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Mitigation of Harmonics In 6.6kv Bus In MTPS By Using MMC

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Abstract

This paper explains and finds a solution to reduce the source side harmonics in Mettur thermal power plant. In general harmonic analysis and its mitigation techniques are carried out only in load side but not in source side. This paper quantifies one way of mitigating the source side harmonics. The Mettur thermal power station consumes 9% of its total power produced, by its auxiliaries. The auxiliaries include inductive loads and non-linear loads. The MTPS has own auxiliary buses for its auxiliary loads. The auxiliary buses having the switching event of Medium voltage equipment. It has non-linear loads like battery chargers and UPS. These auxiliary loads produce harmonics. These harmonics causes insulation failure for the MV motor coil. The aim of this paper is to reduce the THD in source side by using Modular Multi-level Converter (MMC). The modelling of control scheme of the proposed system is simulated using MATLAB/SIMULINK software.

Keywords: Mettur Thermal Power Station (MTPS); Modular Multi-level Converter (MMC); Medium Voltage (MV); Pulse Width Modulation (PWM).

Introduction

Power quality issue has a major impact in power system these days. A power system is said to be well designed if it gives a good quality of reliable supply. The harmonics in power system has made poor quality in supply the power that makes the system to get affected. So power system can be equipped with harmonic mitigating equipment like filters, STATCOM, multilevel inverters etc. In general power quality problems is that waveforms of the supply voltage or load current deviate from the sinusoidal waveform at rated frequency. Power quality disturbance covers sudden, short duration deviation impulsive and oscillatory transients, voltage dips or sags, short interruption, as well as steady-state deviations such as harmonics and flicker.

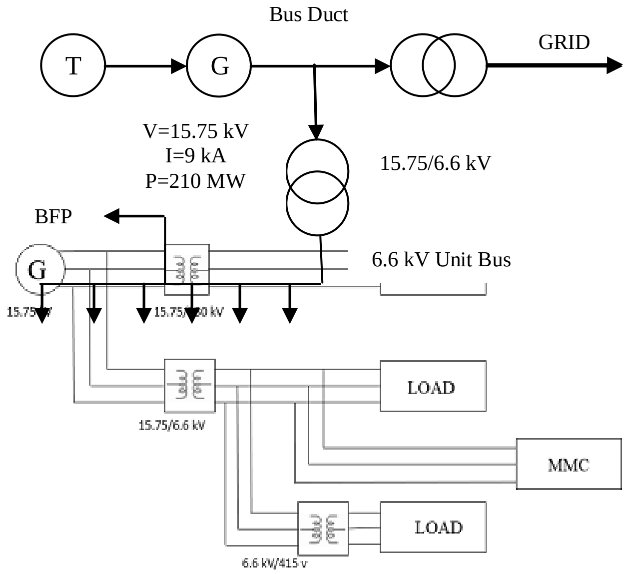
Harmonics are periodic sinusoidal distortions of the supply voltage or load current caused by non-linear loads. Harmonics are measured in integral multiples of the fundamental frequency. In industrial facilities, adjustable-speed drives and other power electronic loads can generate significant amount of harmonics. Solution to problems caused by harmonic distortion include installing active or passive filters at the load or bus, or taking advantage of transformer connections that enable cancellation of zero-sequence components. Harmonics created a major impact in power systems due to the usage of non-linear loads like arc furnaces, computers, current transformers, AC motors, fluorescent lights and power electronics equipment [1]. The paper presents a complete harmonic analysis of 6.6kV bus in Mettur Thermal Power Station. The system is modeled using MATLAB/SIMULINK software. The % THD are measured for voltage harmonics and mitigated by using Modular Multilevel Converter (MMC).

Description of 6.6 KV Bus In MTPS

In general harmonics analysis are carried out in power system in load side not in the source side. The MTPS has auxiliary bus for the equipment like generator, boiler and turbine. The MTPS also has non-linear loads connected in the auxiliary bus which creates the harmonics in the power system. The power to cater the need of auxiliaries are taken from the synchronous generator itself.

The MTPS has main transformer which will step up the output voltage from 15.75 kV to 230 kV and it is connected to the grid. Another transformer is called the auxiliary transformer otherwise called as USAT, which will step down the output voltage of the generator from 15.75kV to 6.6kV for feeding the auxiliary supplies. In this bus certain loads are connected which makes the system to run. These loads produce harmonics in the system for mitigating this harmonics Modular Multilevel Converter is used.

TURBINE GENERATOR 15.75/230 kV



PAF FDF IDF CEP SOP COAL MILL

Fig.1 Single line diagram of 6.6 kV bus in MTPS Fig.2 Block diagram of the system

Since 90% loads connected in 6.6 kV bus are inductive loads it will produce harmonic currents. Fig 1 shows the loads connected in 6.6 kV bus are Primary Air Fan (PAF), Forced Draft Fan (FDF), Induced Draft Fan (IDF), Condenser Extractor Pump (CEP), Stator Oil Pump (SOP), Boiler Feed Pump (BFP), Coal mill motor and non-linear loads. The Fig 2 shows block diagram of the proposed system.

Table 1: Resistance and inductance values for the auxiliary load

Load In 6.6 Kv Bus	**Power (Kw)**	**R Value**			**L Value**		
		R-R'	**Y-Y'**	**B-B'**	**R-R'**	**Y-Y'**	**B-B'**
PA FAN	1250	192mΩ	195mΩ	194mΩ	21.4mH	21.3mH	21.4mH
ID FAN	1500	200mΩ	201mΩ	204mΩ	1422µH	1420µH	1419µH
COAL MILL	340	574mΩ	578mΩ	579mΩ	121.6mH	121.3mH	122.6mH
FD FAN	800	309mΩ	313mΩ	311mΩ	115.3mH	115.5mH	115.4mH
BFP	3000	122mΩ	122mΩ	122mΩ	3215µH	3215µH	3215µH
SOP	200	1.851Ω	1.860Ω	1.855Ω	133.2mH	133.5mH	133.7mH
CEP	500	1.515mΩ	1.526mΩ	1.527mΩ	117.9mH	117.7mH	117.6mH

The R and L values of the above connected loads are measured using digital LCR meter (VLCR 17D) and values are tabulated above for the each connected loads.

Modular Multilevel Converter (MMC)

Modular multilevel converter is a type of voltage source converter which converts dc voltage into ac voltage. Multilevel output voltage gives the pure sinusoidal output voltages so no need for filters or small filters are used. This modular configuration ensures reliable operation. The modular structure has a great advantage over the conventional multilevel inverter, if any module gets faulted it can be replaced with another one. Many multilevel converter has both advantages and disadvantages during the operation. To solve the power quality problems a new Modular multilevel Converter is proposed in [2]-[5].

A. MMC Description And Operation

The design of MMC is shown in the Fig. 3. For an N level there is N-1 submodules in MMC. Fig. 4 shows the design of Sub Module (SM). Each Sub Module composed of two GTO switches (GTO 1 and GTO 2), one capacitor C and two anti-parallel diodes (D1 and D2). Each phase leg of the converter has N number of sub modules.

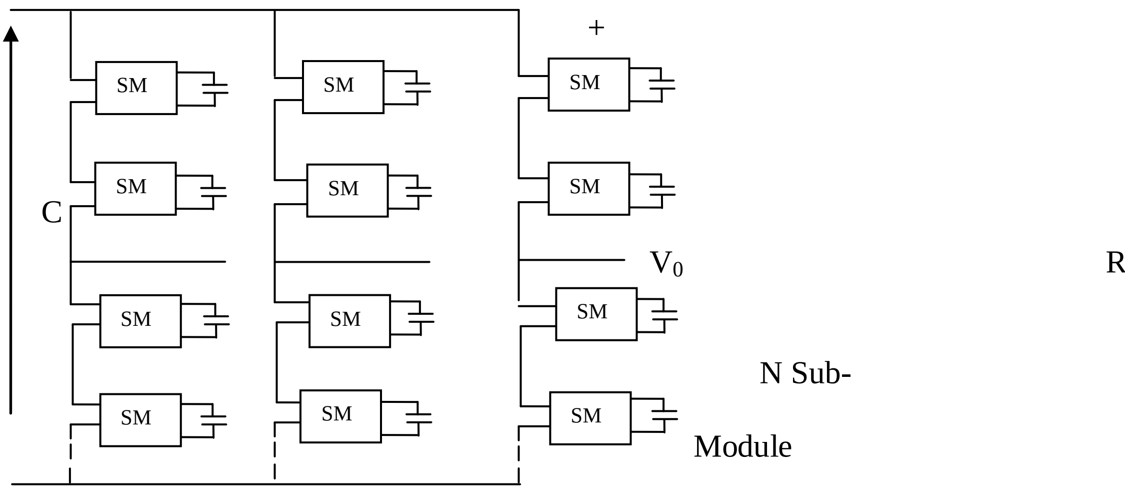


Figure 3: Structure of Three Phase MMC

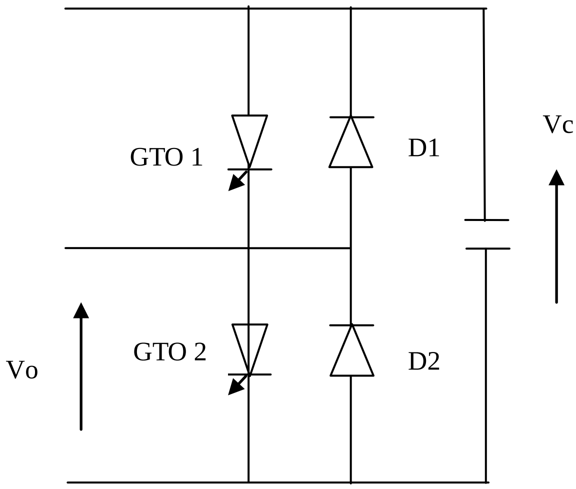


Figure 4: Chopper cell of a Sub-Module

From the Fig. 4, the output voltage Vo of the sub module is given by,
Vo = Vc if GTO 1 is ON and GTO 2 is OFF.
Vo = 0 if GTO 1 is OFF and GTO 2 is ON.
Where Vc is the voltage across the capacitor.

Both GTO 1 and GTO 2 should not get ON as it produce short circuit across the capacitor. Same as both OFF should not be considered because it produce different output voltages. In MMC, number of steps of the output voltage depends on total number of series connected Sub Modules.

B. Eleven Level MMC

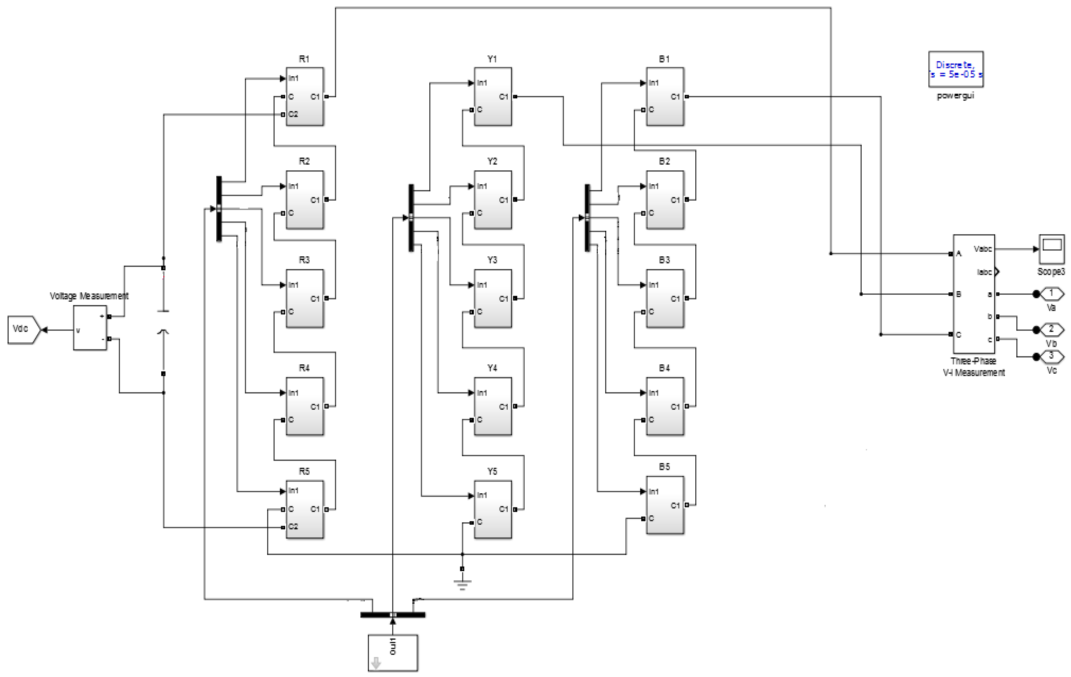


Figure 5: Simulink diagram of eleven level MMC

The simulation of eleven level MMC is shown in the Fig. 5. For eleven level each phase leg of the converter has five sub modules. The input to the converter is given by capacitor source. The simulation of the eleven level voltage output is shown in the Fig. 6.

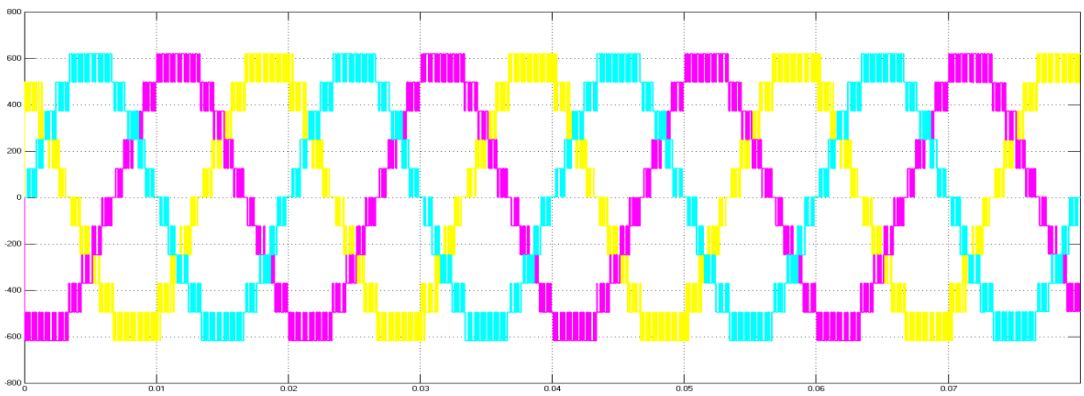


Figure 6: Eleven level voltage level of MMC

Each sub module composed of two GTO switches (GTO 1 and GTO 2), one capacitor C and two anti-parallel diodes (D1 and D2) which is shown in the Fig. 7.

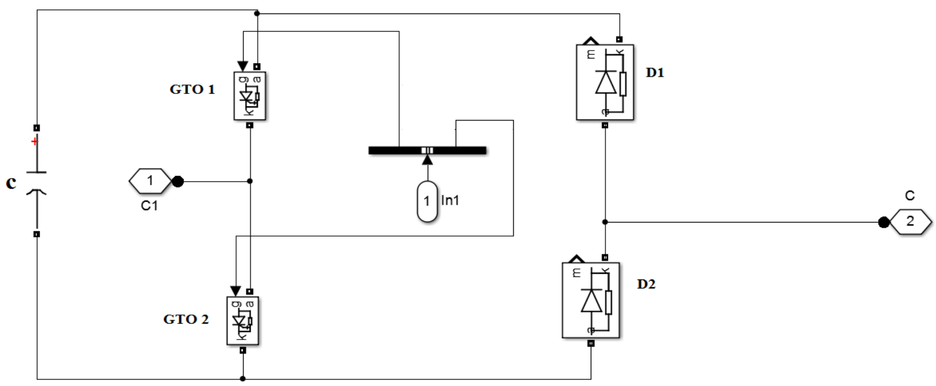


Figure 7: Simulink diagram of Sub Module

C. Multi Carrier Pwm Technique

The switching pulse to the converter is given by using multi carrier sine PWM. For an 11 level inverter, 10 carriers with same frequency and same amplitude. The reference sine wave is given. The reference sine wave is continuously compared with each carrier set. The reference wave is greater than the carrier signal, then GTO corresponding to that carrier is switched ON and if the reference wave is less than the carrier signal, then GTO corresponding to that carrier is switched OFF [6]. The simulation of multicarrier PWM technique for eleven level Modular multilevel converter is shown in the Fig. 8.

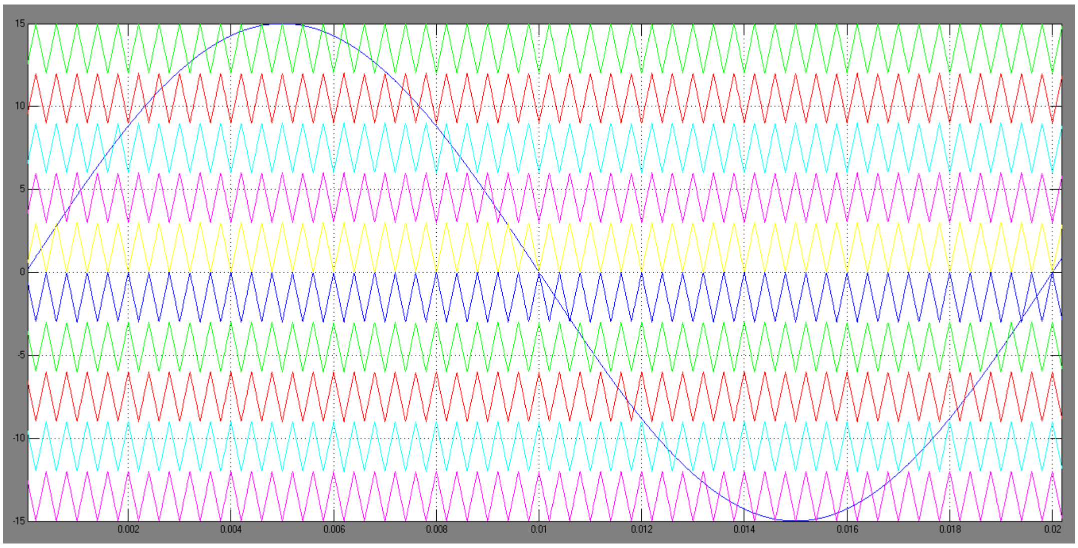


Figure 7: Multicarrier PWM technique for eleven level MMC

D. Controller

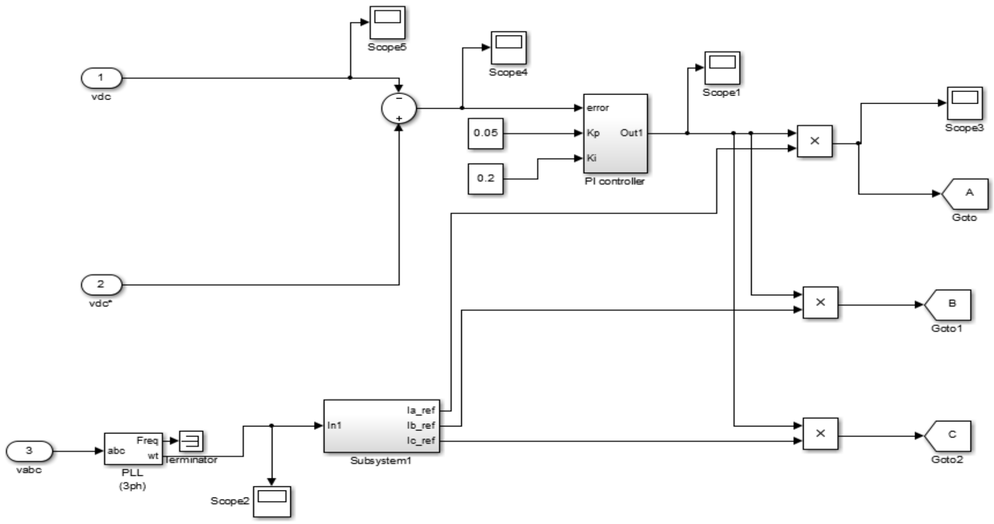


Figure 8: Simulink diagram of controller system

Fig: 8 shows the Simulink diagram of the controller system. The controller system is also the part of the system. The PI controller (proportional-integral controller) is a feedback controller which control the system by sum the error signal (difference between the output and reference value) and the integral of that value. Fig: 9 shows the Simulink diagram of PI controller.

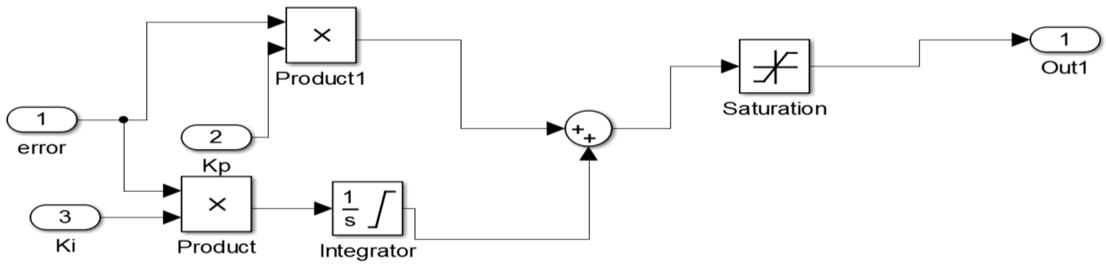


Figure 9: Simulink diagram of PI controller

In this case, the voltage across the capacitor in MMC is summed with the reference voltage and the error signal is given into the PI controller. By tuning the Kp and Ki value the output value is obtained. From the system load voltage is taken and it is given into the phase locked loop (PLL) for the grid synchronizing. The output of the PLL is get as the angle (wt) and it is converted into sinusoidal wave which is compared with the output of PI controller. The compared signal is the reference sine signal in the multicarrier PWM technique.

MMC With Grid Connected Mettur Load

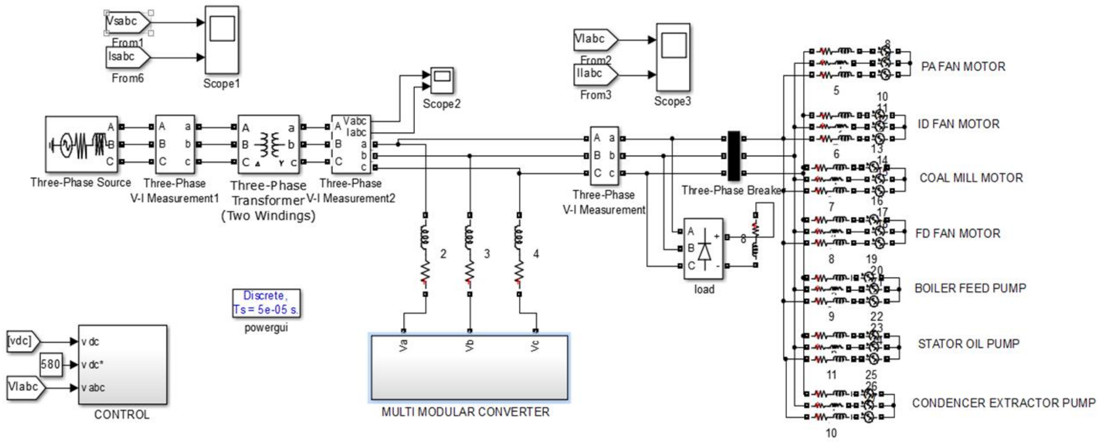


Figure 10: Simulink diagram of MMC with Mettur Load

Fig: 10 shows the Simulink diagram of the test system. For the simulation study a three phase source is consider as the generator of the Mettur thermal power plant and the load is consider as the seven RLE load and one nonlinear load connected in series with the grid. The MMC circuit is connected in shunt with the system nearer to the load point.

Simulation Results

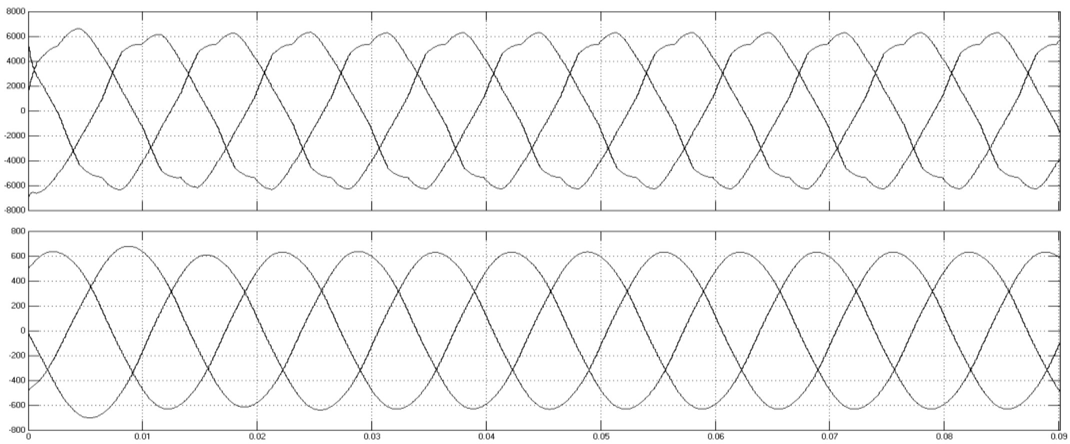


Figure 11: Source voltage and current waveform without MMC

Fig: 11 shows the source voltage and source current waveform without connected to the MMC. Due to the connected loads in the system, the source voltage is distorted.

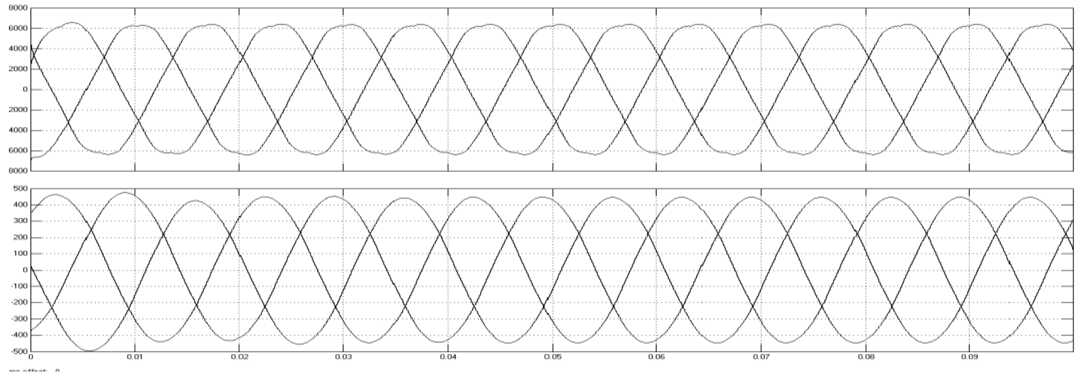


Figure 12: Source voltage and current waveform with MMC

For correcting the distorted voltage waveform in the source side by using Modular multilevel converter. Fig: 12 shows the source voltage and source current waveform with MMC.

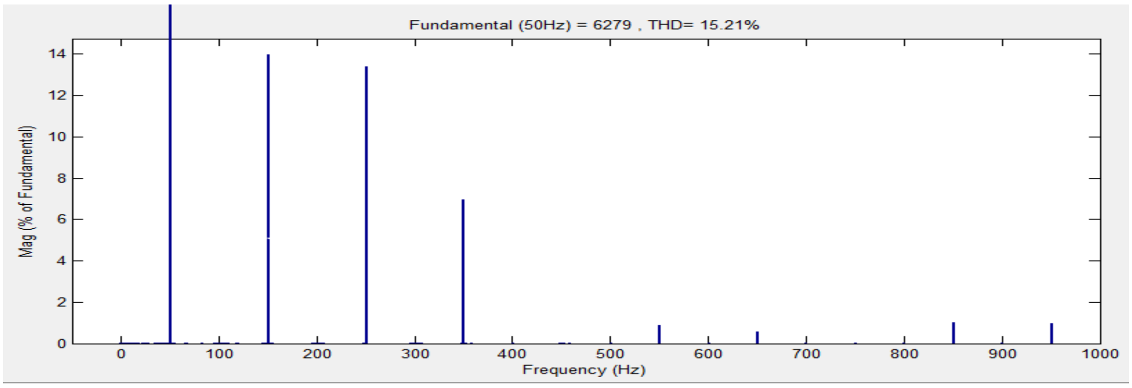


Figure 13: FFT analysis of Voltage harmonics without MMC

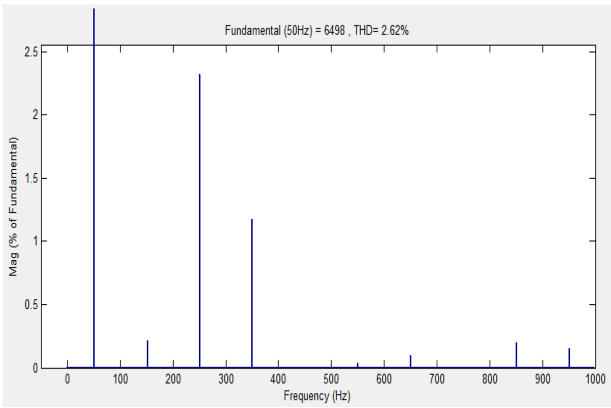


Figure 14: FFT analysis of voltage harmonics with MMC

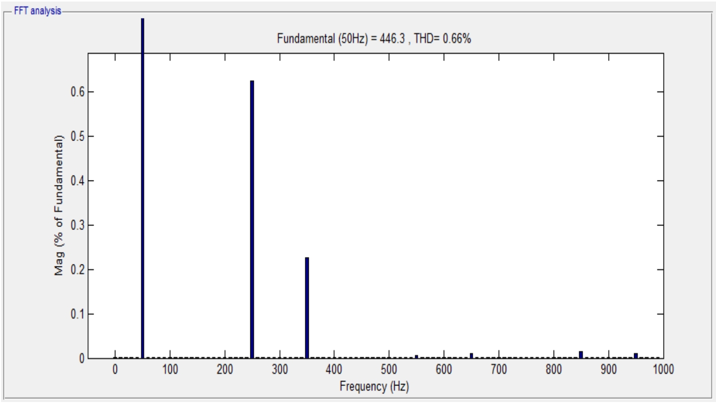


Figure 15: FFT analysis of Current harmonics with MMC

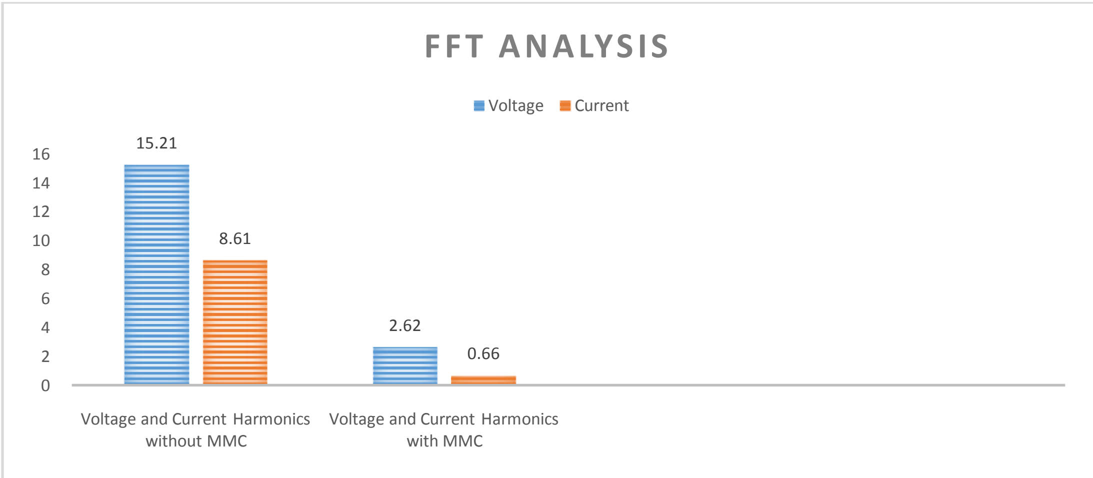


Figure 16: Comparison of FFT analysis of Voltage and current harmonics

Conclusion

In this paper the use and advantages of applying Modular Multilevel Converter to compensate the real and reactive power in the system and to mitigate the harmonics present in the source side due to load. The %THD of MMC coupled system better than the conventional system. The performance of the system satisfies the IEEE-519 standards. Compared with the Fly back Capacitor and Neutral Point Clamped, it has simpler structure, modular design, and easier expansion of the number of level. It has faster implementation of the fault module and replacement. The number of power switching devise will not increase with the number of levels when Modular Multilevel converter is used. In comparison with H-bridge, MMC doesn't need substantial independent DC power Supply.

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