

Five-Level DSTATCOM for Power Quality Improvement Using Intelligent Controllers

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Abstract: Addressing power quality issues is an important task for power engineers as a small disturbance in power system can initiate hefty disaster to the loads connected at user point. FACTS controllers are latest devices which can improve power system stability in case of voltage sag/swell and presence of harmonics. DSTATCOM in distribution system is one of the fine FACTS controllers which can address power quality issues. DSTATCOM is a voltage source converter connected at PCC delivering a three-level output. This 3-level output consists of harmonics which insists for high sized filters increasing system cost. This paper depicts five-level DSTATCOM connected to distribution system delivering qualified output reducing amount of harmonics which excludes high sized filters improving system efficiency and making system economic. PQ theory was employed to drive DSTATCOM. Fuzzy technique in PQ theory of controlling five-level DSTATCOM is presented in this paper comparing with conventional PI controller performance of reducing harmonics in distribution system.

Keywords: Distribution Static Compensator (DSTATCOM), harmonics, control, power, quality.

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1. Introduction

In industrial loads and service loads, dependable and reliable power is very important criterion in their activities. When the power is not characterized with quality, the end loads might be affected with inculcating disturbances in the system which demand additional accessories for mitigation. Maintaining voltage, frequency within normal values is called power quality. Poor power quality is the system having disturbances like sag, swell, harmonics, fluctuations, transients and many more. These disturbances can affect the loads connected, seriously. Power system disturbance can cause to decrease the life period of equipment or even to fail sometime.

Use of custom power devices to improve power system stability and power quality has been extensively used these days. FACTS controllers are one of the methods to improve power quality. DSTATCOM is a type of FACTS controllers used extensively in distribution system for power quality improvement. STATCOM in distribution system is termed as DSTATCOM [1-5]. DSTATCOM is a voltage source converter from which compensating signals are sent. DSTACOM is a shunt controller connected in parallel to the distribution system. DSTATCOM stabilizes the system voltage without sags and swells and also will be very handy in compensating the power system harmonics. DSTATCOM combines the operations of DVR and shunt active filter. DSTATCOM induces compensating currents in to the system and stabilizes the power system nullifying the effect of harmonics at point of common coupling (PCC) [6-8]. Figure 1 shows the conventional DSTATCOM connected to distribution system.

Conventional 3-level converter produces output with more harmonic distortions. Increase in level of output from inverter can reduce the total harmonic distortion at the output. Harmonic content at the output of inverter needs an additional filter circuit to filter the output distortions. As the harmonic content increases, size of filter also increases. Multi-level inverters are used producing higher levels in output to reduce output harmonics. With these multi-level inverters, as harmonic content at the output of the inverter is reduced, filter size may get reduced drastically increasing the system efficiency. This makes system economic and system complexity is also reduced.

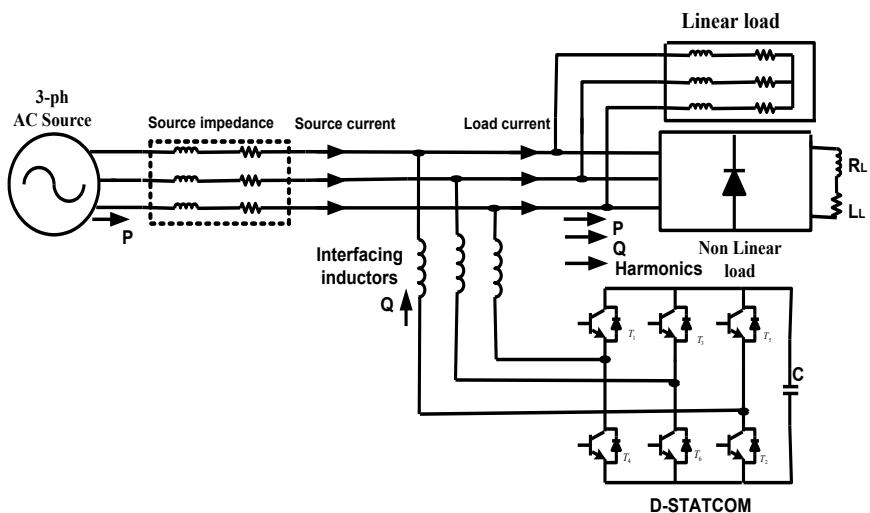


Figure 1: Conventional DSTATCOM connected system.

By proper control over the switches in DSTATCOM, required compensating signals are sent to PCC. Many control strategies were in usage to control the switches in DSTATCOM but in which, instantaneous reactive power (IRF) theory considered in this paper is simple and easy to implement on DSTATCOM to control its switches. IRF theory can also be called as PQ (active and reactive power) theory [9-12]. Use of conventional PI controller is used but intelligent controllers like fuzzy can decrease the total harmonic distortions when compared to PI controller. This paper presents a 5-level diode clamped inverter as DSTATCOM for power quality improvement with fuzzy controllers. Previous research was done with PI controllers but this paper presents the system implementation for reducing total harmonic distortion using fuzzy controller. Results were explained comparing the outputs of PI controller and fuzzy controller.

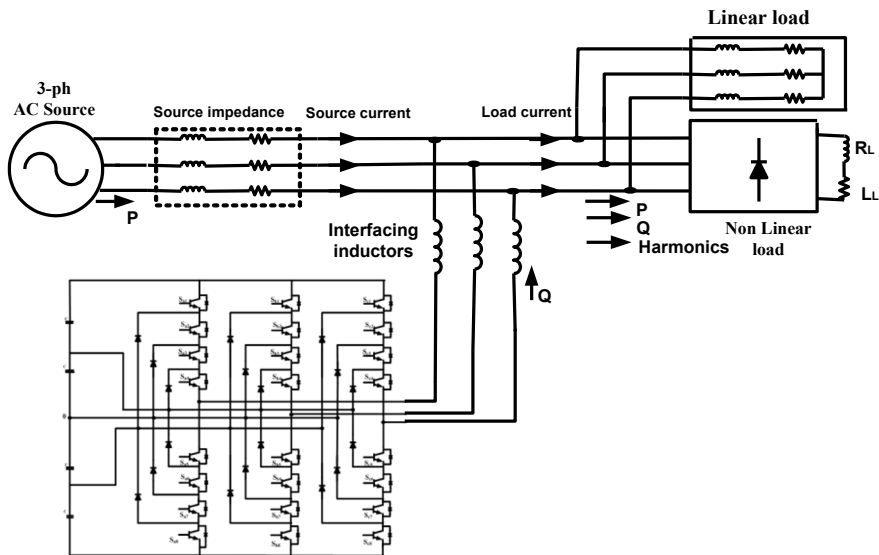


Figure 2: 5-level DSTATCOM

2. Five-level DSTATCOM

Current containing harmonics can seriously affect the connected load when allowed to pass, by generating unwanted issues. Harmonics produces heating in the motor windings, produces electromagnetic interference and many more. Non-linear loads connected at load centres induce harmonics in to the system and affects the other sensitive loads connected at PCC. Non-linear loads, though they draw non-linear components of current, system source current should be maintained without harmonics. DSTATCOM is a shunt FACTS controller connected in parallel to the distribution system as compensating device. STATCOM connected in distribution system is termed as DSTATCOM. DSTATCOM can effectively address the voltage profile and harmonic issues in power distribution system. Compensation by DSTATCOM is done by inducing compensating currents in to the system thus nullifying the harmonics at PCC.

DSTATCOM is a voltage source converter (VSC) and contains switches looking like a conventional 3-level basic converter. A conventional 3-level converter gives output with high harmonic distortions in it. The harmonic distortions at the output of the inverter can be reduced by increasing the level output of the inverter giving rise to multi-level inverter

topology. Diode clamped inverter is one of the topologies in multi-level inverter concept. As the name suggests there is a need of clamping elements in this topology where diodes are used for that purpose. A five-level diode clamped DSTATCOM is shown in figure 2. Multi-level DSTATCOM is able to produce quality output reducing distortions at the inverter output which eliminates the use of additional filters for smoothening of inverter output.

3. Instantaneous Reactive theory of controlling DSTATCOM

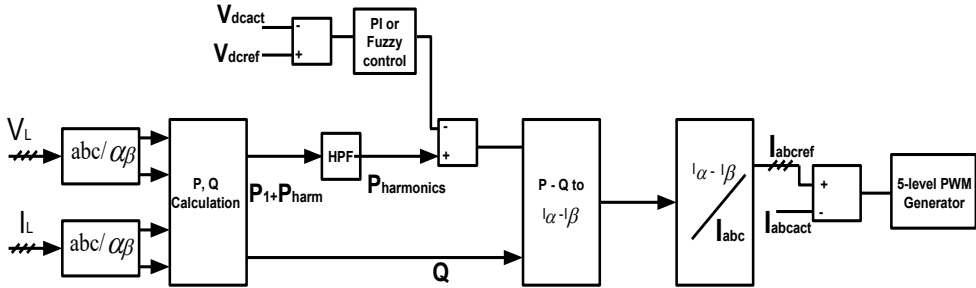


Figure 3: Block diagram of IRF theory.

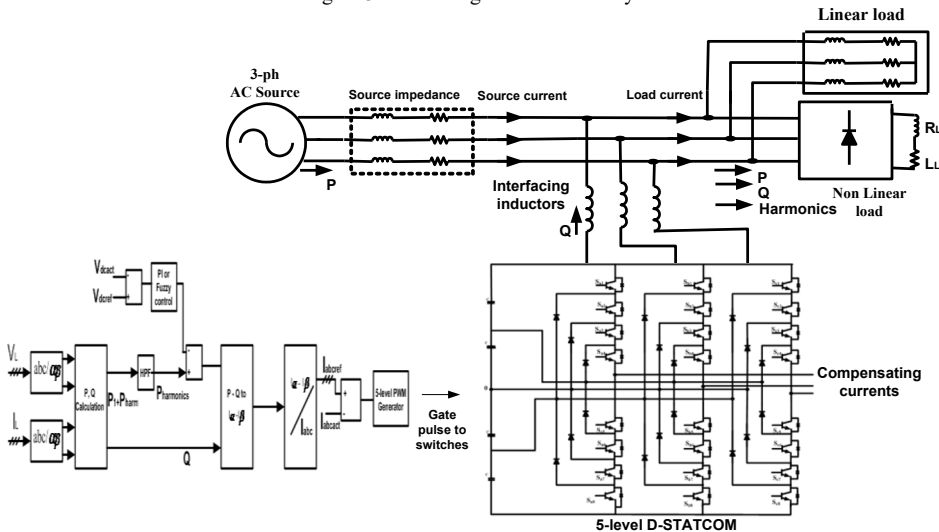


Figure 4: DSTATCOM with IRF theory.

DSTATCOM is a voltage source converter and contains switches for its operation. By proper control of the DSTATCOM switches required compensating signals are generated and sent to the distribution system to reduce the affect of harmonics. 5-level DSTATCOM is controlled using IRF theory. Initially line voltage and line current are sensed and are both sent to transformation for abc- $\alpha\beta$ calculation producing active and reactive components. The active component contains fundamental and harmonic content and using a high pass filter these harmonic components are extracted. Actual DC link voltage of DSTATCOM was compared with the reference signal and the error signal was sent to PI controller or fuzzy controller where control action takes place to reduce the error signal. The selection of controller makes difference in giving accuracy in compensation. This obtained signal was added to harmonic component and along with the reactive component obtained earlier to

transform from PQ to $\alpha\beta$. This $\alpha\beta$ components re again fed to transformation to be converted to abc components and reference current signal was obtained. This final reference current signal was compared with actual current and the reverse harmonic current is calculated and sent to PWM generator producing gate pulses to DSTATCOM. This induces negative harmonic content in to the system at PCC and thus harmonics in the distribution system was nullified [13-16]. Figure 3 shows the complete block diagram of IRF theory and figure 4 shows the DSTATCOM with IRF control theory.

4. MATLAB results and illustrations

4.1. 5-level DSTATCOM with PI controller

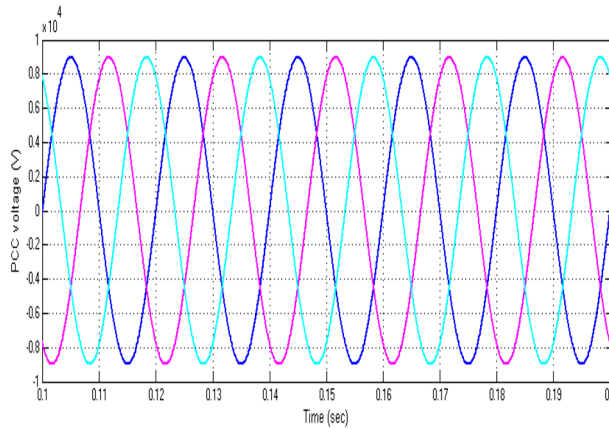


Figure 5: Source voltage at PCC for DSTATCOM with PI control.

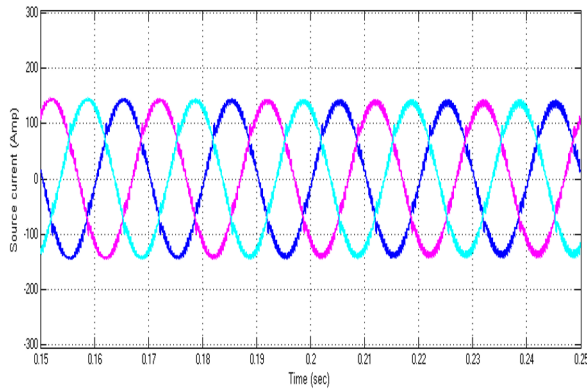


Figure 6: Source current at PCC for DSTATCOM with PI control

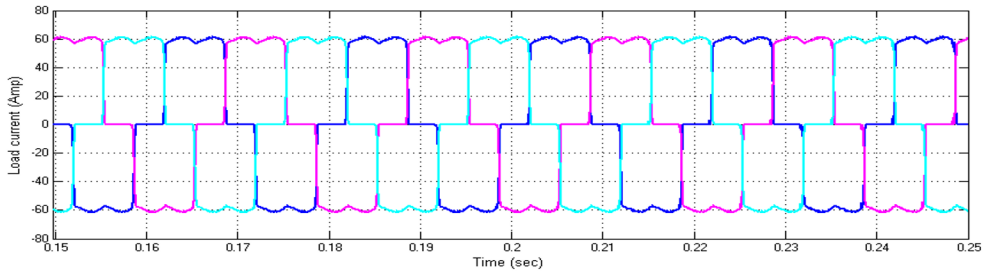


Figure 7: Load currents for DSTATCOM with PI control.

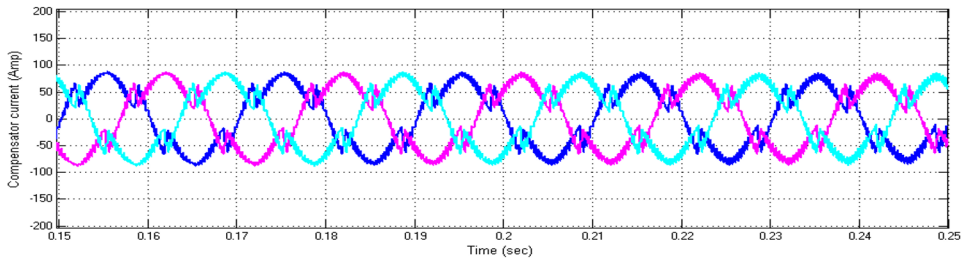


Figure 8: Filter currents for DSTATCOM with PI control

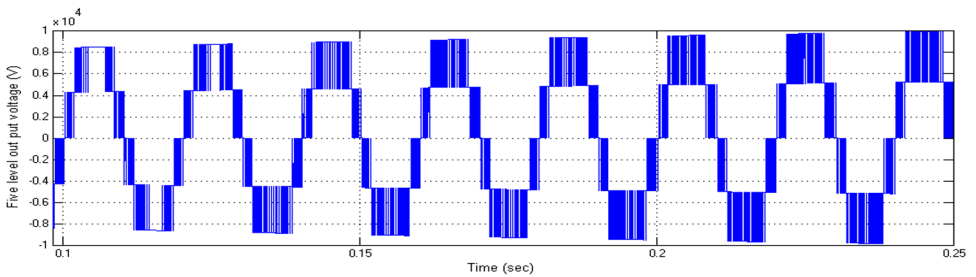


Figure 9: 5-level output of DSTATCOM with PI control

Figure 5 shows the PCC voltage of distribution system and figure 6 shows current at PCC. It is observed to be that source current does not contain heavy distortions indicating the harmonic content to be less. Figure 7 shows the load current. Load containing non-linear elements, draws non-linear component of currents and thus contains distortions. Figure 8 shows filter currents injected in to the system to compensate harmonics at PCC. Figure 9 shows 5-level output of DSTATCOM obtained from the inverter. Figure 10 is DC link voltage maintained constant.

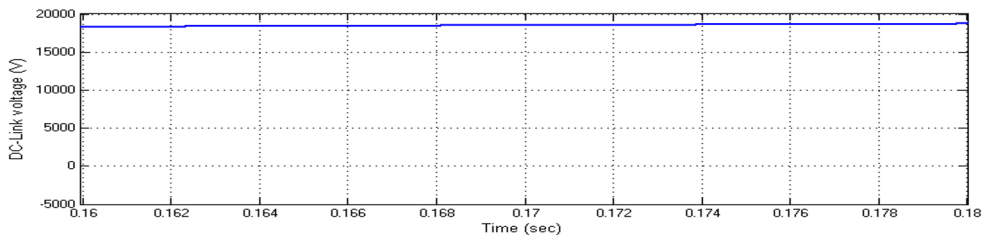


Figure 10: DC link voltage of DSTATCOM with PI control.

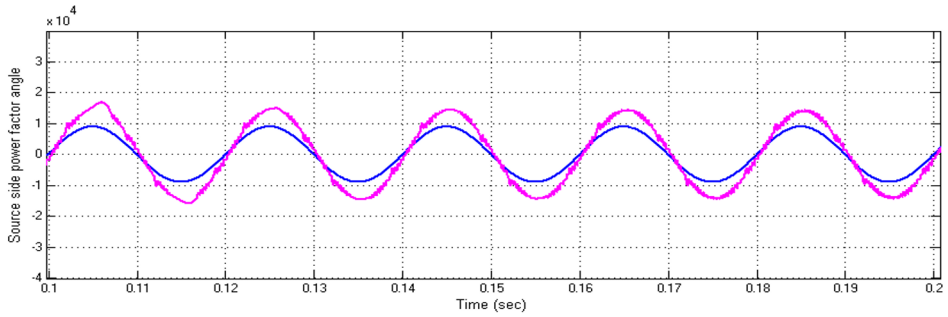


Figure 11: Power factor of system with PI control.

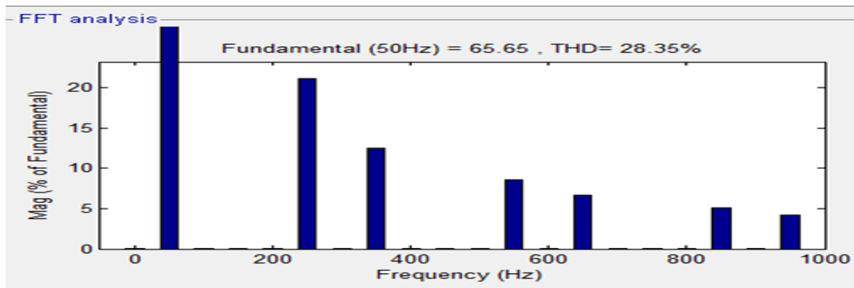


Figure 12: THD spectrum of load current with PI control

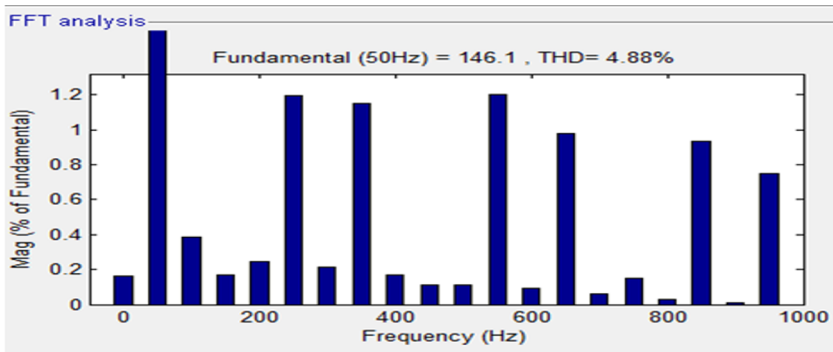


Figure 13: THD spectrum of source current with PI control.

Figure 11 shows power factor of the system with DSTATCOM operated with PI controller. Power factor is maintained nearer to unity as there is no phase difference observed between source current and voltage. Figure 12 shows THD in load current as 28.35% and THD in source current is shown in figure 13 indicating 4.88% of THD. With PI controller the THD is maintained within nominal values below 5%.

4.2. DSTATCOM with fuzzy controller

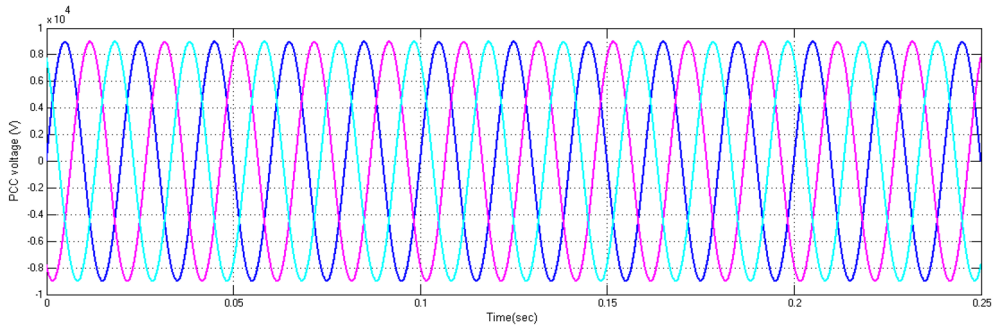


Figure 14: Source voltage at PCC for DSTATCOM with fuzzy control.

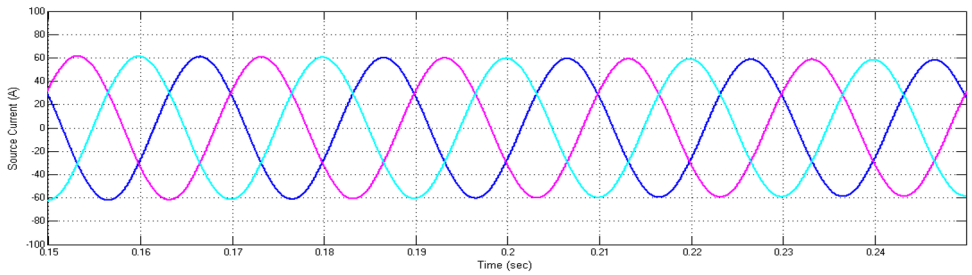


Figure 15: Source current at PCC for DSTATCOM with fuzzy control

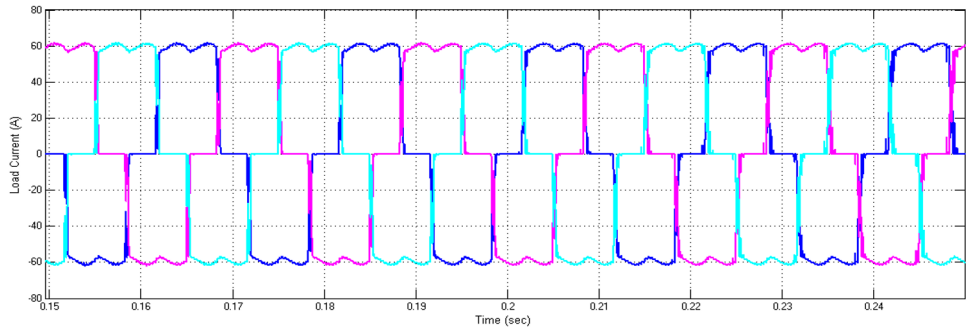


Figure 16: Load currents for DSTATCOM with fuzzy control.

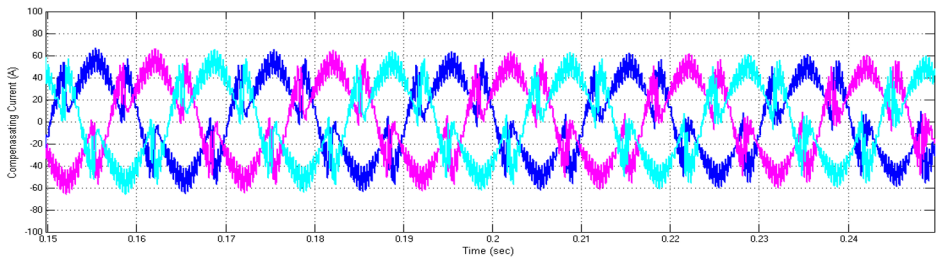


Figure 17: Filter currents for DSTATCOM with fuzzy control.

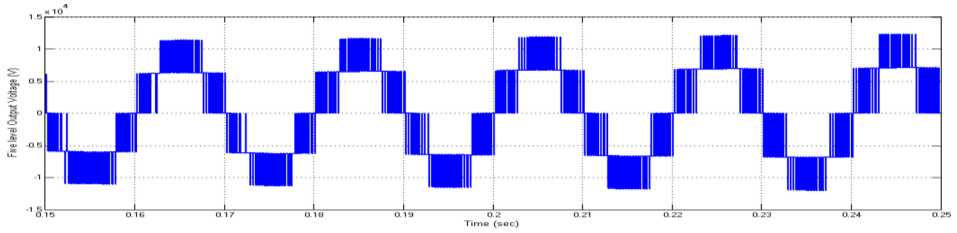


Figure 18: 5-level output of DSTATCOM with fuzzy control.

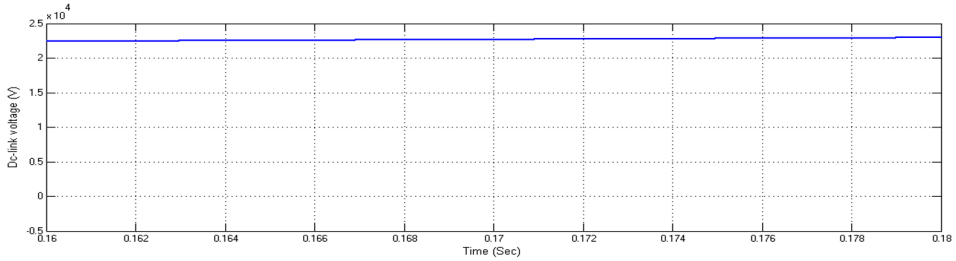


Figure 19: DC link voltage of DSTATCOM with fuzzy control

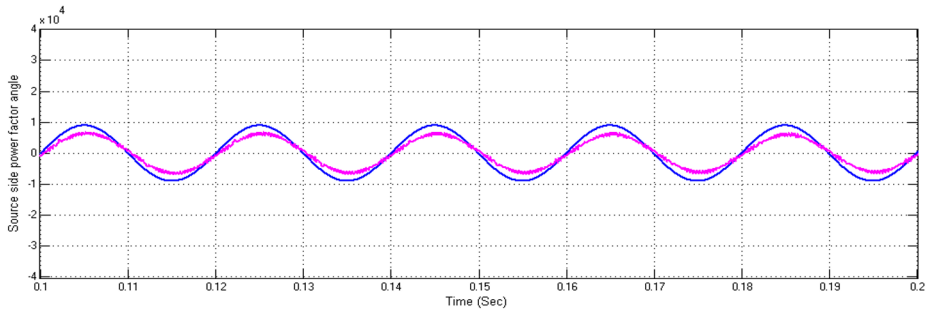


Figure 20: Power factor of system with fuzzy control.

Figure 14 shows the PCC voltage of distribution system and figure 15 shows current at PCC. It is observed to be that source current does not contain heavy distortions indicating the harmonic content to be less. Figure 16 shows the load current. Load containing non-linear elements, draws non-linear component of currents and thus contains distortions. Figure 17 shows filter currents injected in to the system to compensate harmonics at PCC. Figure 18 shows 5-level output of DSTATCOM obtained from the inverter. Figure 19 is DC link voltage maintained constant.

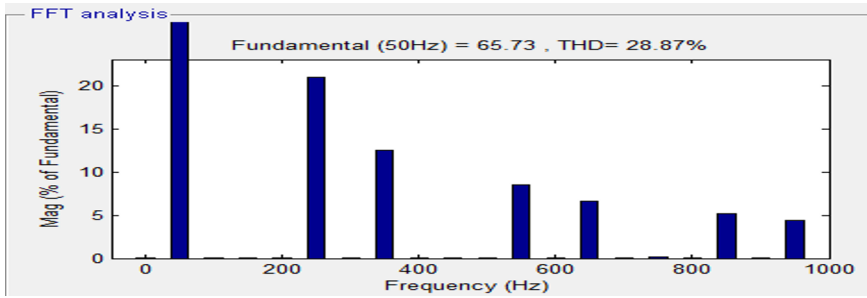


Figure 21: THD spectrum of load current with fuzzy control.

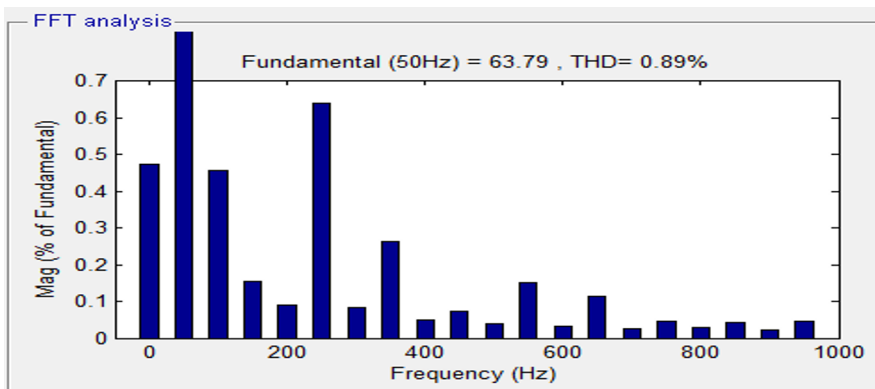


Figure 22: THD spectrum of source current with fuzzy control

Figure 20 shows power factor of the system with DSTATCOM operated with fuzzy controller. Power factor is maintained nearer to unity as there is no phase difference observed between source current and voltage. Figure 21 shows THD in load current as 28.87% and THD in source current is shown in figure 22 indicating 0.89% of THD. With fuzzy controller the THD is maintained within nominal values below 5% and improved over PI controller.

5. Conclusions

Use of intelligent controllers are made extensive these days to improve to improve the system performance and to obtain fast response. IRF theory is used to control DSTATCOM used to improve power quality at PCC. PI controllers are conventionally used in IRF theory but this paper proved to be reducing total harmonic distortion to much less value than obtained with use of PI controller. Harmonic distortion at PCC is found to be 4.8% with DSTATCOM using PI controller but with fuzzy controller harmonic distortion is reduced to 0.89%. Improved performance is achieved with the use of fuzzy controller.

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