DISTRIBUTED GENERATION INTEGRATION TO TRANSMISSION GRID CONTROLLED WITH D-Q THEORY

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ABSTRACT

Power demand is increasing day-by-day in this fast growing technological scenario. Power system stability depends on how far the generation meets the load demand. Increase in load above total generation capacity can degrade the system stability. Use of fossil fuels for conventional power generation can increase the pollution which is most concern of world these days. Also the availability and cost is a concern while using fossil fuels. Distributed generation can be a viable option to generate pollution less, less running cost and cheap electricity. This paper presents the integration of power generated from distributed generation to grid to meet the load demands reducing the operation of conventional power generation from fossil fuels. The inverter used to invert DC power from distributed generation to AC type of power is controlled with d-q control theory. Proposed concept was developed using MATLAB/SIMULINK software and results were presented. The concept was developed for the cases of sending only active power to grid from distributed generation, sending only reactive power to grid from distributed generation and sending both active and reactive power to grid from distributed generation.

Keywords: distributed generation, grid, integration, d-q control.

INTRODUCTION

Power demand is ever growing phenomenon with increase in load intentions. Power demand is a factor cannot be predicted due to ever increasing loads in industries, commercial complexes, and domestic loads. Power engineers are striving hard to meet the load demands by generating sufficient power. Even a slight variation in meeting the load demand can cause power system grid to breakdown. Generation capability increase is the further step to be taken to meet ever increasing load demand [1-2].

Fossil fuels can generate electrical power in bulk but emission of green house gases is the global issue these days with using conventional fossil fuels. To reduce the carbon gases emission from conventional power plants, renewable energy sources is the best alternative to provide stability to power system reducing the power generation from conventional plants. Photo-voltaic (PV) system [3-4], wind system, fuel-cells are examples used in renewable sources for power generation. PV system is one of the forefront generation scheme employed in major. PV cell is a simple P-N junction layer to produce potential barrier between the two layers. Photon from the light energy when absorbed by the charge carriers in PV cell, electrons starts flowing and giving rise to current flow [5-6]. Figure-1 shows general DG integration scheme to grid.

The term distributed generation is often used to depict a small-scale electricity generation. Currently, there is no consensus on how the distributed generation should be exactly defined. As shown by the survey conducted by CIRED [7], there is no consensus on the definition of this term [8]. Some countries define distributed generation on the basis of the voltage level, whereas others start from the principle that distributed generation is connected to circuits from which consumer loads are supplied directly. Other countries define distributed generation as having some basic characteristic (for example, using renewable, cogeneration, being non-dispatchable, etc.).

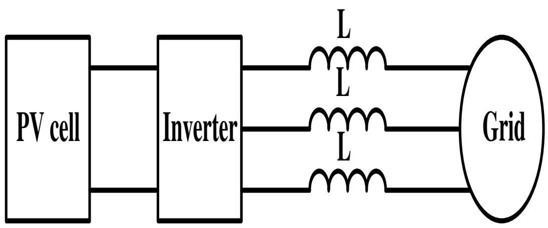

Figure-1. General DG integration scheme to grid.

International Energy Agency IEA [9] lists five major factors that contribute to this evolution, such as developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the electricity market liberalization and concerns about climate change. Especially the last two points seem to offer the most significant benefits, as it is unlikely that distributed generation would be capable of avoiding the development of new transmission lines. At minimum, the grid has to be available as backup supply. Environmental policies or concerns are probably the major driving force for the demand for distributed generation in Europe. Environmental regulations force players in the electricity market to look for cleaner energy- and cost-efficient solutions. Many of the distributed generation technologies are recognized environmentally friendly. Distributed generation contributes to the improvement of power quality. In the areas where voltage support is difficult,

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ARPN Journal of Engineering and Applied Sciences

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distributed generation offers significant benefits for the voltage profile and power factor corrections.

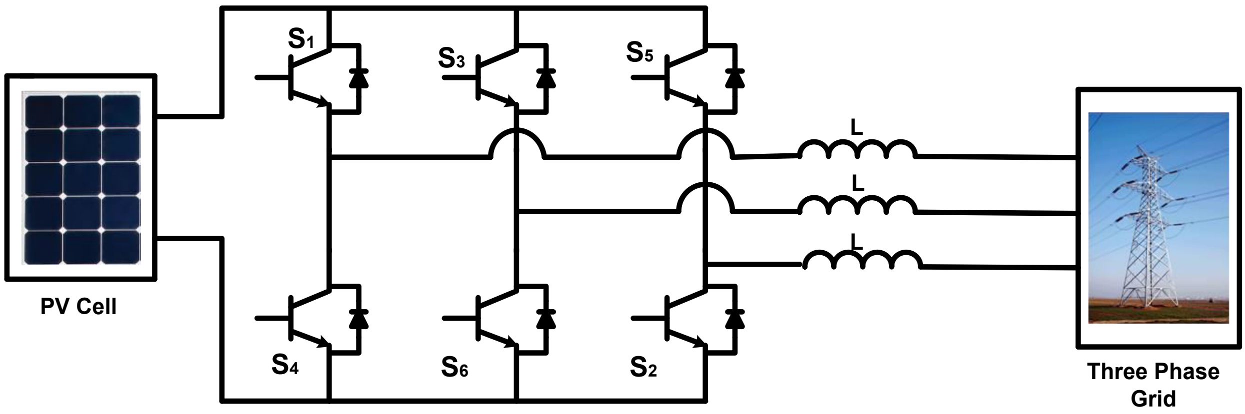

Figure-2. General DG integration scheme to grid.

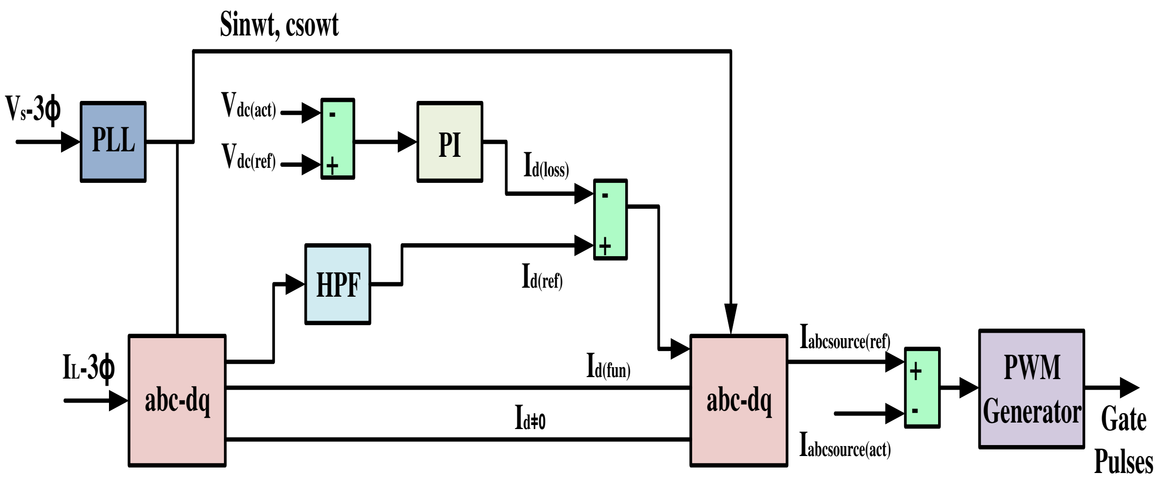

Figure-3. Control scheme of d-q theory.

This paper presents the integration of power generated from distributed generation to grid to meet the load demands reducing the operation of conventional power generation from fossil fuels. The inverter used to invert DC power from distributed generation to AC type of power is controlled with d-q control theory. Proposed concept was developed using MATLAB/SIMULINK software and results were presented. The concept was developed for the cases of sending only active power to grid from distributed generation, sending only reactive power to grid from distributed generation and sending both active and reactive power to grid from distributed generation.

GRID INTERFACING SCHEME WITH DISTRIBUTED GENERATION

The integration of a significant share of variable renewable sources into power grid requires a substantial transformation of the existing networks in order to improve the interconnection of grids at the regional, national and international level, aimed at increasing grid balancing capabilities, reliability and stability. Introduce technologies and procedures to ensure proper grid operation stability and control in the presence of a significant share of variable renewable; and to introduce energy storage capacity to store electricity from variable renewable sources when power supply exceeds demand and aimed at increasing system flexibility and security of supply. The connection of renewable electricity generation plants to distribution grids requires the analysis of several factors which may impact the grid's operation. Increased grid interconnection at regional, national and international level would enable more flexibility in power transmission from regions with an ample availability of renewables to other regions with high electricity demand.

Figure-2 depicts block diagram of the proposed schematic arrangement of DG integration to grid. A PV system equivalent was shown and is connected to inverter. The output from PV system is generally of DC type and for integration PV system to grid; output from PV system is to be inverted to alternating type. An inverter is a power electronic converter inverting the input DC supply to AC

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output. The output of inverter is now passed through a filter to eliminate the distortions in source voltage and current. As the number of output from the inverter is increased, THD at the output of inverter reduces with fewer filters needed.

D-Q CONTROL THEORY FOR GRID INTERFACING SCHEME OF DG

Figure-3 depicts block diagram of the control theory to control inverter for integration of distributed generation to grid. Initially three-phase source voltage and currents are sensed. Three-phase source voltage is sent to PLL where information of sin and cos is obtained.

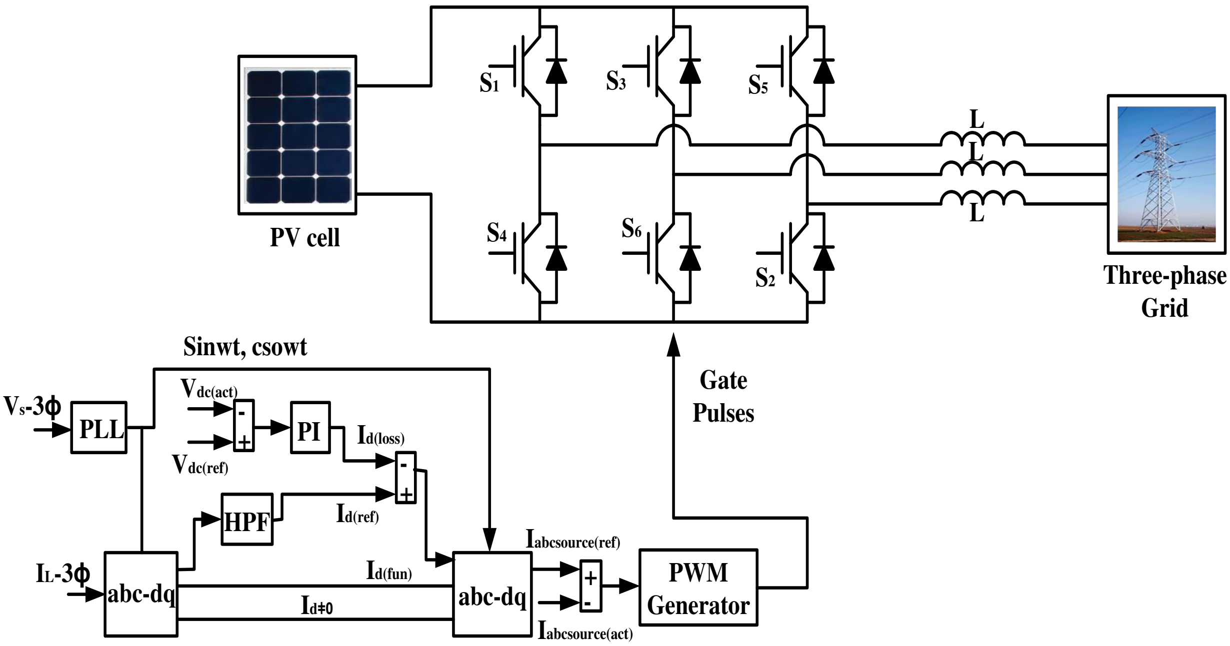

Figure-4. Complete DG interfacing to grid with control scheme of d-q theory.

Three-phase line currents are transformed to d-q co-ordinates from abc coordinated using clarks transformation. Obtained dq coordinates are passed through high pass filter to obtain'd' component of reference current. DC link voltage actual value and reference values are measured and sent to PI controller where error is reduced to produce loss component of current. Loss component of current is compared to reference current signal and sent for inverse transformation to 'abc' coordinates along with fundamental current component and 'q' component of current which is not equal to zero to produce reference source currents. Actual source current is compared to reference current and sent to PWM generator to produce pulses to inverter.

RESULTS AND DISCUSSIONS

DG sending only active power to grid

Figure-5 shows the source voltage in three phases of source before filter. The output obtained from inverter for integration to grid contains harmonics and is not pure sinusoidal in nature.

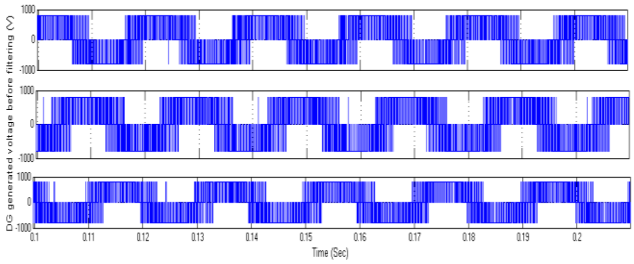

Figure-5. Source voltage before filtering.

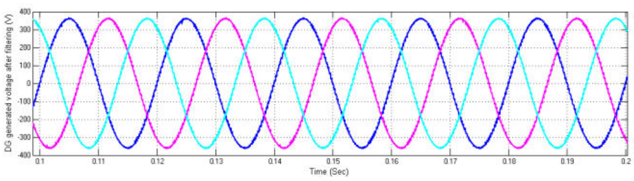

Figure-6. Source voltage after filtering.

Figure-6 shows the source voltage in three phases of source after filter. The obtained output from inverter is passed through a filter connected in three phases reduces the harmonics making the source voltage sinusoidal.

VOL. 12, NO. 24, DECEMBER 2017 ISSN 1819-6608
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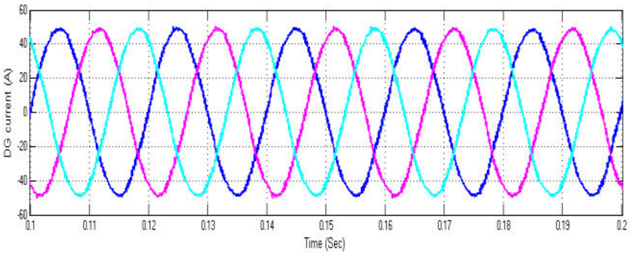

Figure-7. DG current.

Figure-7 shows the three-phase source current from DG to source grid. The currents fed to grid from DG are sinusoidal in nature with 50A magnitude.

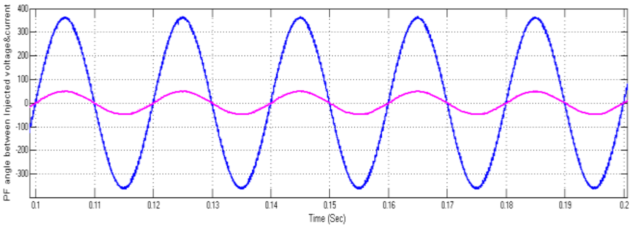

Figure-8. Power factor angle between source voltage and current.

Figure-8 shows the power factor angle between source voltage and source current with no phase angle difference between them indicating the power factor is maintained nearer to unity in source grid.

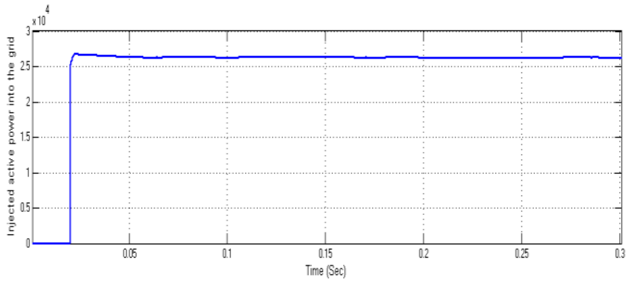

Figure-9. Injected active power into the grid.

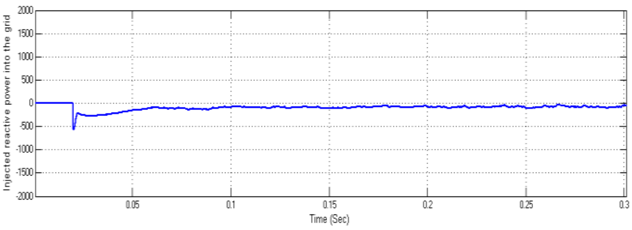

Figure-10. Injected reactive power into the grid.

Figure-9 shows the active power injected to grid from DG while figure 10 shows reactive power injected to grid from DG. As only active power is been injected to grid from DG, reactive power injection is zero as shown and active power of 25 KW is been injected to grid from DG.

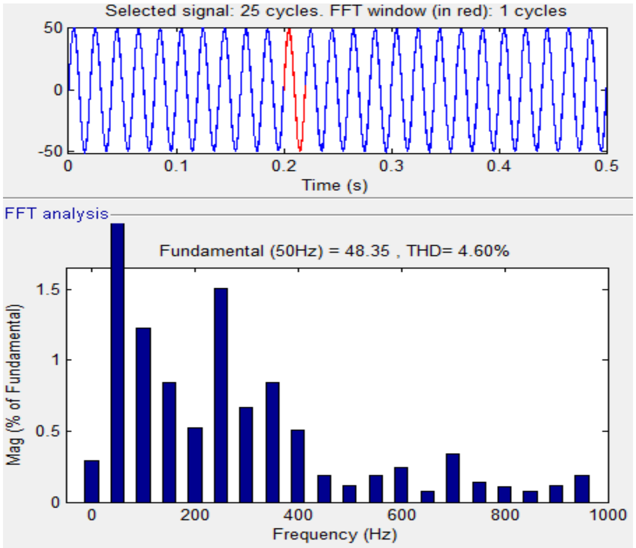

Figure-11. Harmonic distortion in source current.

Figure-11 shows the harmonic distortion in source current while injecting power from DG to grid. Source current is distorted by only 4.6 % which is within acceptable limits. Distortion is not too high and works satisfactorily.

DG sending only reactive power to grid

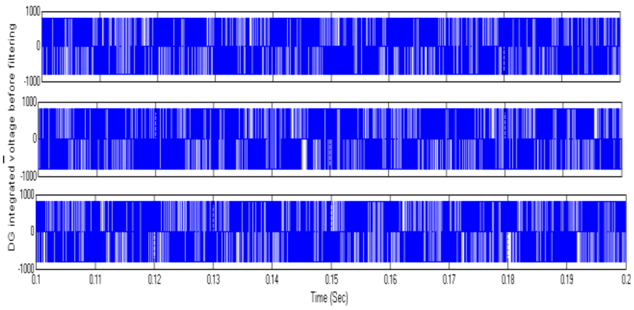

Figure-12. Source voltage before filtering.

Figure-12 shows the source voltage in three phases of source before filter. The output obtained from inverter for integration to grid contains harmonics and is not pure sinusoidal in nature.

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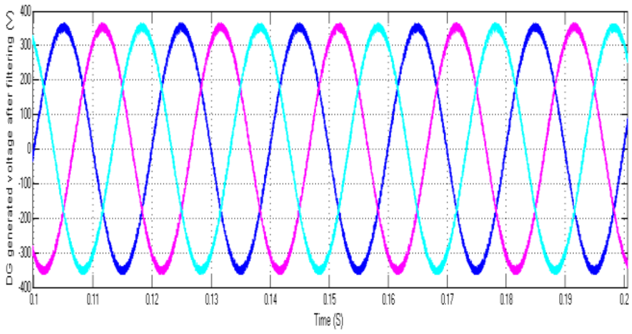

Figure-13. Source voltage after filtering.

Figure-13 shows the source voltage in three phases of source after filter. The obtained output from inverter is passed through a filter connected in three phases reduces the harmonics making the source voltage sinusoidal.

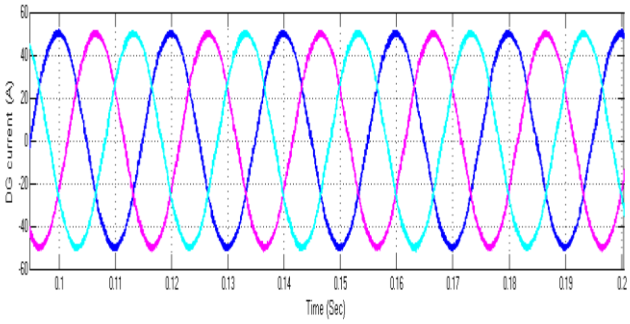

Figure-14. DG current

Figure-14 shows the three-phase source current from DG to source grid. The currents fed to grid from DG are sinusoidal in nature with 50A magnitude.

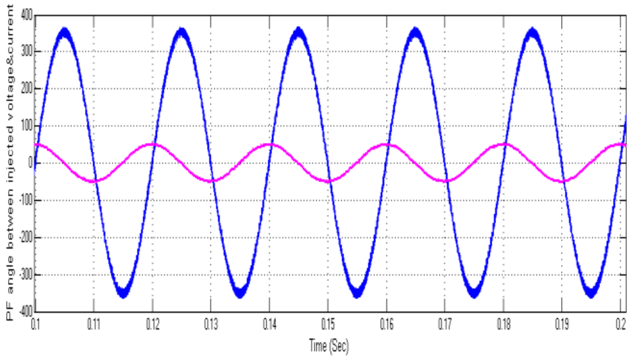

Figure-15. Power factor angle between source voltage and current.

Figure-15 shows the power factor angle between source voltage and source current with some phase angle difference between them indicating the power factor is maintained nearer to non-unity in source grid as only reactive power is sent to grid.

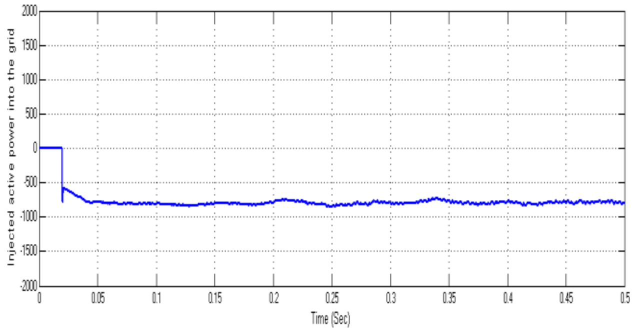

Figure-16. Injected active power into the grid.

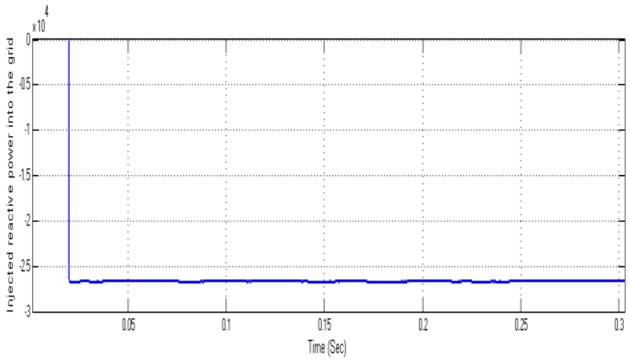

Figure-17. Injected reactive power into the grid.

Figure-16 shows the active power injected to grid from DG while figure 17 shows reactive power injected to grid from DG. As only reactive power is been injected to grid from DG, active power injection is in negative zone indicating no active power sent to grid as shown and reactive power of 25 KVAR is been injected to grid from DG.

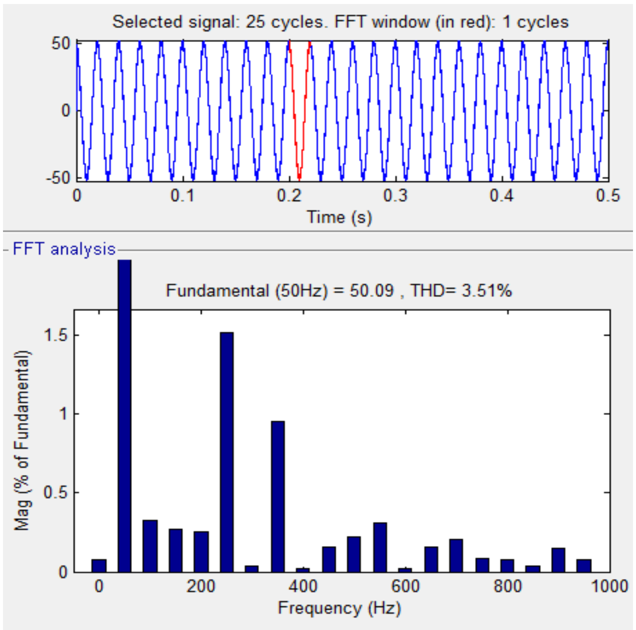

Figure-18. Harmonic distortion in source current.

VOL. 12, NO. 24, DECEMBER 2017 ISSN 1819-6608
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Figure-18 shows the harmonic distortion in source current while injecting power from DG to grid. Source current is distorted by only 3.51 % which is within acceptable limits. Distortion is not too high and works satisfactorily.

DG sending active and reactive power to grid

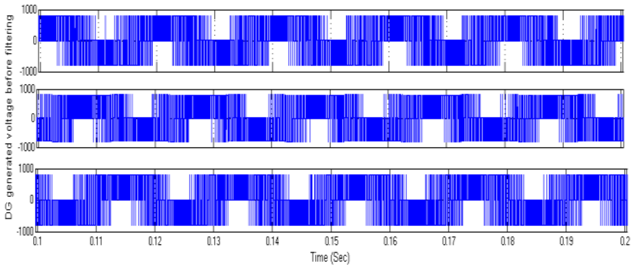

Figure-19. Source voltage before filtering.

Figure-19 shows the source voltage in three phases of source before filter. The output obtained from inverter for integration to grid contains harmonics and is not pure sinusoidal in nature.

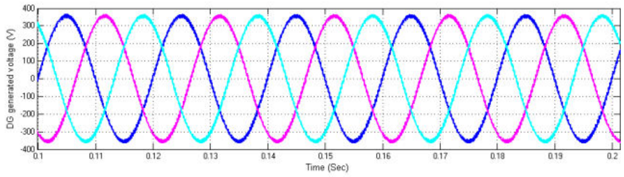

Figure-20. Source voltage after filtering.

Figure-20 shows the source voltage in three phases of source after filter. The obtained output from inverter is passed through a filter connected in three phases reduces the harmonics making the source voltage sinusoidal.

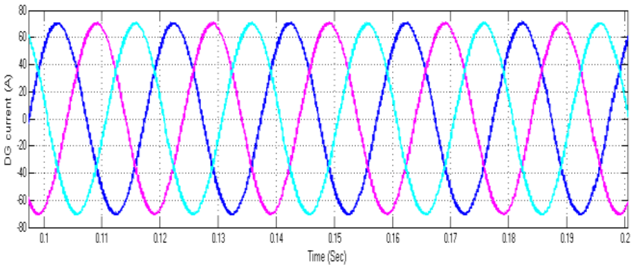

Figure-21. DG current.

Figure-21 shows the three-phase source current from DG to source grid. The currents fed to grid from DG are sinusoidal in nature with 70A magnitude.

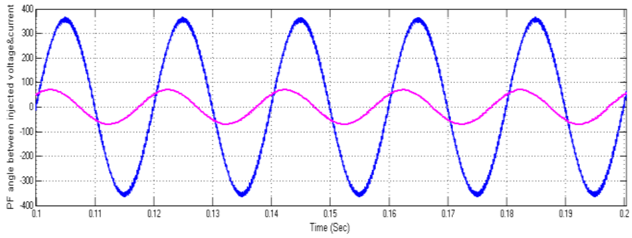

Figure-22. Power factor angle between source voltage and current.

Figure-22 shows the power factor angle between source voltage and source current with some phase angle difference between them indicating the power factor is maintained nearer to non-unity in source grid as reactive power is also sent to grid along with active power.

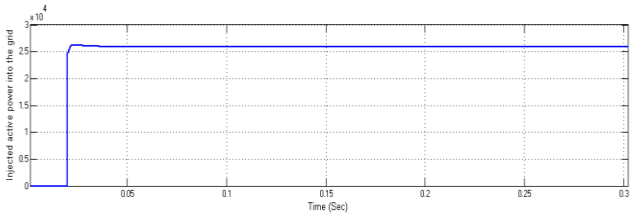

Figure-23. Injected active power into the grid.

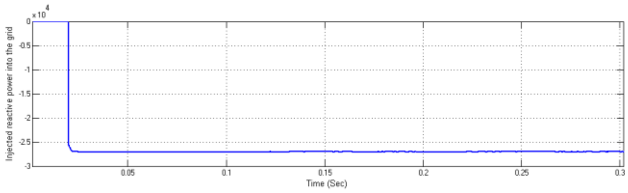

Figure-24. Injected reactive power into the grid.

Figure-23 shows the active power injected to grid from DG while Figure-24 shows reactive power injected to grid from DG. As active power and reactive power is been injected to grid from DG, reactive power injection is non-zero with 25KVAR as shown and active power of 25 KW is been injected to grid from DG.

Figure-25 shows the harmonic distortion in source current while injecting power from DG to grid. Source current is distorted by only 3.76 % which is within acceptable limits. Distortion is not too high and works satisfactorily.

VOL. 12, NO. 24, DECEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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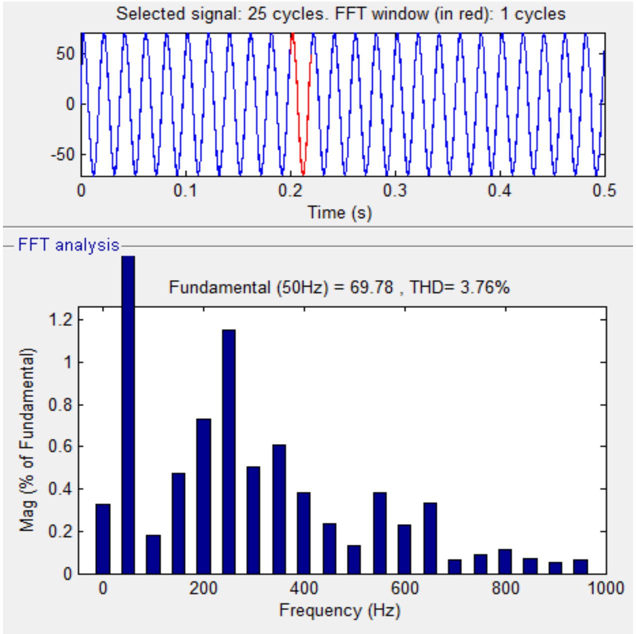

Figure-25. Harmonic distortion in source current.

CONCLUSIONS

Power demand is increasing and power system stability depends on how far the generation meets the load demand. Use of fossil fuels for conventional power generation can increase the pollution and the availability and cost is a concern while using fossil fuels. Distributed generation can be a viable option to generate pollution less, less running cost and cheap electricity. This paper presents the integration of power generated from distributed generation to grid to meet the load demands reducing the operation of conventional power generation from fossil fuels. The inverter used to invert DC power from distributed generation to AC type of power is controlled with d-q control theory which was explained. Proposed concept was developed using MATLAB/SIMULINK software and results were presented. The concept was developed for the cases of sending only active power to grid from distributed generation, sending only reactive power to grid from distributed generation and sending both active and reactive power to grid from distributed generation.

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