Indonesian Journal of Electrical Engineering and Computer Science
Vol. 6, No. 3, June 2017, pp. 489 ~ 496
DOI: 10.11591/ijeecs.v6.i3.pp489-496

Harmonic Compensation using STATCOM for SEIG Feeding Single-Phase Load Connected between Different Phases

Satyanarayan Gorantla*[1], Goli Ravi Kumar[2]
[1]Department of EEE, Anurag Engineering College and Research Scholar in ANU, AP, India
[2]Department of EEE, Bapatla Engineering College, Bapatla, Guntur (Dist), AP, India
*Corresponding author, e-mail: satyanarayana345678@gmail.com

Abstract

The paper presents the analysis of harmonic distortion when non-linear load is connected in different phases of power system with STATCOM for singly excited induction generator system with wind turbine as prime mover. Now-a-days due to the drastically increased in use of non linear loads causes many power quality problems in power system network. Those problems are classified as reactive power problems, harmonics, voltage sags and swells. Out of these problems harmonic problems are major concern. Custom power devices proposed for mitigation of power quality in network. For compensation of harmonic, static compensator (STATCOM) is used. The paper presents the compensation of harmonic power quality issues using STATCOM for the system with singly-excited induction generator feeding non-linear load connected in different phases. STATCOM is controlled using synchronous reference frame theory to produce pulses to switches of STATCOM sensing the input parameters. Proposed concept was developed using MATLAB/SIMULINK software and results are presented for non-linear load connected in different phases of the power system. THD analysis was shown for source current and load current for different cases.

Keywords: *STATCOM, Compensation, Singly excited, Induction Generator, Non-linear load*

1. Introduction

The increasing demand for electric power combined with depleting natural resources has led to the substantial improvements in the usage of renewable energy systems such as wind and solar especially among the developing countries. Wind power is increasingly being viewed as mainstream electricity supply technology. Grid connected wind electricity generation is showing the highest rate of growth of any form of electricity generation, achieving global annual growth rates in the order of 20-25%.

It is increasingly important that wind generation continue to operate during periods of short circuit fault in the grid. The penetration of wind power has reached levels high enough to affect the quality and stability of the grid [3]. According to grid codes issued by utilities, tripping of wind turbines following grid fault is not allowed. Besides to provide voltage support to the grid, mandatory reactive current supply is necessary [1]. Main ancillary services in a power system are power-frequency control and voltage control. These services must be provided by each generator connected to the grid. In order to provide the ancillary service of voltage, generators must have some reactive power capability as required by the corresponding grid codes [2, 4-8].

On the other hand, Static Synchronous Compensators (STATCOM) can be use to provide harmonic compensation when non-linear loads are present. There are various voltage source or current source inverter based on FACTS devices for flexible power control damping of power system and stabilization of wind generators, but in this work STATCOM based on a voltage source converter (VSC) is used to compensate the harmonics in power system due to non-linear loads of single phase and three-phase.

The paper presents the compensation of harmonic power quality issues using STATCOM [9] for the system with singly-excited induction generator feeding non-linear load connected in different phases. Non-linear load induces harmonics in source components and the problem is addressed using STATCOM. The paper presents the compensation of harmonic power quality issues using STATCOM [10-12] for the system with singly-excited induction

Received February 22, 2017; Revised April 30, 2017; Accepted May 15, 2017

generator feeding non-linear load connected in different phases. STATCOM is controlled using synchronous reference frame theory to produce pulses to switches of STATCOM sensing the input parameters. Proposed concept was developed using MATLAB/SIMULINK software and results are presented for non-linear load connected in different phases of the power system. THD analysis was shown for source current and load current for different cases.

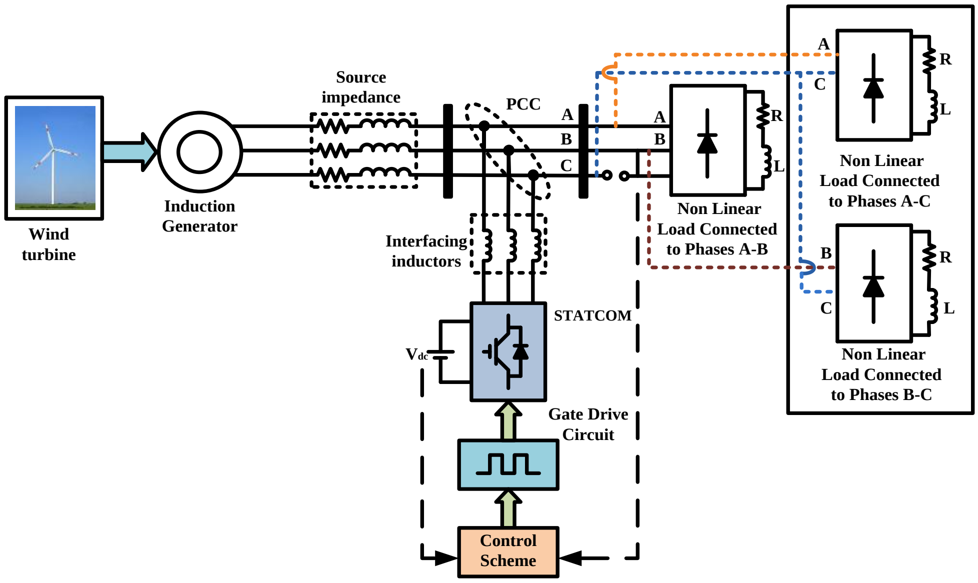

Figure 1. Schematic arrangement of SEIG feeding non-linear load connected in different phases and STATCOM connected at PCC

2. Non-Linear Load Connected in Different Phases of Power System

Figure 1 represents the system with singly excited induction generator feeding non-linear load connected in phase AB, BC and AC respectively. STATCOM is connected at point of common coupling (PCC). A control scheme drives the STATCOM producing pulses to switches.

Power quality has gained more importance in the power industry. Everybody does not agree with the use of the term power quality, but they do accept that it has become an important aspect of power delivery especially in 1990s. There is a lot of difference about what power quality actually incorporates. Other sources use similar but slightly different terminology like quality of power supply or voltage quality. The power quality is seriously disturbed due to the widely use of nonlinear loads and various faults in power system. This kind of devices are sensitive to small changes of power quality, a short time change on PQ can cause great economic losses. Because of the two reasons mentioned above, no matter for the power business, equipment manufacturers or for electric power customers, power quality problems had become an issue of increasing interest. Under the situation of the deregulation of power industry and competitive market, as the main character of goods, power quality will affect the price of power directly in near future. In most of the industries voltage sag/swell and harmonics are the common problems encountered in the industrial processes.

STATCOM is a converter type FACTS device, which generally provides superior performance characteristics when compared with conventional compensation methods employing TSCs and TCRs. STATCOM based on VSC topology utilize either GTO or IGBT devices. In its simplest form, the STATCOM is made up of a VSC, and a DC energy storage device. The energy storage device is a relatively small DC capacitor.

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.

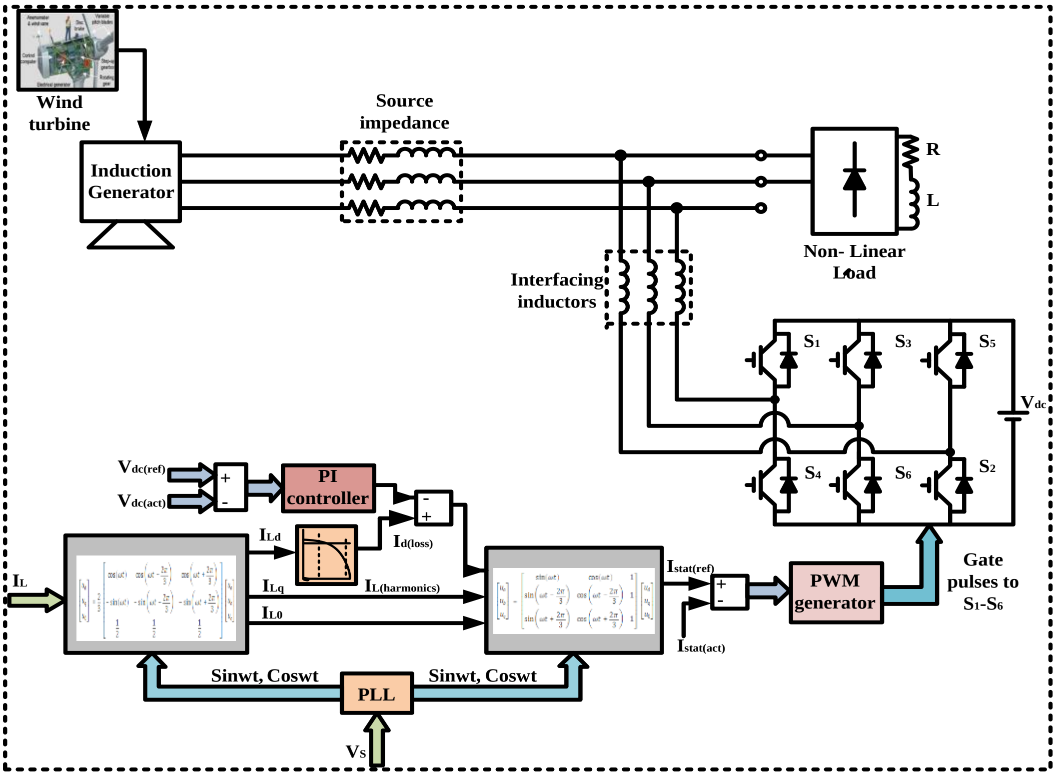

Figure 2. Schematic arrangement of control circuit to STATCOM

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 2 shows schematic arrangement of SEIG with STATCOM and its control strategy. Non-linear type of load is connected across two phases and here in Figure 2, load is connected between phases AB.

4. Simulation Results and Discussions

4.1. Non-Linear Load Connected between Phases A and B

Figure 3 shows the three-phase source voltage with amplitude of 320V. Three-phase source current of magnitude 20A is shown in figure 4. Both source voltages and three-phase source currents are maintained sinusoidal in shapedue to the presence of STATCOM compensating harmonic distortions in source currents at point of common coupling when non-linear load is connected between AB phases.

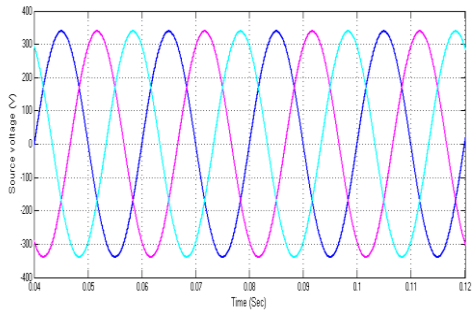

Figure 3. Source voltage

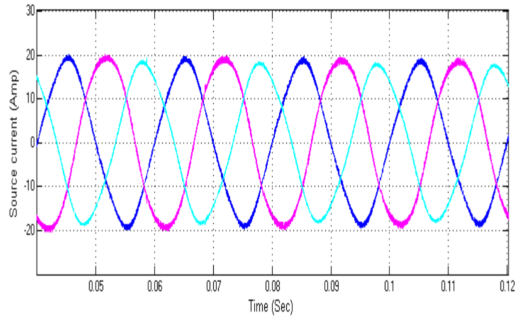

Figure 4. Source current

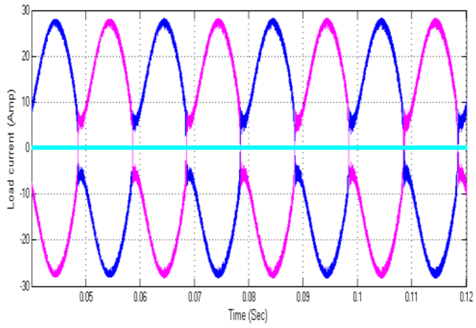

Figure 5. Load current

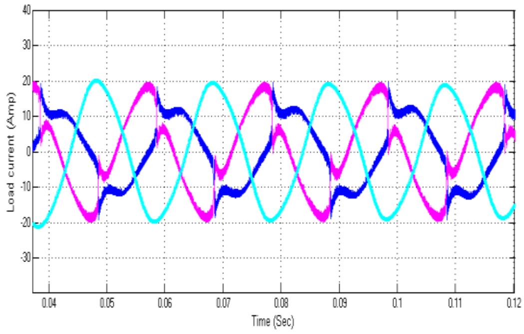

Figure 6. STATCOM current

Figure 5 shows the load currents where only two phase currents are indicated as non-linear load is connected between AB phases. The third phase current is zero as in Figure 5. Load current contains distortions in two phases as load of non-linear type is connected and Figure 6 represents the induced STATCOM currents in to PCC for compensation.

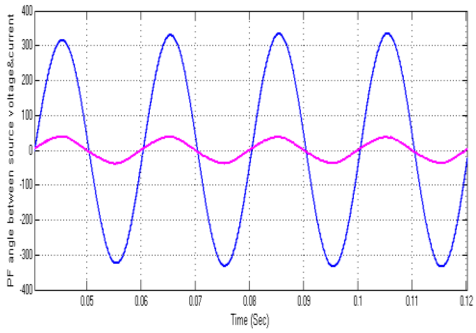

Figure 7. PF angle between source voltage and current

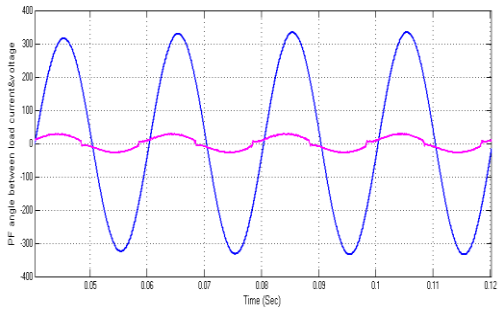

Figure 8. PF angle between load voltage and current

Figure 7 shows the power factor angle between source voltage and source current. As no phase difference is observed between source voltage and current, power factor is nearer maintained unity. Figure 8 shows the power factor angle between voltage and current of load component. As load is non-linear type, phase difference is present and power factor is non-unity.

Harmonic distortion in source current is maintained at 5.06 % and harmonic distortion content in load current is 14.11% as shown in Figure 9 and Figure 10 respectively.

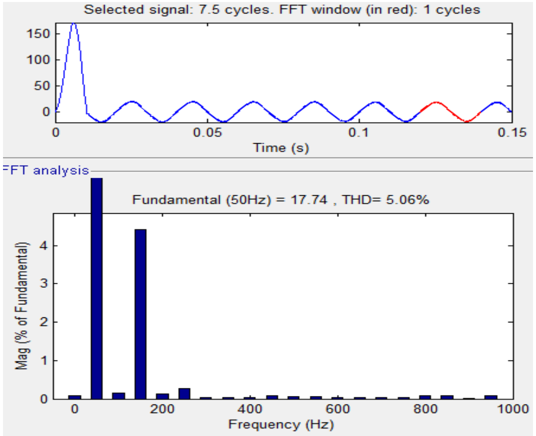

Figure 9. Source current THD

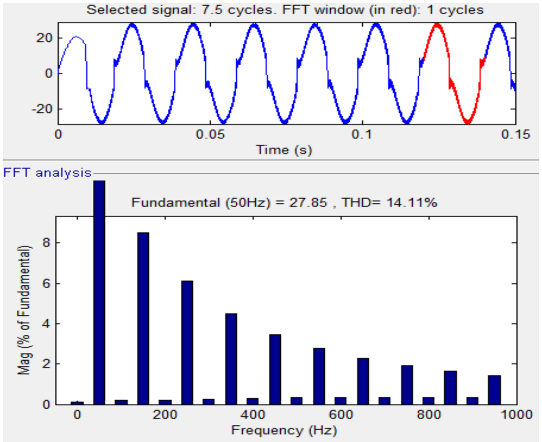

Figure 10. Load current THD

4.2. Non-Linear Load Connected between Phases B and C

Figure 11 shows the three-phase source voltage with amplitude of 320V. Three-phase source current of magnitude 20A is shown in Figure 12. Both source voltages and three-phase source currents are maintained sinusoidal in shapedue to the presence of STATCOM compensating harmonic distortions in source currents at point of common coupling when non-linear load is connected between BC phases.

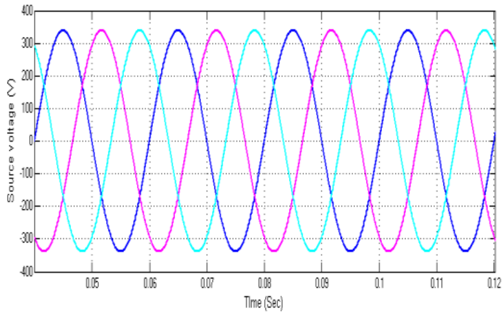

Figure 11. Source voltage

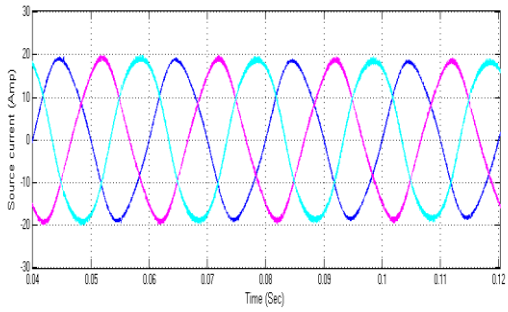

Figure 12. Source curren

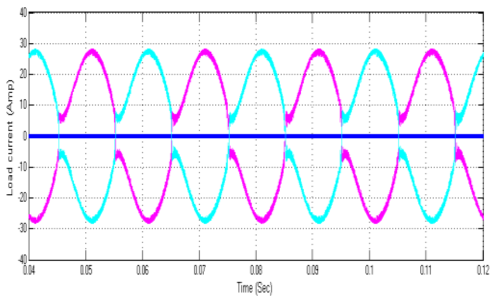

Figure 13. Load current

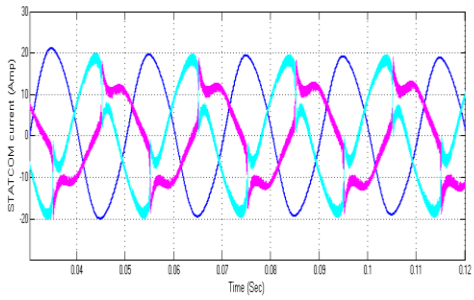

Figure 14. STATCOM current

Figure 13 shows the load currents where only two phase currents are indicated as non-linear load is connected between BC phases. The third phase current is zero as in Figure 13. Load current contains distortions in two phases as load of non-linear type is connected and Figure 14 represents the induced STATCOM currents in to PCC for compensation.

Figure 15 shows the power factor angle between source voltage and source current. As no phase difference is observed between source voltage and current, power factor is nearer maintained unity. Harmonic distortion in source current is maintained at 4.69 % as shown in Figure 16.

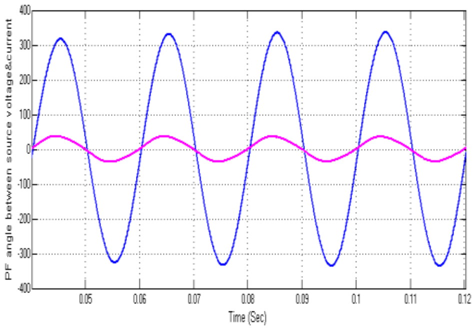

Figure 15. PF angle between source voltage and current

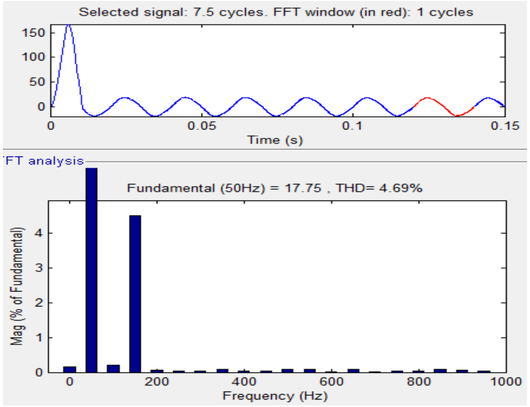

Figure 16. Source current THD

4.3. Non-Linear Load Connected between Phases A and C

Figure 17 shows the three-phase source voltage with amplitude of 320V. Three-phase source current of magnitude 20A is shown in Figure 18. Both source voltages and three-phase source currents are maintained sinusoidal in shape due to the presence of STATCOM compensating harmonic distortions in source currents at point of common coupling when non-linear load is connected between AC phases.

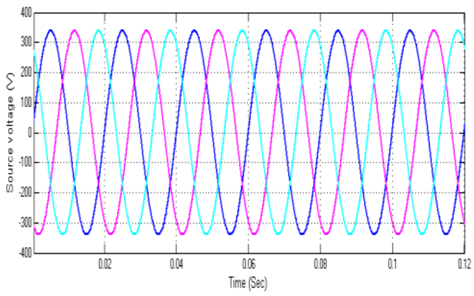

Figure 17. Source voltage

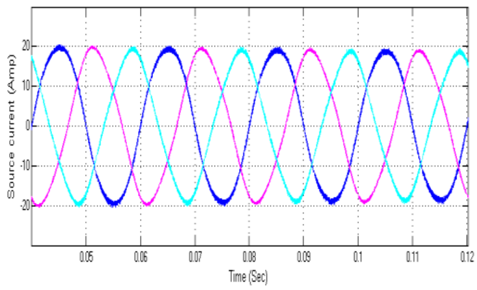

Figure 18. Source current

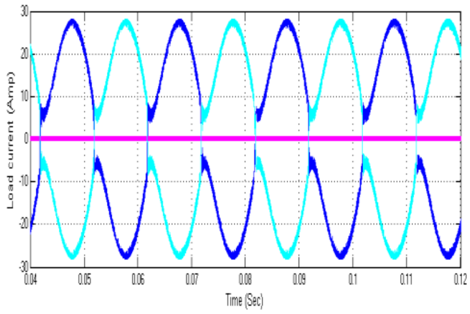

Figure 19. Load current

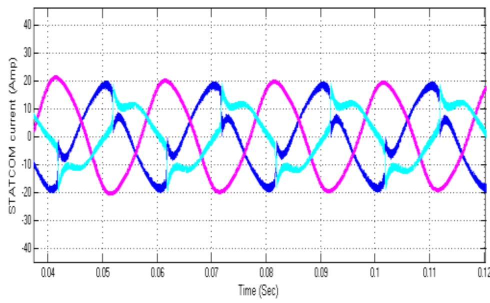

Figure 20. STATCOM current

Figure 19 shows the load currents where only two phase currents are indicated as non-linear load is connected between AC phases. The third phase current is zero as in Figure 19. Load current contains distortions in two phases as load of non-linear type is connected and Figure 20 represents the induced STATCOM currents in to PCC for compensation.

Figure 21 shows the power factor angle between source voltage and source current. As no phase difference is observed between source voltage and current, power factor is nearer maintained unity. Figure 22 shows the power factor angle between voltage and current of load component. As load is non-linear type, phase difference is present and power factor is non-unity.

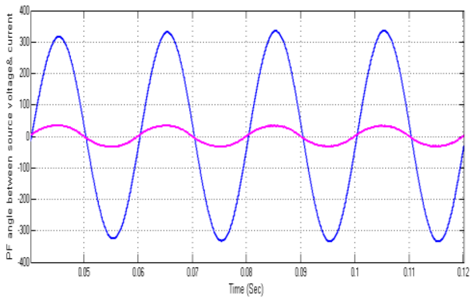

Figure 21. PF angle between source voltage and current

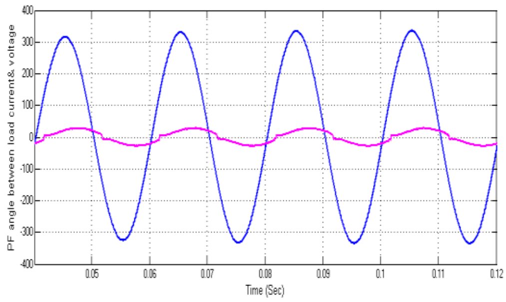

Figure 22. PF angle between load current and voltage

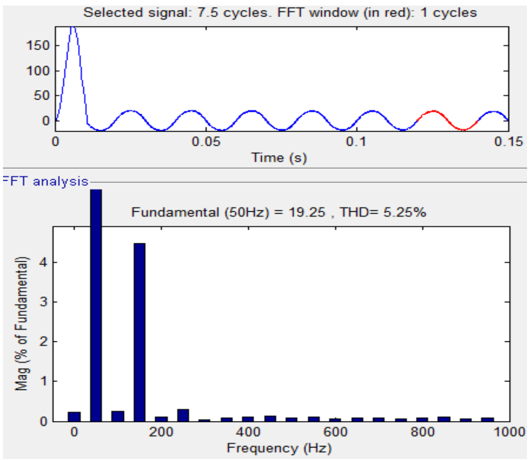

Figure 23. Source current THD

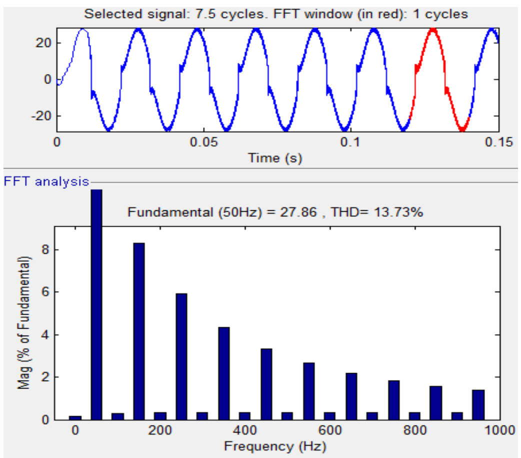

Figure 24. Load current THD

Harmonic distortion in source current is maintained at 5.25 % and harmonic distortion content in load current is 13.73% as shown in Figure 23 and Figure 24 respectively. Table 1 shows THD analysis when non-linear load connected in different phases. THD in source current is maintained within nominal values.

Table 1. THD analysis when non-linear load connected in different phases

Connecttion of non-linear load	THD in source current at PCC
Between phases AB	5.06 %
Between phases BC	4.69 %
Between phases AC	5.25 %

5. Conclusion

Non-linear loads distort source parameters and this phenomenon affects the other sensitive loads connected at point of common coupling. Due to increase in usage of power electronic components at load side induces harmonics at source side. STATCOM is a shunt compensating device used for compensation of harmonics at point of common coupling. This paper examines the performance of single-phase non-linear load connected at different phases between AB, BC and AC. THD analysis in source current is tabulated when single phase non-linear load is connected at different phases. STATCOM affectively compensates harmonics in source currents due to connection of non-linear load at different phases.

References

[1] J Sun, D Czarkowski, Z Zabar. Voltage Flicker Mitigation using PWM-Based Distribution STATCOM. *IEEE Power Engineering Society Summer Meeting*. 2002; 1: 616- 621.
[2] Mahmood Joorabian, Davar Mirabbasi Alireza Sina. Voltage Flicker Compensation using STATCOM. *ICIEA*. 2009: 2273 – 2278.
[3] J Mckim. *The UIE Flicker-meter Demystified*. Hewlett- Packard's Power Products Division. 1997.
[4] L Tang, S Kolluri, MF McGranaghan. Voltage Flicker Prediction for Two Simultaneously Operated AC Arc Furnaces. *IEEE Trans. on Power Delivery*. 1997; 12(2): 985-991.
[5] CS Chen, HJ Chuang, CT Hsu, SM Tscng. Stochastic Voltage Flicker Analysis and Its Mitigation for Steel Industrial PowerSystems. *IEEE Power Tech Proceedings.* 2001; 1.
[6] JR Clouston, JH Gurney. Field Demonstration of a Distribution Static Compensator Used to Mitigate Voltage Flicker. *IEEE Power Engineering Society Winter Meeting*. 1999; 2: 1138- 1141.
[7] S Suzuki, Y Hara, E Masada, M Miyatake, K Shutoh. *Application of Unified Flow Controller for Power Quality Control at Demand Side*. The Third International Power Electronics and Motion Control Conference Proceedings (PIEMC 2000). 2000; 3: 1031-1036.
[8] JHR Enslin. Unified Approach to Power Quality Mitigation. *IEEE Proceedings International Symposium on Industrial Electronics (ISIE '98)*. 1998; 1: 8-20.
[9] Mahamood Joorabian, Davar Mirabbasi, Alireza Sina. Voltage Flicker Compensation using STATCOM. *IEEE proceedings*. 2009.
[10] G Ramya, V Ganapathy, P Suresh. Power Quality Improvement using Multi-Level Inverter Based DVR and DSTATCOM Using Neuro-Fuzzy Controller. *International journal of power electronics and drive systems (IJPEDS)*. 2017; 8(1): 316-324.
[11] Tanneeru Renuka, Gattu Kesavarao. STATCOM with Battery and Super Capacitor Hybrid Energy Storage System for Enhancement of Voltage Stability. *Indonesian Journal of Electrical Engineering and Computer Science*. 2017; 5(2): 250 ~ 259.
[12] Xia Zhenglong, Shi Liping, Li Qianqian. Control Strategy of Cascade STATCOM Based on Internal Model Theory'. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2014; 12(3): 1687 ~ 1694.