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Distributed Generation Integration to Grid Using Multi-Level CHB Inverter

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Abstract

Environmental conditions, electrical modeling and developments in industries led to new power generation epoch where fat section of power required for load section is fed through extensive induction of distributed resources generally known as distributed generation [DG]. Distributed generation reduces the risk of environmental pollution and distance criterion posed from conventional power generation. This paper presents grid integration scheme of distributed generation using five-level cascaded H-Bridge (CHB) inverter. Reference currents used to produce pulses for switches in CHB are generated using a simple control strategy. Performance of the system was evaluated when only active power is fed from distributed generation to grid and also when both active and reactive powers were fed to grid from distributed generation. Proposed system was developed using MATLAB/SIMULINK software and results are presented.

Keywords: *Distributed generation, grid, integration, CHB, multi-level*

1. Introduction

Power generation from conventional thermal, gas and nuclear stations pose a serious threat to environmental conditions. Due to pollution constraint, these conventional power plants cannot be placed near to load centers. Transmitting power to long distances to feed the load increases the transmission line loasses. Environmental conditions, electrical modeling and developments in industries led to new power generation epoch where fat section of power required for load section is fed through extensive installation of distributed resources generally known as distributed generation [DG] [1-5]. Distributed generation can be done at the load points and reduces the transmission distance which eventually reduces the line losses. DG is defined as the integrated or stand-alone use of small, modular electric generation close to the point of consumption.

DG is generally will be from photo-voltaic array, fuel cell or wind system. To integrate the output produced from DG to grid, inverter is employed. Conventional square-wave inverter produces high amount of distortion at the output and requires high sized filters for smoothing the output wave shape which eventually increases the cost and size of the overall equipment. Conventional two-level inverter pressures the switch since change in voltage is very high. Owing to size and stress on switches, multi-level inverters (MLI) [6-9] which can produce higher output levels with stepped shape are used.

Diode clamped or neutral point clamped type, flying capacitor type and cascaded H-Bridge type are the types of multi level inverters [10-13]. Diode clamped MLI require more number of diodes and increases the circuit complexity. Flying capacitor type uses more capacitors as clamping elements and voltage balance across capacitors is a complex process. These disadvantages make CHB topology a reliable and simple MLI. Number of switches used in CHB is also less compared to other two types. Number of sources used in CHB topology is the only concern while using CHB multi-level inverter. The multilevel inverter can operate at both fundamental switching frequencies that are higher switching frequency and lower switching frequency. It should be noted that the lower switching frequency means lower switching loss and higher efficiency is achieved.

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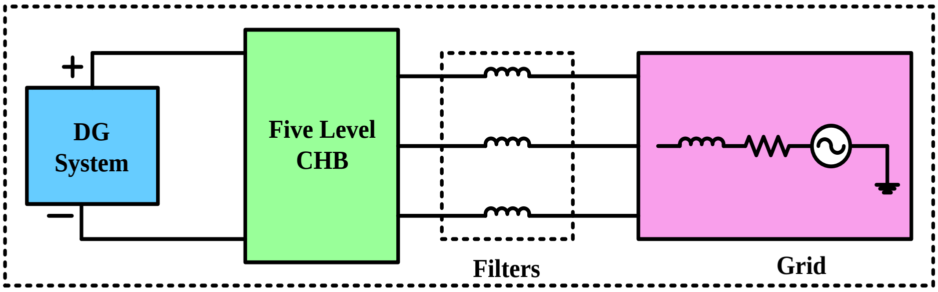

Figure 1. Schematic block diagram of DG integration to grid

Figure 1 shows the schematic block diagram representation of DG integration to grid. Output of DG system (DC) is fed to five-level inverter. Five-level inverter produces stepped shape output which will be further filtered out by filter circuit and integrates power to grid from DG. This paper presents grid integration scheme of distributed generation using five-level cascaded H-Bridge (CHB) inverter. Reference currents used to produce pulses for switches in CHB are generated using a simple control strategy. Performance of the system was evaluated when only active power is fed from distributed generation to grid and also when both active and reactive powers were fed to grid from distributed generation. Proposed system was developed using MATLAB/SIMULINK software and results are presented.

2. Grid Integration Scheme of DG to Grid

Figure 2 shows the DG integration scheme to grid with 5-level CHB inverter. For simple understanding, only phase-A of three-phase CHB inverter was shown in the figure. The power generated from DG is fed to a five-level CHB inverter which inverts the DC power from DG to AC type. The output of CHB inverter is fed to grid through filter circuit.

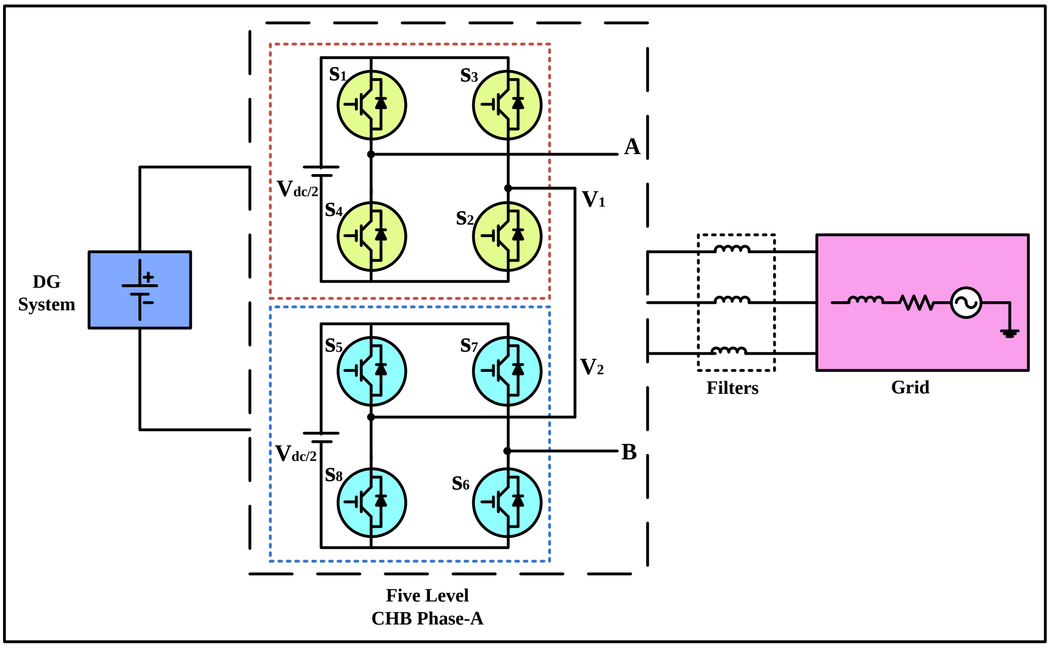

Figure 2. DG integration scheme to grid through 5-level inverter

Cascaded H-Bridge multi-level inverter is in magnificent usage especially in medium voltage and high power applications. A cascaded H-Bridge multi-level inverter is formed by cascading number of H-Bridge cells in each phase. The number of H-Bridge cells used depends on the level of output required. Each H-Bridge is supplied with a detached DC source. For 5-level output, the number of H-Bridge cells required in each phase is two and consists of eight switches in each phase with two isolated DC sources to drive each H-Bridge cell. The two H-Bridge cells in each phase are cascaded. Similar two other phases with similar construction as said above constitutes three-phase CHB multi-level inverter to produce three-phase five-level output.

3. Simple Control Strategy for 5-Level CHB Inverter

The simple control strategy to produce pulses to CHB was shown in figure 3. In this simple control strategy, directly the values of $I_{d(ref)}$ and $I_{q(ref)}$ components are directly fed to dq-abc transformation along with the waveshape information from PLL. The obtained reference current signal in abc co-ordinates are again compared with actual components of currents from three phases. The error signal is sent to PWM generator to produce pulses to switches in CHB. Only three drive circuits are employed and using not signals, pulses are sent to remaining switches.

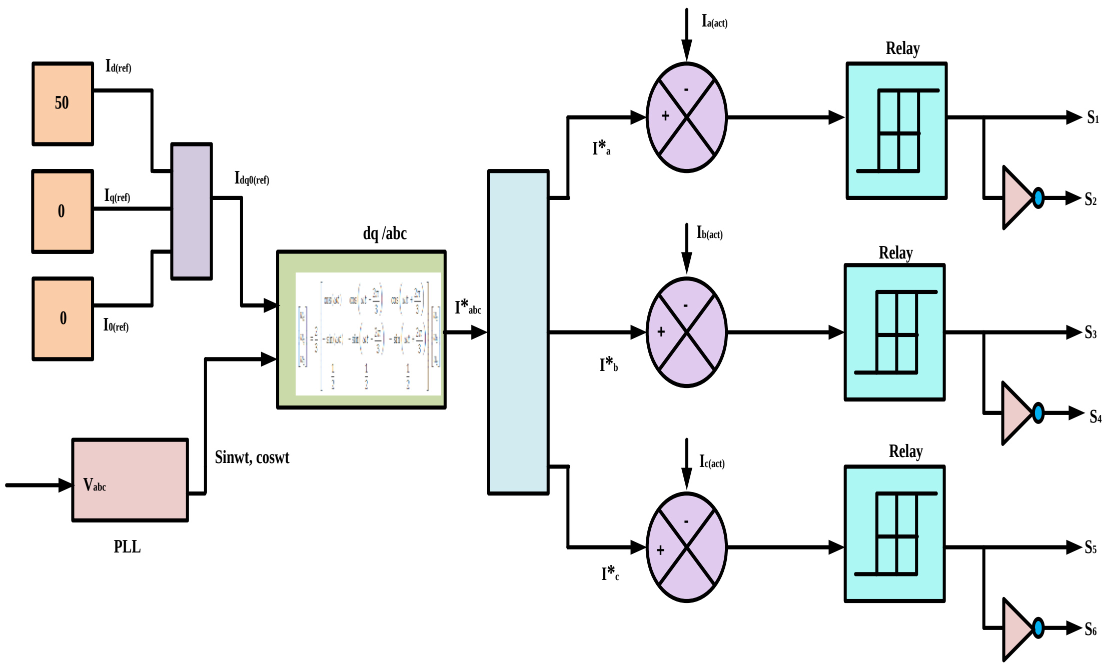

Figure 3. Simple control strategy for 5-level CHB

The complete schematic picture of DG system integration to grid through 5-level inverter with its control strategy was depicted in figure 4. Level shifted (LSCPWM) multi-carrier pattern of pulse width modulation was used in this context to produce pulses to switches in inverter. In LSCPWM, all the carrier signals will have same amplitude and frequency but the carrier signals are shifted with levels two carriers above zero reference and two carrier signals below zero reference. All the carrier signals will be in-phase. When the reference signal is higher than carrier signal pulse will be high otherwise low.

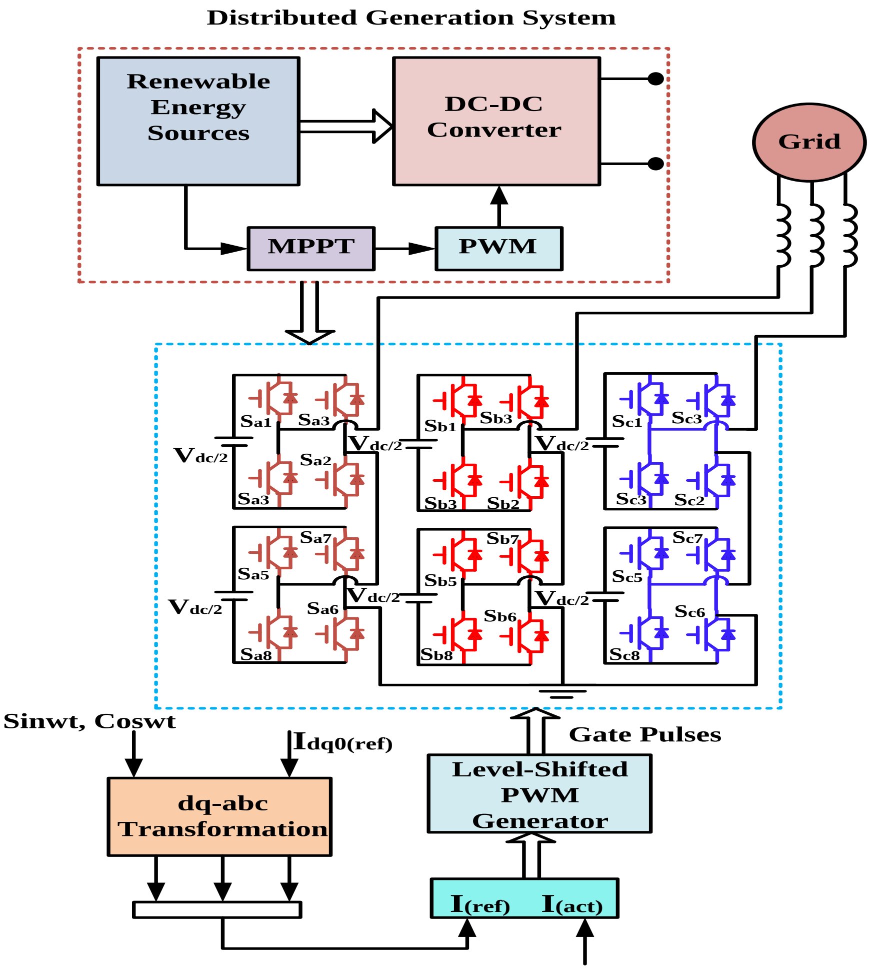

Figure 4. Complete picture of DG integration to grid through 5-level inverter with its control strategy

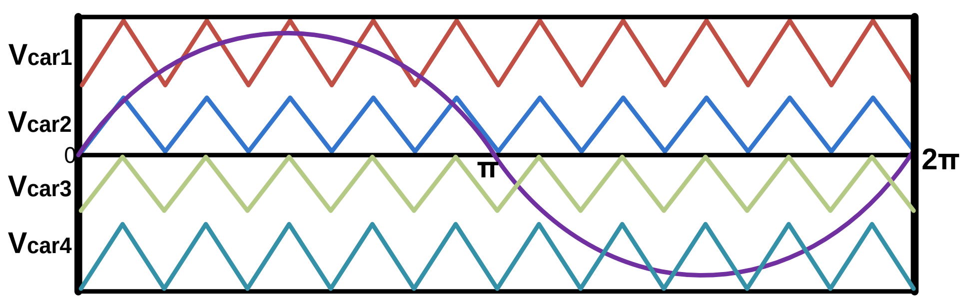

Figure 5. In-phase disposition PWM pattern

The pattern of in-phase carrier based level shifted SPWM technique to produce firing pulses to power switches was shown in figure 5. In this pattern of producing firing pulses, all the carrier signals will have same amplitude and frequency but the carrier signals are shifted with levels two carriers above zero reference and two carrier signals below zero reference. All the carrier signals will be in-phase. When the reference signal is higher than carrier signal pulse will be high otherwise low.

4. Simulation Results and Analysis

4.1. DG Inducing Only Active Power to Grid

Figure 6 shows the three-phase grid voltage and figure 7 shows the three-phase grid currents when DG is sending only active power to grid. Three-phase grid voltage is maintained sinusoidal with 360V peak value. Three-phase grid current is sinusoidal with 50A peak value. Figure 8 shows the five-level output obtained from the three phases of CHB inverter.

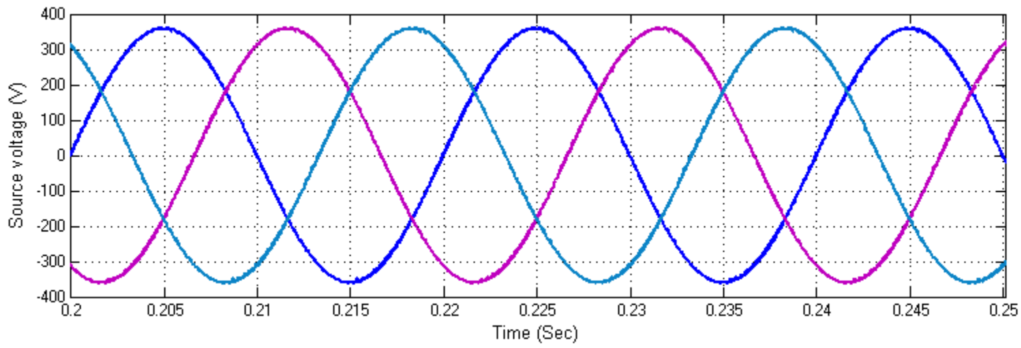

Figure 6. Source voltage of grid

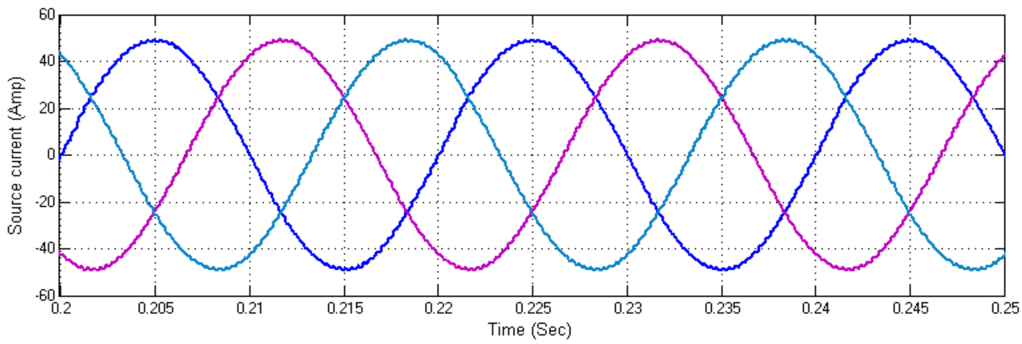

Figure 7. Source current of grid

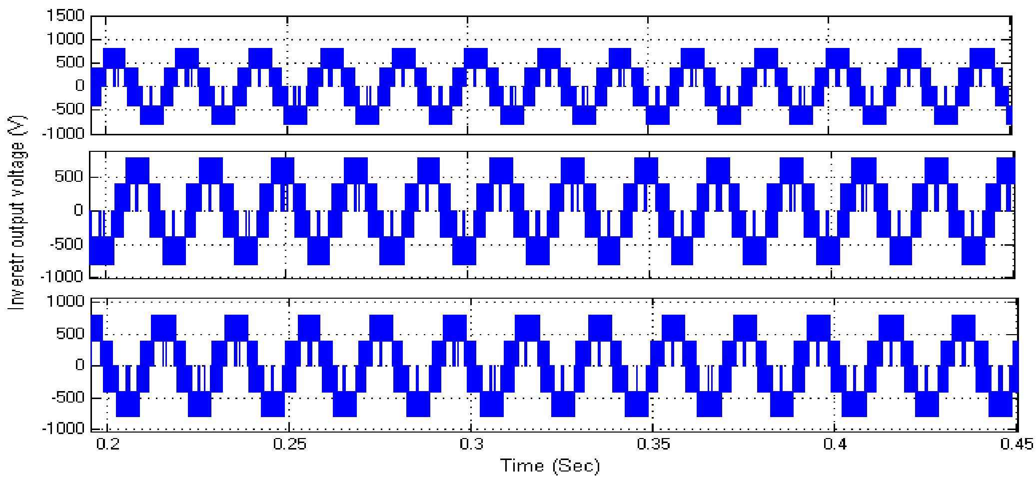

Figure 8. Three phase 5-level inverter output voltage

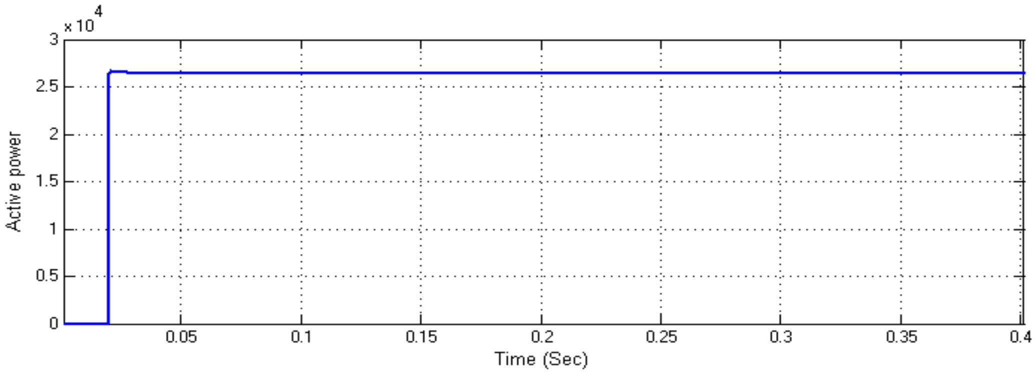

Figure 9. Active power induced in to grid

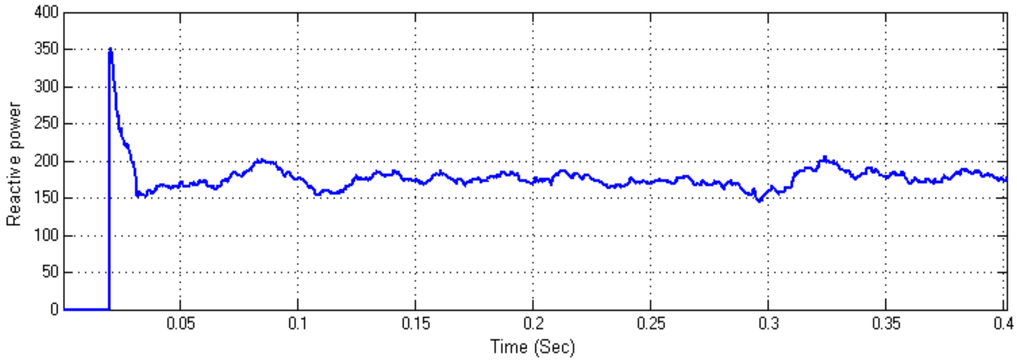

Figure 10. Reactive power induced in to grid

Figure 9 shows the active power fed to grid from DG and figure 10 shows the reactive power fed to grid from DG. Active power of 26KW is fed to grid and reactive power of just 150 VAR is fed to grid. Reactive power is not much high and do not affect the grid characteristics.

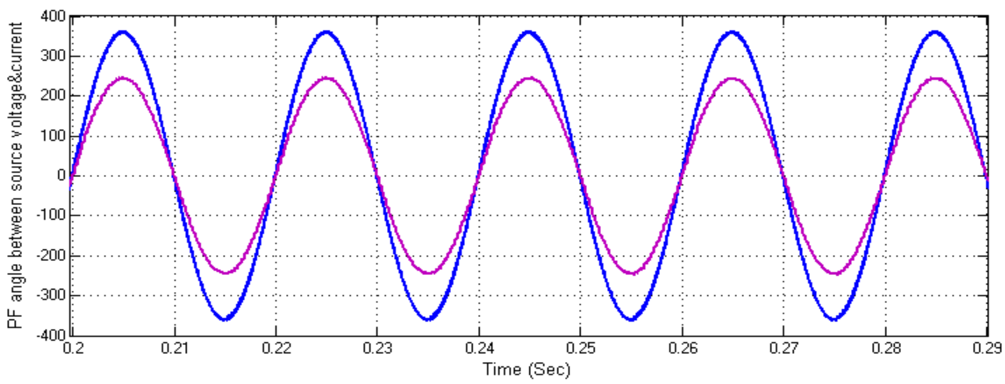

Figure 11. Power factor angle between source voltage and source current

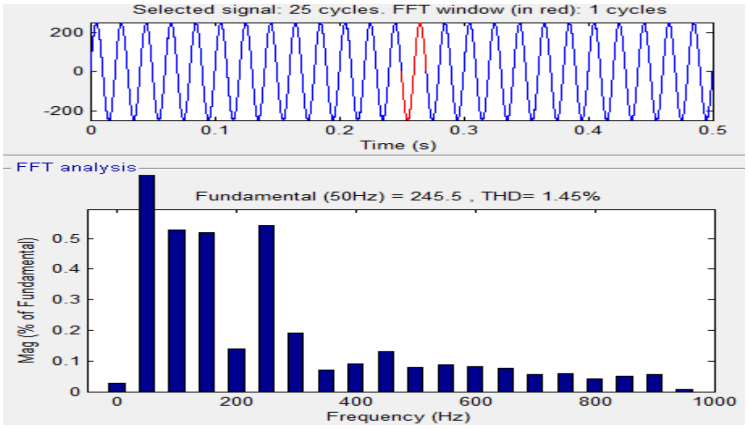

Figure 12. Source current THD

Figure 11 shows the power factor angle between source voltage and source current. The phase angle between source voltage and current is almost zero and thus the power factor in source is maintained nearer unity. Figure 12 shows the harmonic distortion in source current indicating just 1.45% of distortion which is well within nominal value.

4.2. DG Inducing Both Active Power and Reactive Power to Grid

Figure 13 shows the three-phase grid voltage and figure 14 shows the three-phase grid currents when DG is sending active and reactive power to grid. Three-phase grid voltage is maintained sinusoidal with 360V peak value. Three-phase grid current is sinusoidal with 35A peak value.

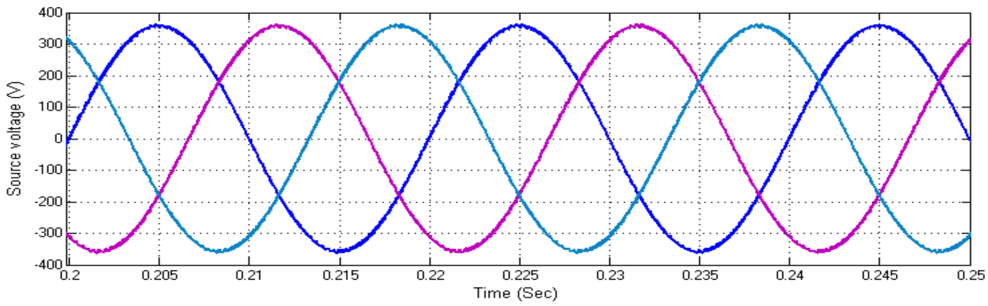

Figure 13. Three-phase Source voltage of grid

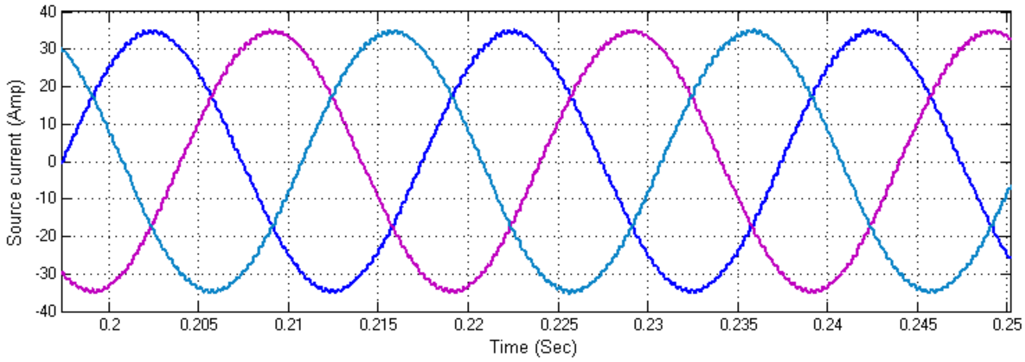

Figure 14. Three-phase Source current of grid

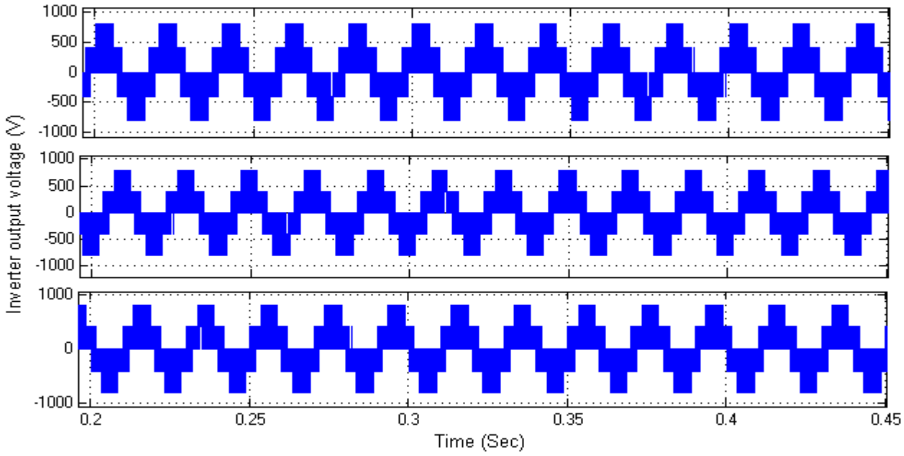

Figure 15. Three phase 5-level inverter output voltage

Figure 15 shows the five-level output obtained from the three phases of CHB inverter.

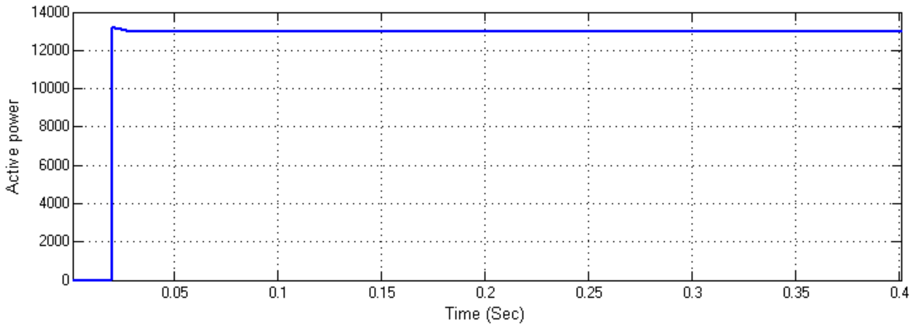

Figure 16. Active powe fed to grid from DG

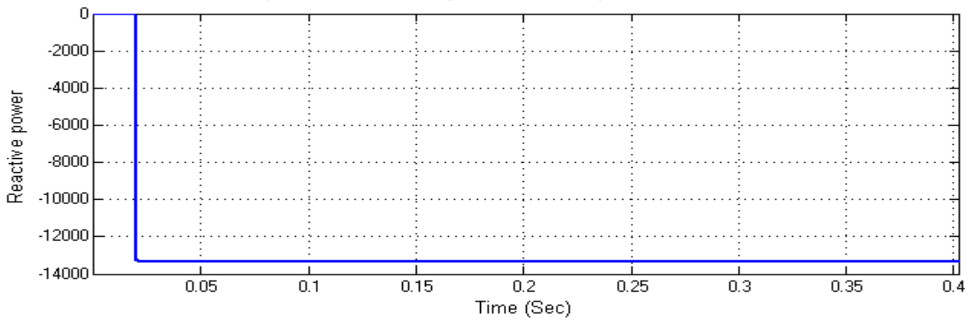

Figure 17. Reactive power fed to grid from DG

Figure 16 shows the active power fed to grid from DG and figure 17 shows the reactive power fed to grid from DG. Active power of 13 KW is fed to grid and reactive power of 13 KVAR is fed to grid.

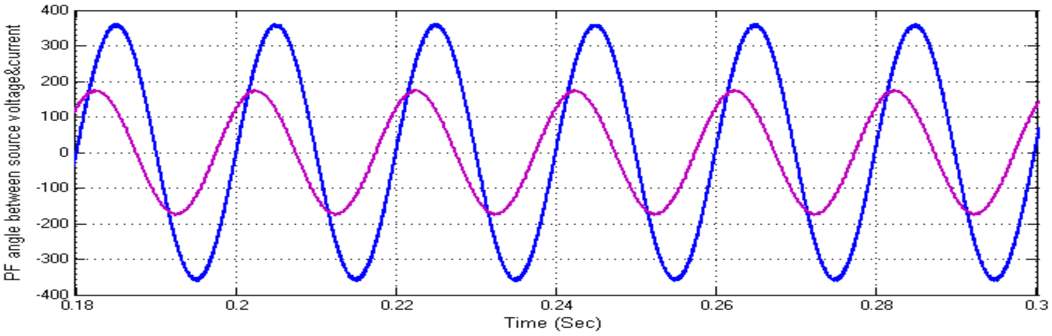

Figure 18. Power factor angle between source voltage and source current

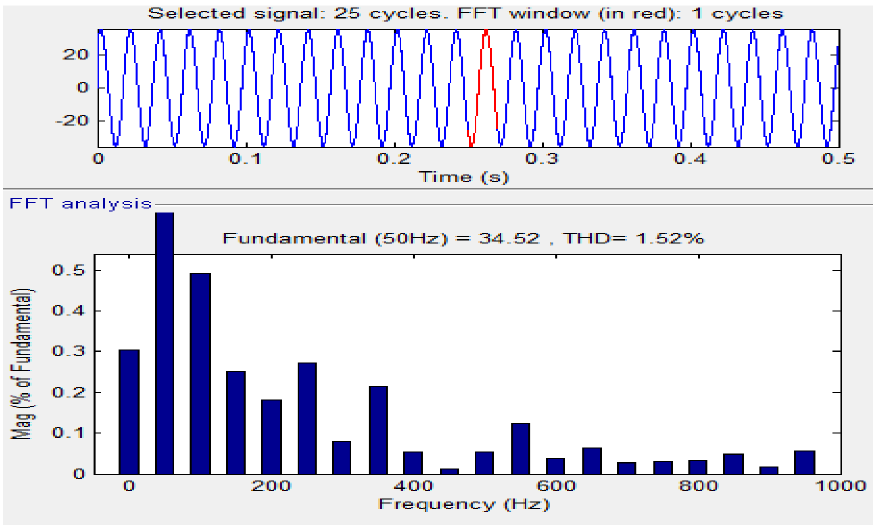

Figure 19. Source current THD

Figure 18 shows the power factor angle between source voltage and source current. The phase angle between source voltage and current is non-zero and thus the power factor in source is not maintained nearer unity since reactive power is also fed to grid from DG. Figure 19 shows the harmonic distortion in source current indicating just 1.52% of distortion which is well within nominal value.

5. Conclusion

Evolution of new source generating power at load centers emitting no pollution can enhance system performance. Distributed generation is such a type generating power with zero pollution at load place. The paper presents DG integration to grid to send power generated from DG to grid. DG produces DC pwer and is to be inverted. 5-level CHB inverter is employed to invert DC to AC type of power. DG when feeding only active power and when sending active and reactive power to grid is discussed. The 5-level output of 5-level CHB is shown. Harmonic distortion in source current of grid was shown in both the cases and is maintained within nominal limit. 5-level CHB inverter is controlled using a simple control strategy explained and controls active power and reactive power cases.

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