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Harmonic Elimination Using STATCOM for SEIG Fed Induction Motor Load

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ABSTRACT

Non-linear loads connected to distribution system induce harmonics in to source components and the presence of harmonics in source components affects the performance of other sensitive loads connected at the same point. Induction motor load for drive system should be operated with variable frequency and variable voltage for its speed control. To vary the voltage and frequency, induction motor is fed from an inverter. This total drive set-up constitutes non-linear load type and will be the source of harmonics. This paper depicts the suppression of harmonics with STATCOM in distribution system when induction motor load is fed from SEIG (singly excited inductin generator). STATCOM is controlled with simple synchronous reference frame theory and the results are shown for source current, load current. THD in source current and load current was also shown for the said system. System for single-phase and three-phase induction motor drive was developed and results are shown using MATLAB/SIMULINK software.

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1. INTRODUCTION

Induction motor being constructed robust and requires less maintenance is used in almost every industrial applications for mechanical operations. Industries emit pollution and the electric motor drive system employed for industrial applications should be tolerant to pollution. Induction motor is such a kind of machine and is used mostly. Drive system is generally used in many applications as speed control of motors gives high efficiency of process output. Induction motor when used for drive system, either terminal voltage of motor or frequency of input supply or both can be varied to run the motor at desired speed. To vary the frequency or terminal voltage of motor, induction motor is supplied from an inverter. Inverter can produce desired voltage and frequency at the output. Inverter fed induction motor can work effectively as drive system. For inverter, the input supply should be DC type and thus the input supply is to be rectified first and then fed as input to inverter. This complete power electronic converter set-up constitutes non-linear load.

Non-linear loads when connected to distribution system induce harmonics in source components. Non-linear loads draw non-linear components of source currents and hence induce harmonics in the source components. Distortions in source components are not allowed and insist for compensation. Harmonics can cause excessive heating in coils and eventually may damage the coils. Custom power devices [1]-[4] are proved to be good for compensating power quality issues [5]-[8]. STATCOM is a type of flexible AC transmission (FACTS) compensator employed for power quality mitigation especially harmonics.

This paper depicts the suppression of harmonics with STATCOM [9]-[12] in distribution system when induction motor load is fed from SEIG (singly excited inductin generator). STATCOM is controlled with simple synchronous reference frame theory and the results are shown for source current, load current. THD in source current and load current was also shown for the said system. System for single-phase and three-phase induction motor drive was developed and results are shown using MATLAB/SIMULINK software.

2. STATCOM FOR HARMONIC SUPPRESSION WHEN SEIG IS FEEDING SINGLE-PHASE AND THREE-PHASE INDUCTION MOTOR LOAD

Figure 1 shows the SEIG feeding three-phase induction motor load and Figure 2 shows the schematic circuit of SEIG feeding three-phase induction motor load to which STATCOM is connected to distribution system at point of common coupling for harmonic suppression for both single-phase and three-phase load conditions.

STATCOM is a shunt active FACTS device used to compensate harmonics in source components when connected to power distribution system. STATCOM is connected in parallel to distribution system and induces compensating currents to eliminate harmonics. STATCOM is a simple voltage source converter (VSC) with a small DC source. Voltage source converter consists of power electronic switches and power switches are controlled with the triggering signals from control circuit.

Singly excited induction generator (SEIG) feeds single-phase induction motor load and three-phase induction motor loads. SEIG through source impedance is connected to load. STATCOM is connected at point of common coupling to power distribution system. STATCOM sends compensating signals through filters to point of common coupling for harmonic suppression.

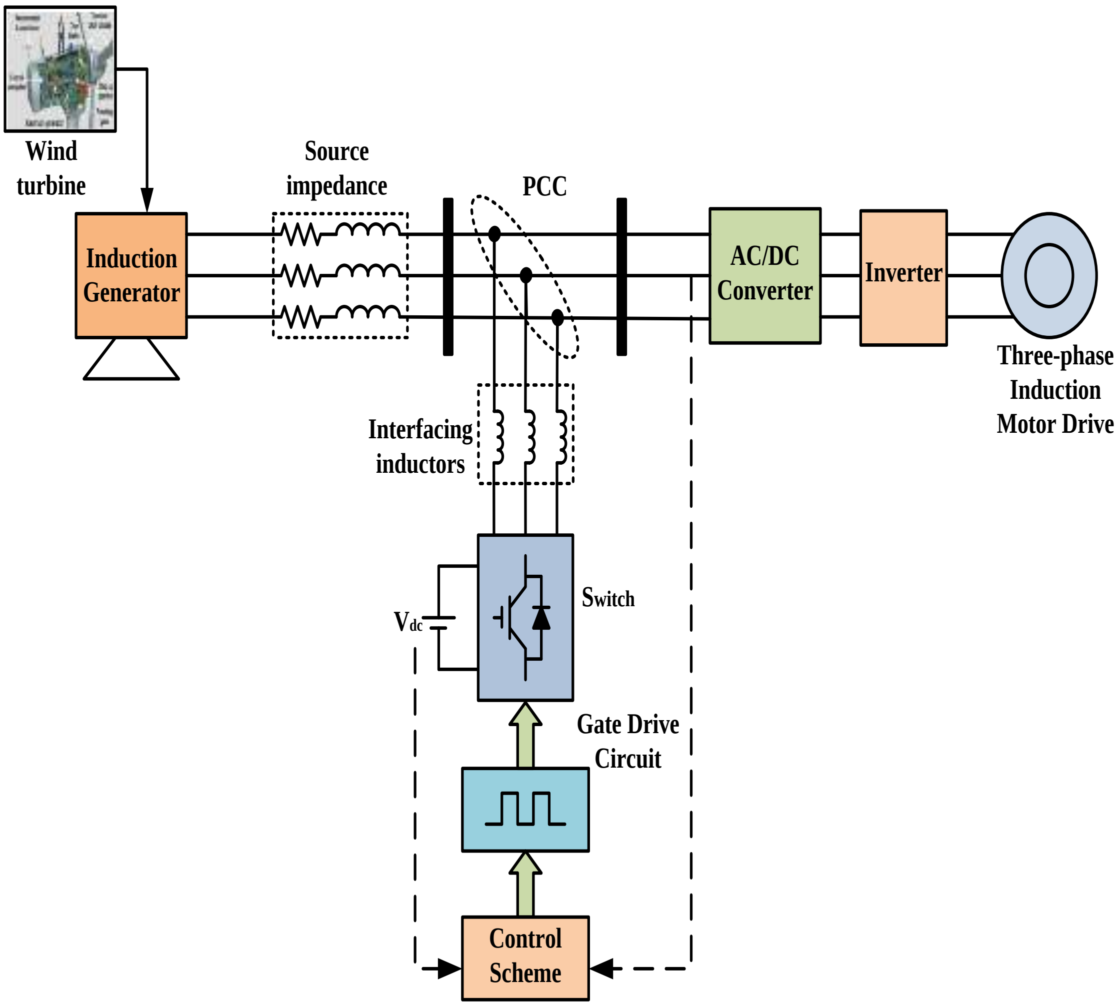

Figure 1. Schematic connection of STATCOM for SEIG feeding three-phase induction motor load

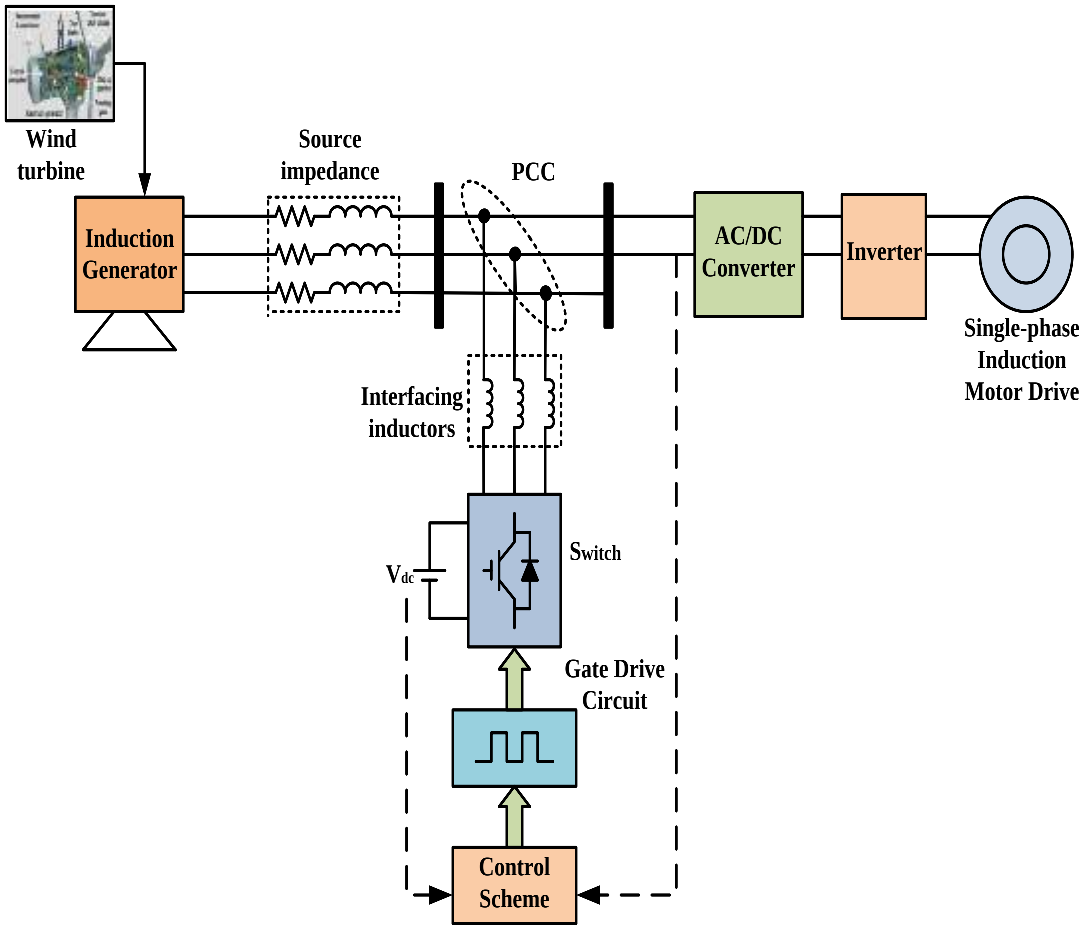

Figure 2. Schematic connection of STATCOM for SEIG feeding single-phase induction motor load

3. CONTROL OF STATCOM

In general, direct control is preferred where very fast voltage control is required (absence of capacitor dynamics) makes the response fast but THD of converter voltage varies with modulation index, thereby producing more harmonic distortion in the voltage at low modulation index. On the other hand, indirect control operation is slow as AC output voltage of STATCOM varies according to variation of DC capacitor voltages (presence of capacitor dynamics make the response slow) but harmonic injection in the power system bus voltage can be kept at a very low level by operating the inverter at a high modulation index where THD of converter voltage is least. Out of different control strategies, more efficient method of controlling the STATCOM is by the synchronous reference frame strategy, which uses co-ordinate transformations to generate the current reference.

It employs the well known Clarkes Transformation and Parks Transformation for this purpose. Though, the transformations remind us of the primitive machine model concept, it may be noted that here there is no need to satisfy the condition of Power Invariance as the transformations are employed just to reduce the computations involved in generating the current reference and not to develop any equivalent system. Once the controller output is obtained, reverse transformations are employed to transform the quantities back to the actual three-phase system. Figure 3 shows the control strategy producing pulses to STATCOM.

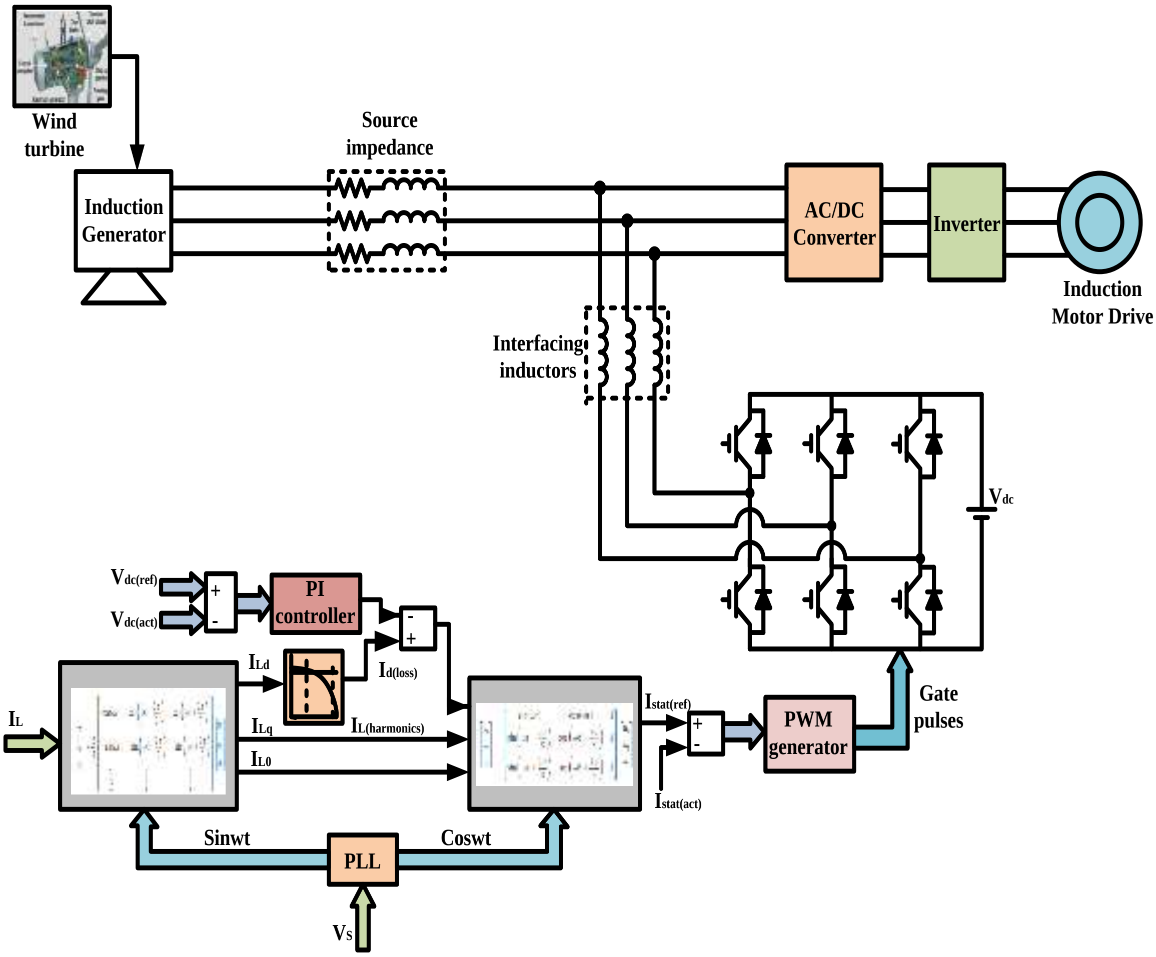

Figure 3. Control of STATCOM for SEIG feeding induction motor load

4. SIMULATION RESULTS AND DISCUSSIONS

4.1. SEIG feeding single-phase induction motor load with STATCOM at PCC

Figure 4 shows three-phase source voltages, source currents, load current and injected currents from STATCOM when SEIG is feeding single-phase induction motor load. The waveforms shows source current is maintained sinusoidal and contains less harmonics. To compensate source currents, STATCOM injects compensating currents as shown in Figure 4. Figure 5 shows the power factor angle between source voltage and source current. Source voltage and source current are in phase and thus power factor on source side is maintained nearer to unity. Figure 6 shows the power factor angle between load voltage and load current. Load voltage and load current do not have same phase angle and load power factor is not unity as it is non-linear load.

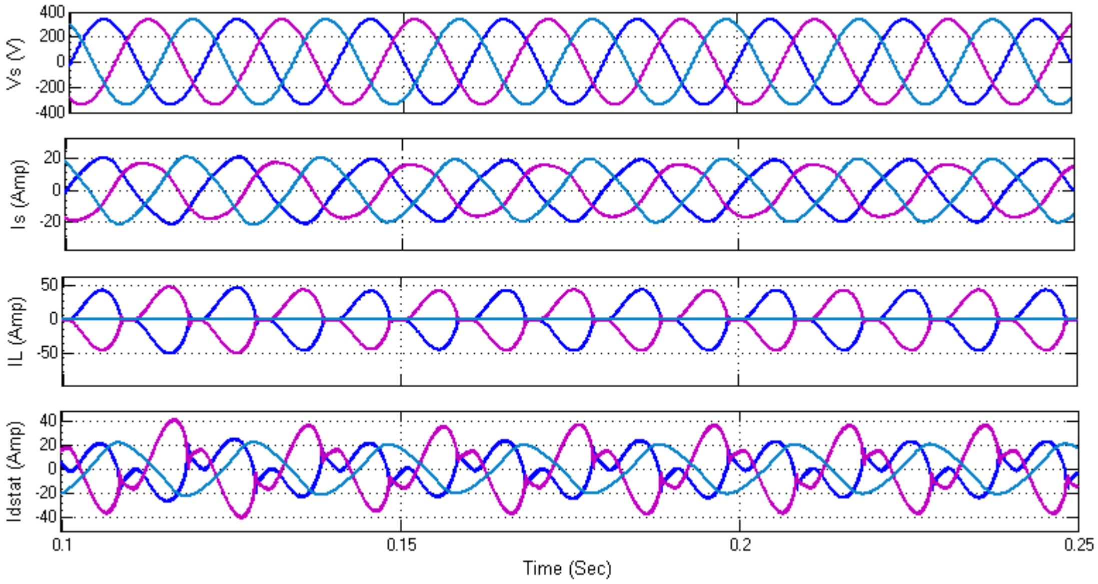

Figure 4. Source voltage, Source current, Load current, DSTATCOM injected curren

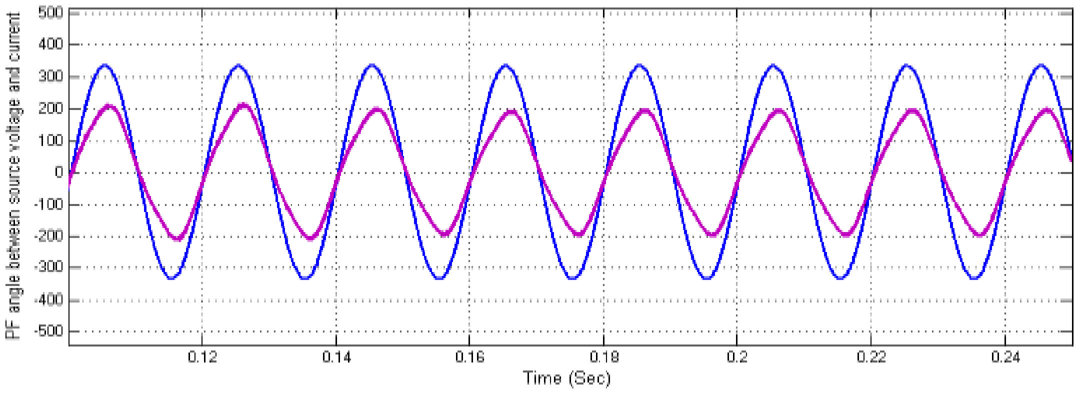

Figure 5. Power factor angle between source voltage and source current

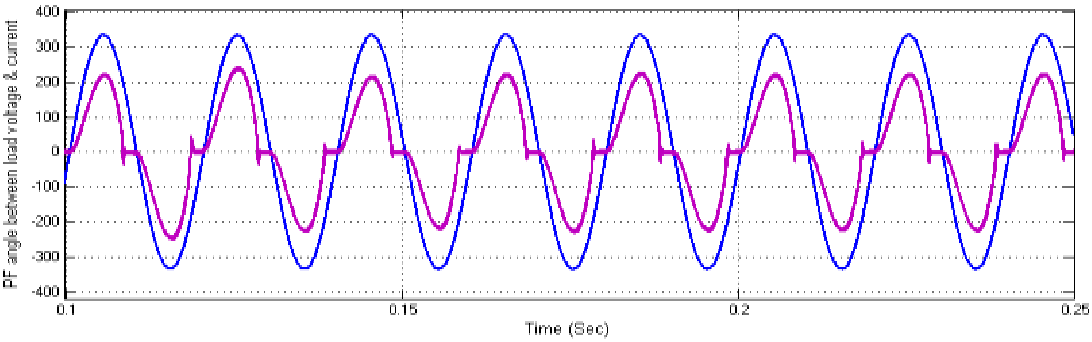

Figure 6. Power factor angle between Load voltage and load current

Figure 7 shows induction motor characteristics showing stator current drawn by induction motor, speed of induction motor and torque. Speed and torque are maintained constant after reaching steady-state condition.

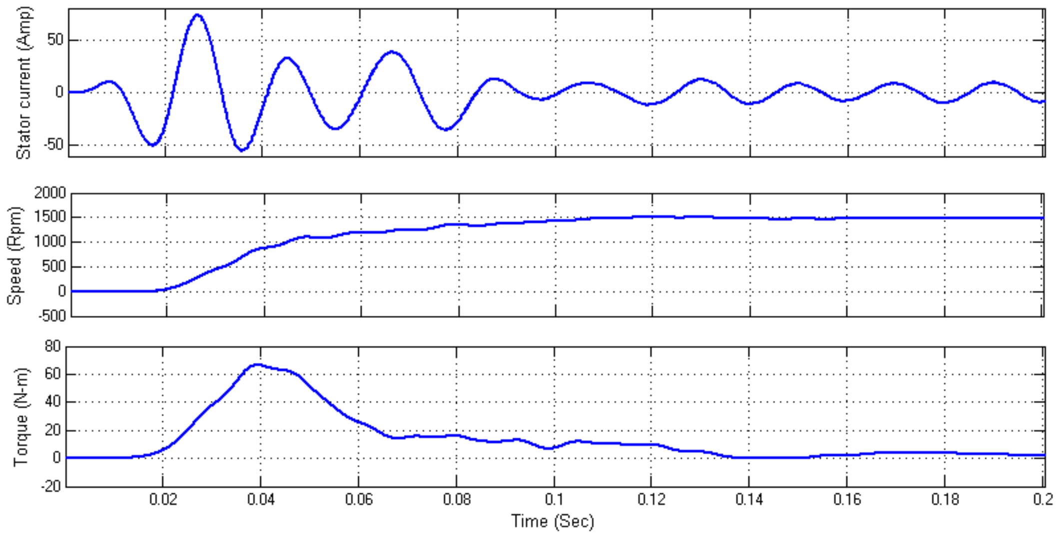

Figure 7. Stator current, Speed, torque

Figure 8 shows THD in load current and Figure 9 shows the source current THD. THD in load current is 27.71% since the load is of non-linear type. Source current THD is reduced to 1.42%.

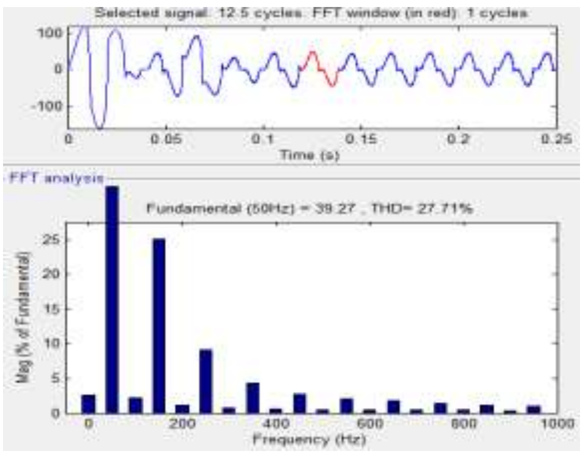

Figure 8. Load current THD

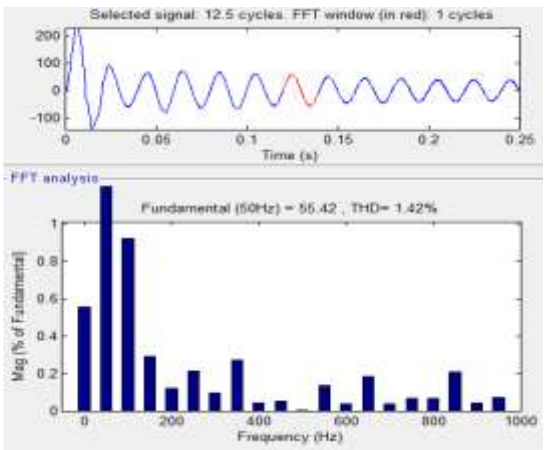

Figure 9. Source current THD

4.2 SEIG feeding three-phase induction motor load with STATCOM at PCC

Figure 10 shows three-phase source voltages, source currents, load current and injected currents from STATCOM when SEIG is feeding three-phase induction motor load. The waveforms shows source current is maintained sinusoidal and contains less harmonics. To compensate source currents, STATCOM injects compensating currents as shown in Figure 10.

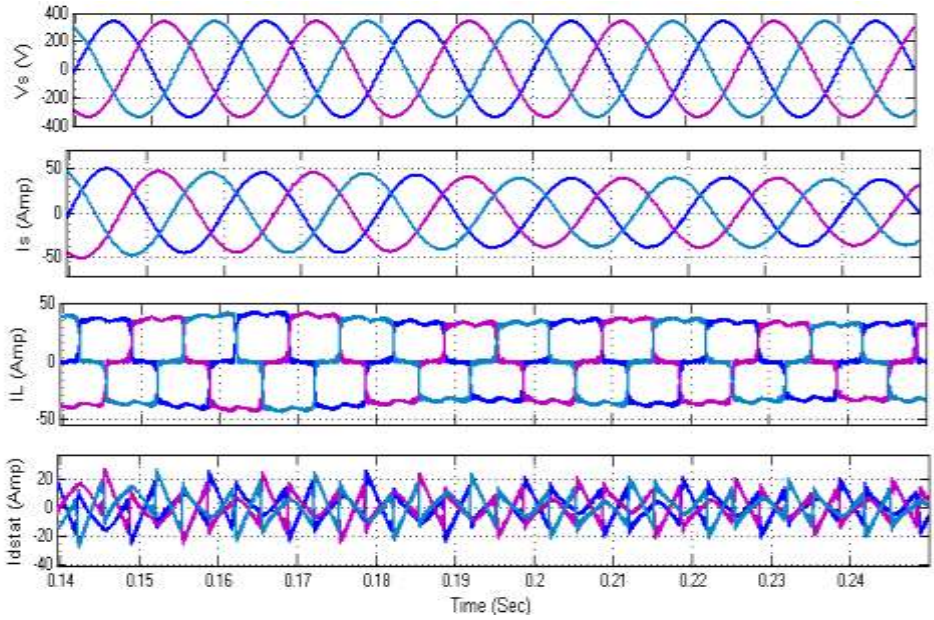

Figure 10. Source voltage, Source current, Load current, DSTATCOM injected current

Figure 11 shows the power factor angle between source voltage and source current. Source voltage and source current are in phase and thus power factor on source side is maintained nearer to unity. Figure 12 shows the power factor angle between load voltage and load current. Load voltage and load current do not have same phase angle and load power factor is not unity as it is non-linear load.

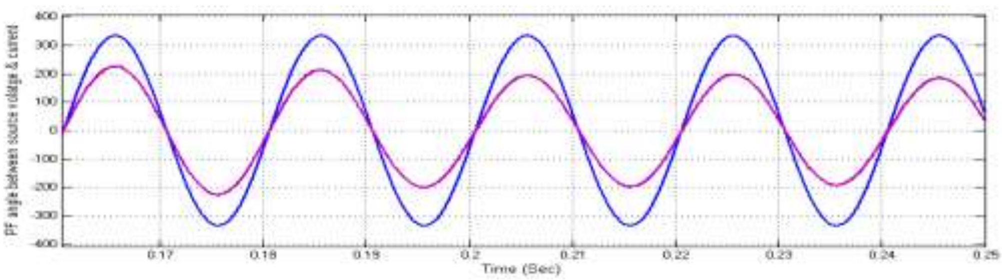

Figure 11. Power factor angle between source voltage and source current

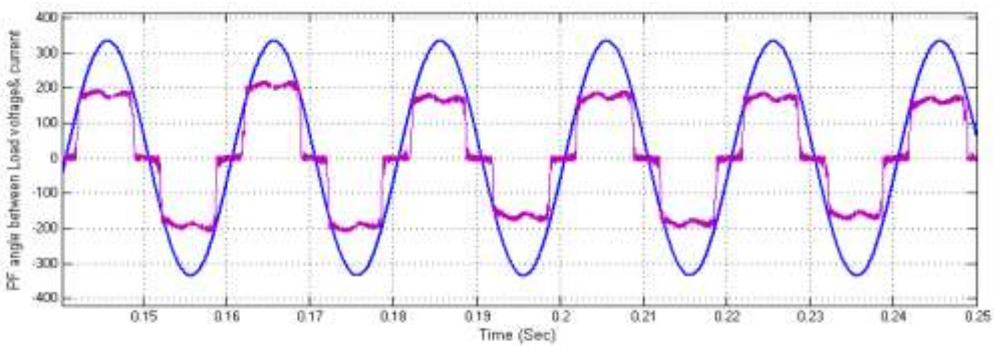

Figure 12. Power factor angle between Load voltage and Load current

Figure 13 shows induction motor characteristics showing stator current drawn by induction motor, speed of induction motor and torque. Speed and torque are maintained constant after reaching steady-state condition.

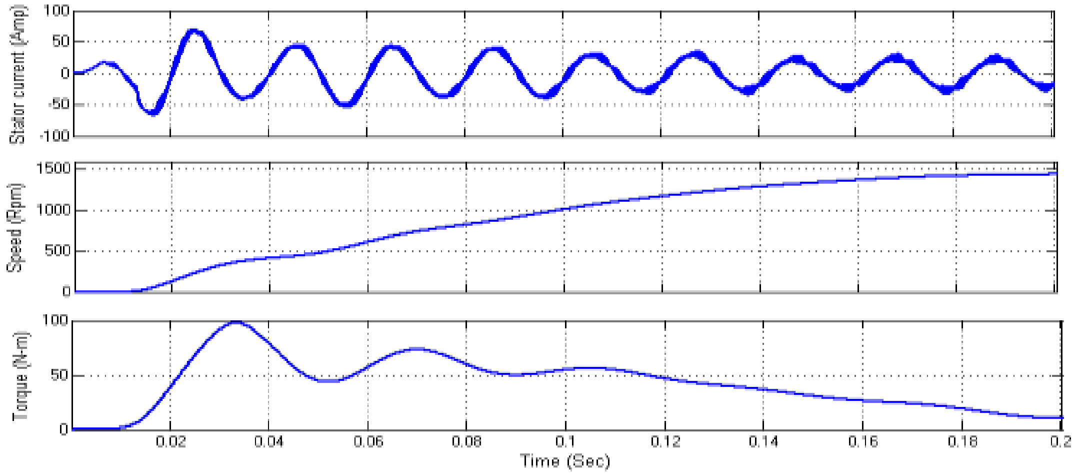

Figure 13. Stator current, Speed and Torque of induction motort

Table 1 shows the THD analysis of STATCOM compensating single-phase and three-phase harmonic load when fed from SEIG. Figure 14 shows THD in load current and Figure 15 shows the source current THD. THD in load current is 27.83% since the load is of non-linear type. Source current THD is reduced to 1.42%.

Table 1. THD Analysis

Induction Motor	THD in load current	THD in source current
Single-phase	27.71%	1.42%
Three-phase	27.83%	1.42%

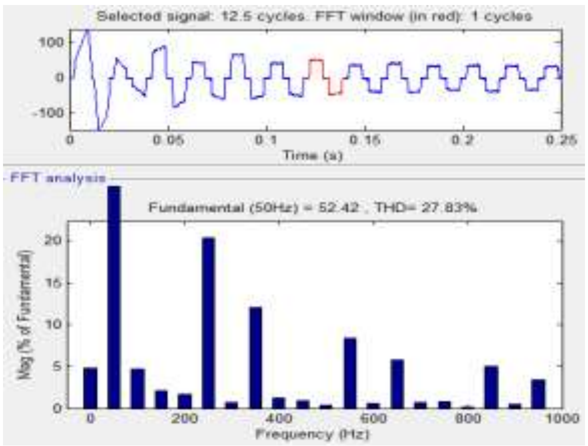

Figure 14. Load current THD

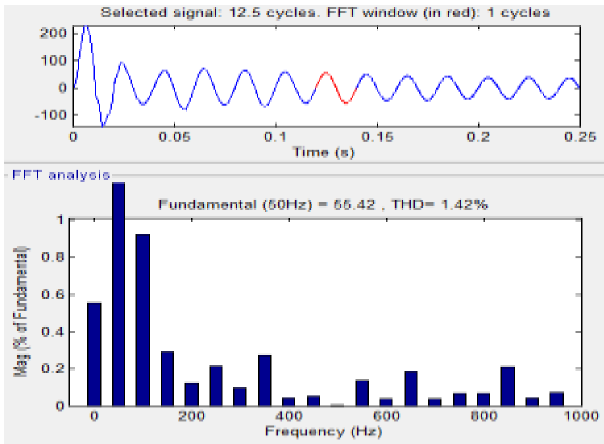

Figure 15. Source current THD

5. CONCLUSION

Paper presents comprehensive analysis of harmonic compensation with STATCOM when SEIG if feeding single-phase and three-phase induction motor load. Induction motor when used as drive is fed from an inverter for better control. Power electronic front-end converters for induction motor constitutes harmonic load and induce harmonics in to source components. Suppression of harmonics using STATCOM is analyzed for single-phase and three-phase induction motor load conditions and THD in source current and load current were tabulated. THD in source current was well below nominal value and source current is maintained nearer sinusoidal. Power factor of source and load are also shown and source power factor is nearer unity.

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