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Eradication of Harmonic Distortion in Smart Grid by Integrating VSI Operated in Current Controlled Mode

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Abstract: When smart grids are introduced, we tend to expect growth both in production at lower voltage levels and in new sorts of consumption. A number of these new sorts of consumption can emit power-quality disturbances and therefore they will scale back grid potency. Major disturbance that causes hindrance within the system is harmonic distortion. The pure sinusoidal wave shape generated by electrical utilities is distorted by the harmonics produced attributable to augmented use of non linear loads. However, it provides rise to additional distortions in current and voltage waveforms on the ac power systems and pollutes the system. Understanding and solving issues becomes possible with the right data and interpretation. An adequate power quality guarantees the required compatibility between all equipment connected to the grid. It is thus a crucial issue for the successful and efficient operation of existing as well as future grids. Therefore a improved version of technology is required to eliminate harmonic distortions within the system and so as to improve the system performance .This paper presents a control technique equipped with VSI operated in current controlled mode with hysteresis control in order to eliminate harmonics and improve power quality of system. And FFT analysis is carried out to analyze the reduction in total harmonic distortion after enabling the operation of control technique.

Keywords: Total Harmonic distortion, power quality, FFT (Fast Fourier transform), VSI (Voltage source inverter).

I. INTRODUCTION

It is the target of the electrical utility to provide its customers with a sinusoidal voltage of fairly constant magnitude and frequency. The generators that produce the electrical power generate a very close approximation to a sinusoidal signal. But there are loads and devices on the system that have nonlinear characteristics and result in harmonic distortion of both the voltage and current signals. As a lot of non-linear loads are introduced inside a facility, these waveforms get more distorted .There are totally different approaches for harmonic analysis of various non-linear loads [1]. The voltage distortion caused by the harmonic producing load could be a function of both the system electrical phenomenon and also the quantity of harmonic current injected. A harmonic producing load will have an effect on the neighboring sensitive loads if vital voltage distortion is caused. If the system impedance is low, the voltage distortion is typically negligible in the absence of harmonic resonance. However, if harmonic resonance prevails, intolerable harmonic voltage and currents are doubtless to result. In an exceedingly sensible facility, the frequency and voltages are deviated from their selected values. The nonlinear characteristics of many system elements produce system harmonics which can degrade the signal transmission in near telephone lines. The power quality issues are stormy with the proliferation of nonlinear devices that draw non-sinusoidal current waveforms provided by a sinusoidal voltage supply. once these devices are present in an electrical power system, they cause harmonic distortion of voltages and currents. separately, single-phase non-linear load might not cause serious harmonic drawback however massive concentrations of these loads have the potential to raise harmonic voltages and currents to unacceptable high levels which ends up in accumulated neutral currents in four wire system, over heating of distribution system elements and mechanical oscillations in generators and motors [2]. Different undesirable effects are electrical device and insulation failure owing to harmonic resonance, unpredictable behavior of put in protection systems, rapid voltage fluctuations and heating of electrical device.

II. SOURCES OF HARMONICS

(1) Tooth ripple or ripples in the voltage waveform of rotating machines.
(2) Variation in air-gap reluctance over synchronous machine pole pitch.
(3) Flux distortion in the synchronous machine form sudden load changes.
(4) No sinusoidal distribution of the flux in the air gap of synchronous machines.

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(5) Transformer magnetizing currents.
(6) Network non linearity's from loads such as rectifiers, inverters, welders, arc furnaces, voltage controllers, frequency converters.[3]

III. ADVERSE EFFECTS OF HARMONICS

- Conductor Overheating: Harmonic currents on undersized conductors or cables can cause a "skin effect", which increases with frequency.
- Capacitors: If a capacitor is tuned to one of the characteristic harmonics like the fifth or seventh, overvoltage and resonance will cause insulator failure or rupture of the capacitor.
- Fuses and Circuit Breakers: Harmonics can cause false or spurious operations and trips, damaging or blowing components for no apparent reason.
- Transformers: Have augmented iron and copper losses or eddy currents attributable to stray flux losses. This causes excessive overheating within the transformer windings. Typically, the employment of appropriate "K factor" rated units are suggested for non-linear loads.
- Generators: Have similar issues like transformers. Sizing and coordination is crucial to the operation of the voltage regulator and controls. Excessive harmonic voltage distortion can cause multiple zero crossings of the current waveform. Multiple zero crossings have an effect on the temporal arrangement of the voltage regulator, inflicting interference and operation instability.
- Utility Meters: May record measurements incorrectly, resulting in higher billings to consumers.
- Drives/Power Supplies: can be affected by disoperation due to multiple zero crossings. Harmonics can cause failure of the commutation circuits, found in DC drives and AC drives with silicon controlled rectifiers (SCRs).
- Computers/Telephones: may experience interference or failures.[4]-[6]

IV. SYSTEM REPRESENTATION FOR POWER QUALITY IMPROVEMENT

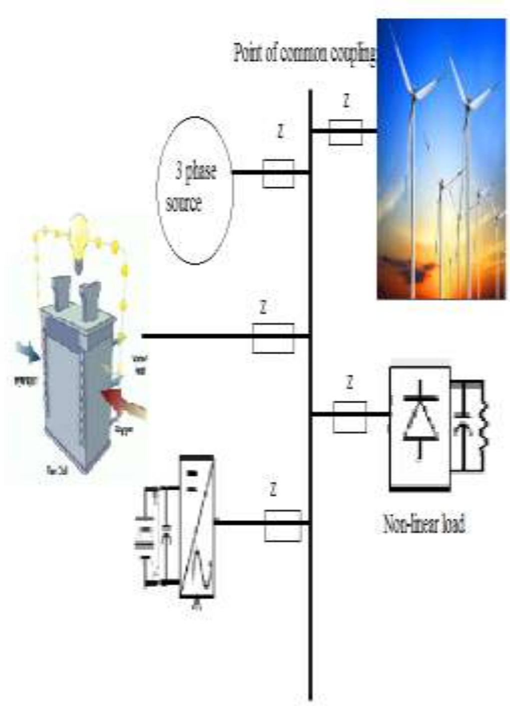

Fig 1 System representation for power quality improvement

The system shown in fig 1 is a integration of renewable energy sources like wind, fuel cell and battery energy storage system with VSI. The Smart grid system representation for power quality improvement is based on current control voltage source inverter , which injects the current into the grid in such a way that the source current are harmonic free and their phase-angle with respect to source voltage has a desired value. The injected current will cancel out the reactive part and harmonic part of the load and induction generator current, thus it improves the power factor and the power quality. To accomplish these goals, the grid voltages are sensed and are synchronized in generating the current command for the inverter. The proposed smart grid connected system is implemented for power quality improvement at point of common coupling is shown in figure 1 . [7]- [8]

V CONTROL STRATEGY

It consist of power electronics converter which can absorb or supply the active and reactive power into the grid. The control allows the sharing of power between the power converter and to the grid. The use of this power converter has distinct benefit in the grid operation. The grid voltage control, harmonic reductions and in-phase operation are the power quality benefit that can be gain without excessive compromise.

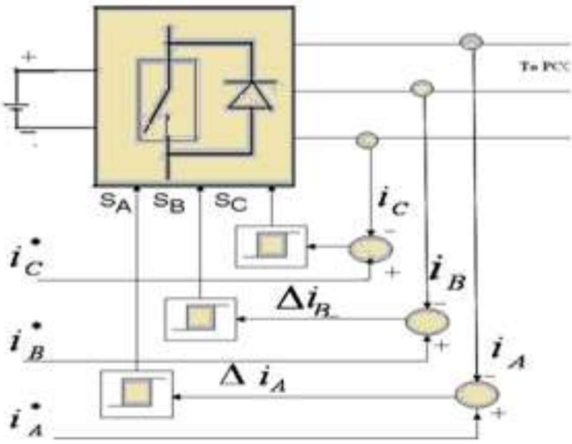

Fig 2 Hysteresis current controller

Hysteresis current controller is shown in fig 2.The major reason for this choice includes simplicity in implementation, high speed of current loop, and independency from load parameters. Figure 2 shows the basic schematic diagram for the control of proposed current controlled VSI. Hysteresis current control is a closed loop control system. Comparison of the calculated reference current and the actual DG injection currents generated by the VSI will result in the error signal e, which controls switches of inverter. When the error reaches the upper limit of the hysteresis comparator, IGBT's are switched on to increase the current ; whereas when the error reaches the lower limit as shown in fig 3 the current is forced to decrease by switching the IGBT's off. These operations lead to the fast dynamic response that characterizes hysteresis current control among the other current control techniques .The range of the error signal, 'h' directly controls the amount of ripples of the output current from the VSI and is called hysteresis band. The current is forced to stay within these limits even while the reference current is changing. By increasing switching frequency, output current ripple and the distortion of voltage and current at PCC are decreased . To have the source current in distortion free, the correct amount of current must injected to cancel out the distortion effect.

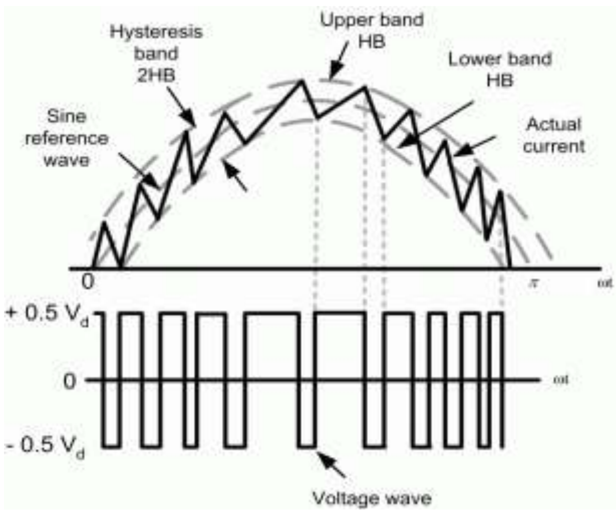

Fig 3 Hysteresis band

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VI. FFT ANALYSIS

Fast Fourier transform can be used for harmonic analysis because of its computational efficiency. FFT can be used to calculate the harmonic distortion and to separate even/odd/inter harmonics etc. FFT analysis is used to convert time domain waveforms in to their frequency components and vice versa. With this tool it is possible to have an estimation of the fundamental amplitude and its harmonics with reasonable approximation.

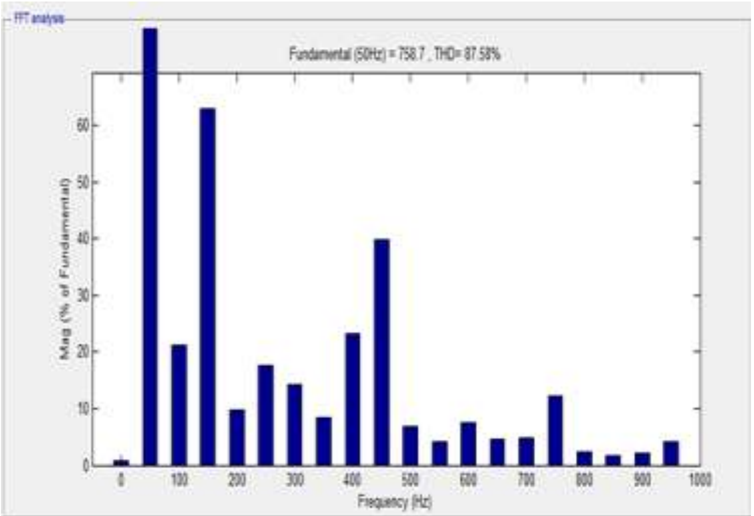

Fig 4 FFT analysis without applied control scheme

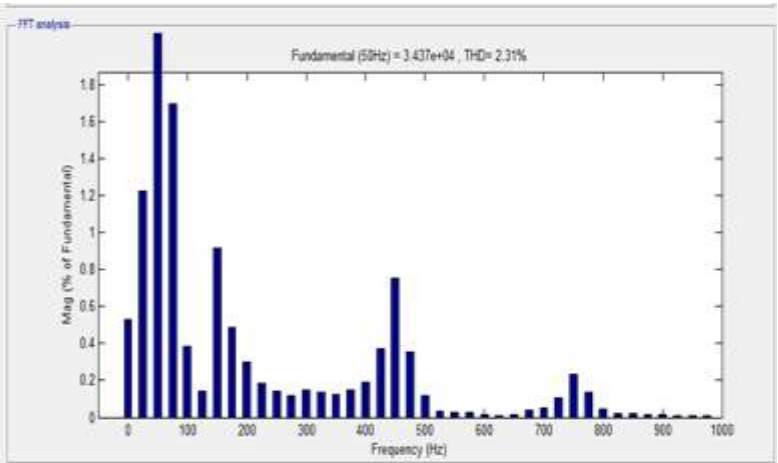

Fig 5 FFT analysis with applied control scheme

From the fig 4 it can be observed that without control scheme total harmonic distortion is about 87.58%. But by carrying out the FFT analysis after applied control scheme total harmonic distortion reduces to 2.31% as shown in fig 5. Which shows drastic reduction in THD.

$$THD = \frac{\sqrt{(V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2)}}{V_1} * 100\%$$

VII RESULTS AND DISCUSSION

Fig 6 shows source current which is free from harmonics. Fig 7 shows the load current which is non-sinusoidal due to the presence of harmonics. Fig 8 shows the inverter current. Fig 9 shows the voltage at the point of common coupling which is a pure sinusoidal wave and hence it confirms that by using control scheme harmonics are eliminated.

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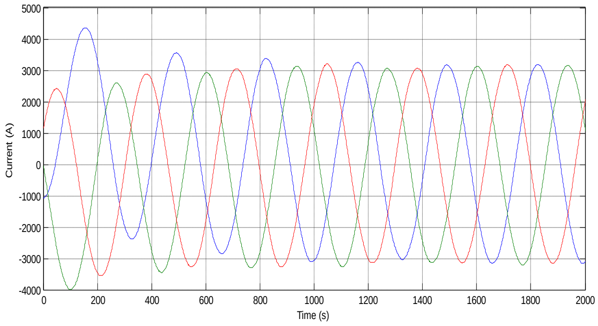

Fig 5 Source current

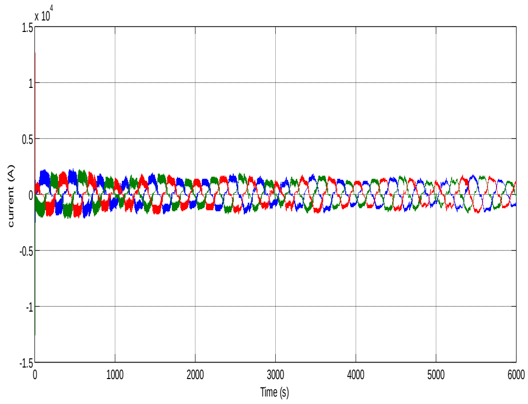

Fig 6 Load current

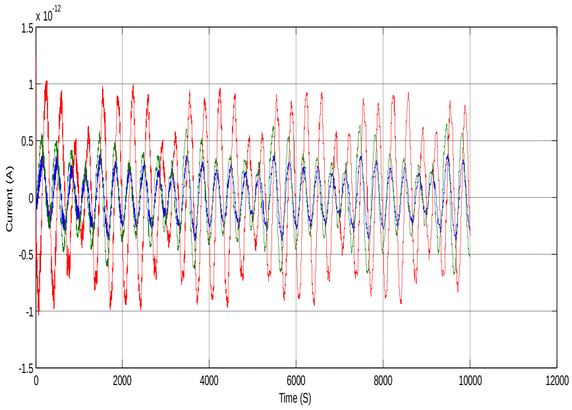

Fig 7 Inverter current

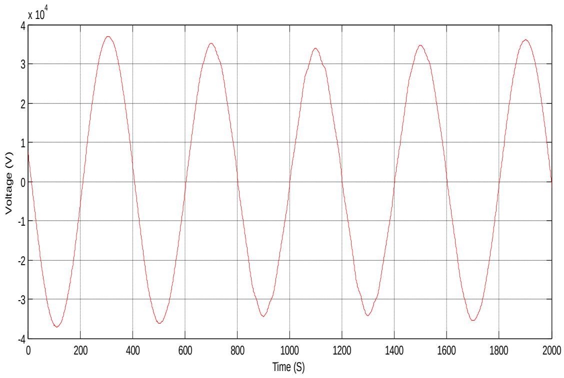

Fig 8 Voltage at the PCC

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VIII. CONCLUSION

This paper mainly interprets the harmonic reduction in the smart grid. The system is integration of multiple sources to the grid. Non-linear load is considered and identified some harmonic distortions and hence leads to power quality disturbances in the system. In order to enhance the power quality by reducing harmonic distortion in the smart grid, voltage source converter based on current controlled mode , with hysteresis control is integrated in the system. In this paper we have carried out detailed analysis of voltage waveforms at point of common coupling by applied control strategy using MATLAB simulation and noticed the harmonic reduction and hence power quality enhancement in the smart grid power system. And also FFT analysis is carried out which shows reduced total harmonic distortion in the system.

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