltaic (PV) and fuel cells, do not generate a 50 Hz voltage, so they require a voltage-source inverter (VSI) as an interface to the grid. These power-electronic interfaces have different properties as compared to conventional power plants. DG systems with VSI's are promising because of their possibility of high service reliability, power quality and flexibility, lower losses in transmission and distribution and a lower dependence on fuel costs when using renewable energy sources.Tamil nadu Energy Development Agency (TEDA) presents a microgrid as a system providing both power and heat where most of the sources are connected to the ac-grid via power-electronic interfaces. The microgrid architecture insures that the electrical impact of distributed energy resources (DER, [5]) on its bulk power provider at least qualifies the microgrid as a good citizen, meaning that it complies with grid rules. Potentially the microgrid behaves as a model citizen [2], meaning that inverter-based DG always acts to improve the local electrical environment.

DER can operate in parallel to the grid or islanded from it. The microgrid will disconnect from the main grid during large disturbances (voltage collapse, faults, poor power quality).

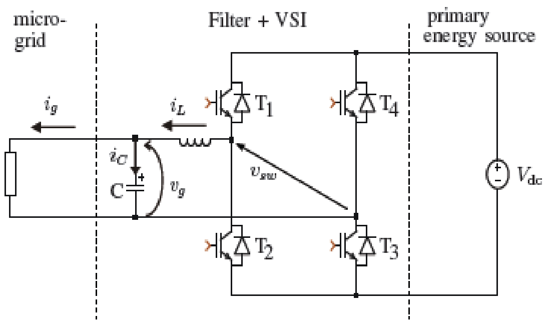


Figure 1: VSI, interface between the microgrid and an energy source

In this paper, a microgrid in islanded mode with a single VSI-connected DG-unit is studied. The control of the VSI is usually obtained in the rotating dq-reference frame synchronous to the grid voltage, for example in [5–8]. An advantage of this method is that the ith harmonic of the signals 50Hz component can easily be evaluated using a low pass filter after transformation to a reference frame rotating with i times the fundamental pulsation. A disadvantage of this method is the numerical complexity, because of, for example, the need for harmonic reference. By using the Clarke and Park transformations, the quantities in a three phase balanced sinusoidal system in steady state are transformed into dc-Park components, which is an advantage for control issues. However, in three-phase asymmetrical systems or in systems with voltage harmonics, the Park transformation does not result in dc-quantities. In single phase systems, the Park or Clarke transformations are even not applicable.

Therefore, in [10], a Kalman-filter technique is used for the transformation to values that match an ideal sinusoidal waveform as closely as possible, even if the voltage is highly distorted by the presence of harmonics. Those values are the inputs of a phase-locked loop (PLL) for transformation to the dq-reference frame and this ensures a fast and low distorted operation of the PLL.

In this paper, the control is performed in the time domain without transformation of reference frame and by using conventional PI-regulators. A single-phase grid is studied and, in further research, this will be extended to a three-phase grid. The voltage of the grid is controlled only voltage control loop. To constrain the inverter current within its safety limits, a fast current controller is used in the inner loop, having a reference current obtained by the outer-loop voltage regulation.

II. CONTROL STRATEGY

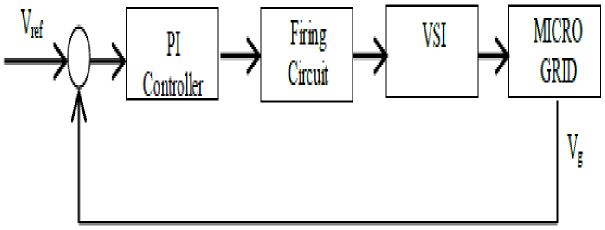


Figure 2: Control strategy

In this paper, a control strategy for inverters in island mode is described; the topology of the VSI is shown in Figure 1. In this figure the grid is represented as a load. The aim is to control both the amplitude and the frequency of the grid voltage $v_g(t)$. A schematic overview of the control strategy is shown in Figure. 2.

The input voltage that is fed to the VSI should be such that the output voltage should be constant.

Hence to maintain constant output voltage the feedback is taken from the output voltage and fed to the error controller loop. In error controller loop the feedback output voltage is compared with the reference grid voltage (v_{ref}) and the error signal is fed to the PI controller. The PI controller process the error and generates control signal which is send to the firing circuit.

The firing circuit produces corresponding gate pulses required to maintain the output voltage equal to grid voltage at the VSI output. The above topology is very simple one which has only one loop i.e., voltage loop, this circuit work independent to load current and it is verified in simulation with resistive load

II. DESIGN OF VOLTAGE CONTROL

In general single phase inverter are 2-step inverter, which offers simple control and low switching loss, lower order harmonics are relatively high leading to high distortion of the current wave unless significant filtering is performed

PWM inverter offers better harmonic control of the output than 2-step inverter. The dc input to the inverter is chopped by switching devices in the inverter. The amplitude and harmonic content of the ac waveform is controlled by the duty cycle of the switches. The fundamental voltage v_1 has maximum amplitude = $4V_d/\pi$ for a square wave output but by creating chopped pulses, the amplitude of v_1 is reduced as shown in figure 4.

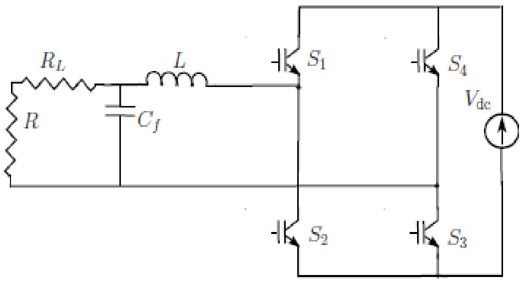


Figure 3: Resistive load: topology

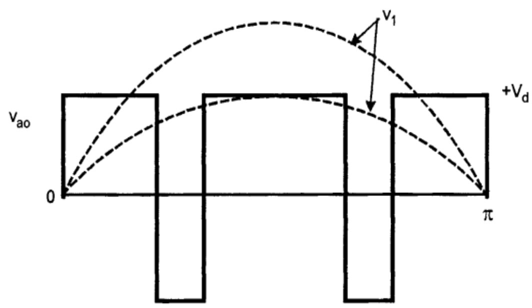


Figure 4: PWM principle to control output voltage

There are various PWM techniques available for effective control of output voltage which is listed below

- Sinusoidal PWM
- Selected Harmonic Elimination PWM
- Space-Vector PWM
- Instantaneous current control PWM
- Hysteresis band current control PWM
- Sigma-delta modulation

The most common PWM approach is sinusoidal PWM. In this method a triangular wave is compared to a sinusoidal wave of the desired frequency and the relative levels of the two waves is used to control the switching of devices.

PI Control

Proportional Integral (PI) control in VSI provides superior control over traditional Pulse Width Modulation or Sinusoidal Pulse Width Modulation (SPWM). In order to obtain a smooth desirable waveform at the output side, the switching frequency must be constant and should be independent of output frequency and this can be achieved by PI Control.

Advantages of PI Control

- Fixed inverter switching frequency resulting in known harmonics.
- Instantaneous control and wave shaping.

PI Control Structure

When a load is connected to the inverter output. The output voltage at the load side is sensed by means sensors and it is feedback to a comparator or subtractor which compares this load output with the reference signal (desired signal) and it produces the voltage error signal. This instantaneous error is fed to a proportional-integral (PI) controller. The integral term in the PI controller improves the tracking by reducing the instantaneous error between the reference and the actual voltage. The error is forced to remain within the range defined by the amplitude of the triangular waveform. The resulting error signal is compared with a triangular carrier signal and intersections decide the switching frequency and pulse width.

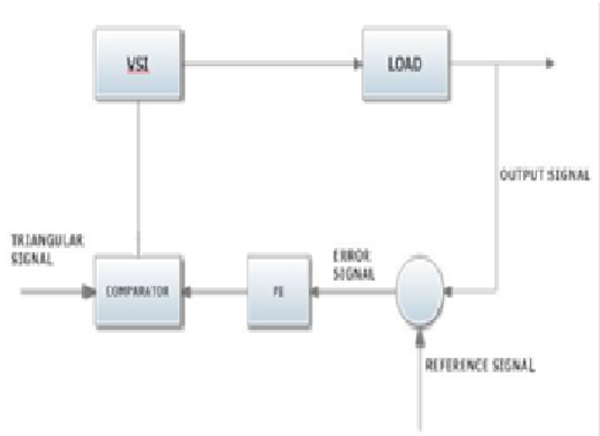


Figure 5: Block Diagram

PI controller is a feedback controller which detects the error value which is the difference of the output signal and the desired or reference signal. PI controller works to minimize this error by controlling the system inputs. PI controller has two elements namely Proportional (P) and Integral (I). Proportional part reduces the error while Integral part reduces the offset. P depends on present error and I depends on past errors. So, step response of a system can be improved by using PI controller.

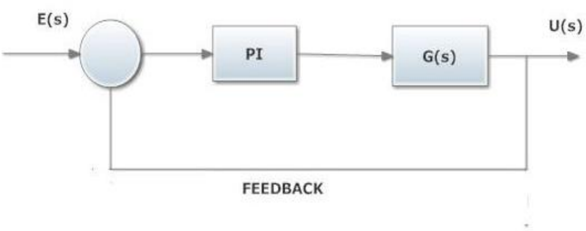


Figure 6: PI loop

After installing a PI Controller block the new response of the system will be

$$\frac{U(s)}{E(s)} = PI * G(s)$$

$$PI = Kp + \frac{Ki}{s}$$

$$\frac{U(s)}{E(s)} = Kp + \frac{Ki}{s} * G(s)$$

Now PI element gains, Kp (proportional gain) and Ki (integral gain) should be tuned to obtain a better system response. The effect of each parameters value on increasing is given below.

Response	Rise Time	Overshoot	Settling Time	Steady State Error
k_p	Decrease	Increase	Minor change	Decrease
k_i	Decrease	Increase	Increase	Eliminate

Table 1: Block Diagram

IV.SIMULATION AND RESULT

Matlab Circuit Diagram:

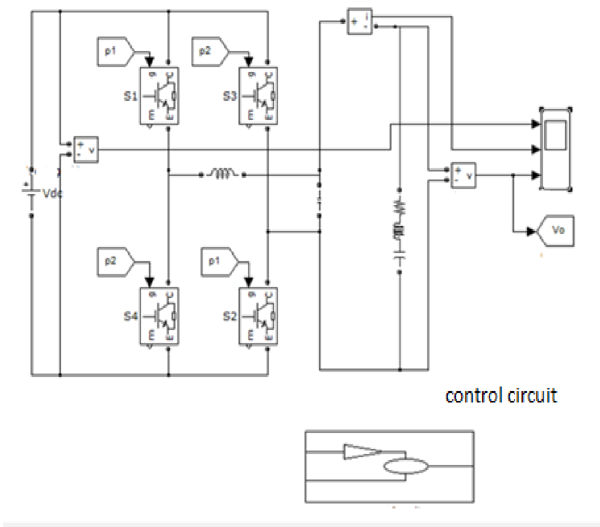


Figure 7: VSI model in Simulink

Control Circuit:

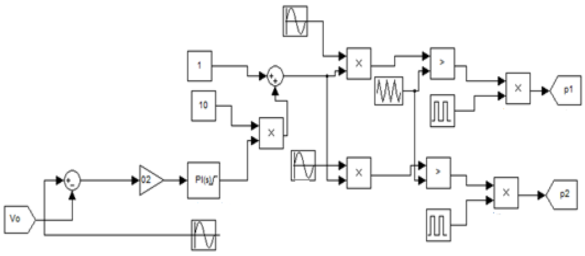
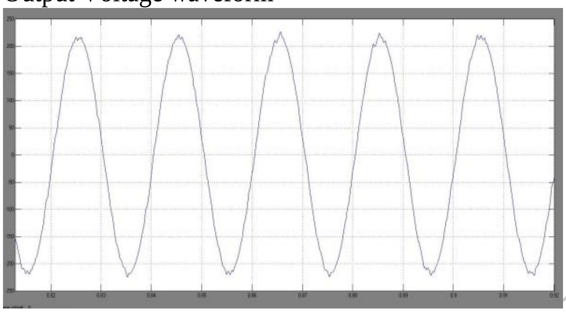
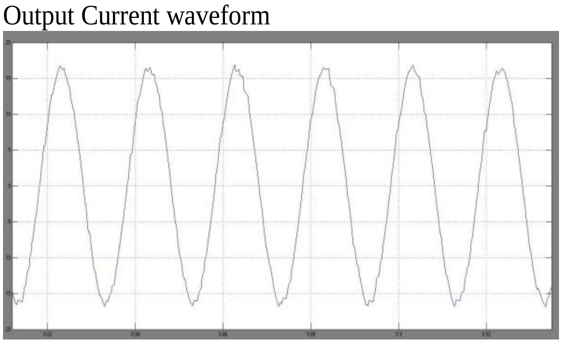


Figure 8: PI control block

Output Voltage waveform



Output Current waveform



In the simulations, a sample frequency of 10 kHz is used. The dc-bus voltage V_{dc} equals 300 V and the desired grid rms voltage v_g equals 163 V with a fundamental frequency of 50 was verified in simulation. In first simulation only resistive load is consider with R = 1kilo ohms, In the second and third simulation RL and RLC loads are consider and outputs was verified

V. CONCLUSION

The control of the voltage of a single-phase microgrid with one VSI is obtained. The Simulink model has been simulated in MATLAB. Its various parameters such as L and C for LC Filter design, kp and ki for PI controller and parasitics has been calculated for Simulink modelling and then simulated. These parameters are varied and the resulting voltage and current graphs has been studied.

VI.REFERENCES

[1] Tine Vandoorn, Bert Renders, Frederik De Belie, Bart Meersman and Lieven Vandevelde"A Voltage-Source Inverter for Microgrid Applications with an Inner Current Control Loop and an Outer Voltage Control Loop"International Conference on Renewable Energies, and Power Quality (ICREPQ09), Valencia (Spain), 15th to 17th April, 2009

[2] T. Green and N. Pogaku, "A model citizen approach to integrating Inverter-based distributed generation." World Renewable Energy Congress (WREC), 2005, pp. 1101–1108.

[3] E. Barklund, N. Pogaku, M. Prodanovi´c, C. Hernandez-Aramburo, and T. C. Green, "Energy management in autonomous microgrid using stability constrained droop control of inverters," IEEE Trans. Power Electron., vol. 23,no. 5, pp. 2346–2352, Sept. 2008.

[4] R. H. Lasseter, A. Akhil, C. Marnay, J. Stephens, J. Dagle, R.Guttromson, A. Meliopoulous, R. Yinger, and J. Eto, "The CERTS microgrid concept, white paper on integration of distributed energy resources."California Energy Commission, Office of Power Technologies - U.S. Department of Energy, Apr. 2002.

[5] D. Moskovitz, "Profits and progress through distributed resources."Regulatory Assistance Project, Tech. Rep., Feb.2000.

[6] M. Prodanovi´c and T. C. Green, "High-quality power generation through distributed control of a power park microgrid,"IEEE Trans. Ind. Electron.,vol. 53, no. 5, pp. 1471–1482, Oct. 2006.

[7] N. Pogaku and T. Green, "Harmonic mitigation throughout a distribution system: a distributed-generator-based solution,"IEE Proc. Gener. Transm. Distrib., vol. 153, no. 3,pp. 350–358, May 2006.

[8] R. Teodorescu and F. Blaabjerg, "Flexible control of small wind turbines with grid failure detection operating standalone and grid-connected mode,"IEEE Trans. Power Electron.,vol. 19, no. 5, pp. 1323–1332, Sept. 2004.

[9] M. Prodanovi´c, "Power quality and control aspects of parallel connected inverters in distributed generation," Ph.D.dissertation, University of London, Imperial College, 2004.

[10] K. De Brabandere, T. Loix, K. Engelen, B. Bolsen, J. V.Keybus, J.Driesen, and R. Belmans, "Design and operation of a phase-locked loop with kalman estimator-based filter for single-phase applications," in Conf. of the IEEE Ind. Electron. Society (IEEE IECON'06), Paris, France, pp. 525–530,Nov. 7-10, 2006.

[11] D. M. Van de Sype, K. De Gussem´e, A. P. M. Van den Bossche, and J.A. Melkebeek, "Duty-ratio feed-forward for digitally controlled boost PFC converters," IEEE Trans. Ind.Electron., vol. 52, no. 1, pp. 108–115, Feb.2005.

[12] B. Renders, K. De Gussem´e,W. R. Ryckaert, and L. Vandevelde,"Input impedance of grid-connected converters with programmable harmonic resistance," IET Electr. Power Appl., vol. 1, no. 3, pp. 355–361, May 2007.