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HARMONIC REDUCTION IN HYBRID FILTERS FOR POWER QUALITY IMPROVEMENT IN DISTRIBUTION SYSTEMS

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ABSTRACT

A flexible and versatile solution to voltage quality problems is offered by active power filters. Currently they are based on PWM converters and used to connect to low and medium voltage distribution system in shunt or in series. Active power filters can perform one or more of the functions required to compensate power systems in improving power quality. Hybrid Filter, which is a combination ofan active series filter and passive shunt filter is quite popular because the solid-state devices used in the active series part can be of reduced size and cost (about 5% of the load size) and the major part of the hybrid filter is made of the passive shunt *L-C* filter used to eliminate lower order harmonics. It has the capability of reducing voltage and current harmonics at a reasonable cost. To provide high power quality at the Point of Common Coupling (PCC) of power distribution systems, elimination of the harmonics is indispensably necessary. The power quality and allowable Harmonic levels in power system are defined by International standards (like IEEE-519-1992, IEC-61000). Hence, it is invariably necessary to design filters meeting the said International standards. Harmonics in hybrid filters can be reduced by using multilevel inverter. A seven level cascaded multilevel is used in the present work to mitigate the harmonics in Hybrid filter. The simulation results of the same are presented in this paper for a distribution system of voltage 11KV.

Keywords: H*ybrid Filters, Harmonic Reduction, Multilevel Inverter, Power Quality, Cascaded Multilevel Inverter.*

1. INTRODUCTION

Power quality in three-phase AC systems could be analyzed by; Voltage unbalance, Voltage sags, Voltage swells, partial or total loss of one or more phases. A major cause of voltage unbalances is the uneven distribution of single-phase loads, which may be continuously changing across a three-phase power system. Additional causes of power system voltage unbalances can be due to asymmetrical transformer winding impedances, open star and open delta transformer banks and asymmetrical transmission line impedances [1]. Voltage unbalance causes a lot of ill effects on induction motors. The adverse effects of voltage unbalance in induction motor performance are overheating, line-current unbalance, de-rating, torque pulsation, and inefficiency. The overheating leads to winding insulation degradation [2]. The poor power quality can degrade or damagethe electrical equipment connected to the system. Improving the power quality may be provided using a three-phase series active filter [5]. Active filter may correct the voltage unbalances and regulate it to the desired level [20]. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current

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source and series active power filters as a controllable voltage source. Both schemes are implemented preferable with voltage source PWM inverters [14], with a dc bus having a reactive element such as a capacitor. Here Cascaded Seven Level Inverter is used as Active Power Filter to compensate the voltage sag during the presence of non-linear loads with reduced harmonics.

2. HYBRID ACTIVE POWER FILTER

The indiscriminate use of non-linear loads has given rise to investigation into new compensation equipment based on power electronics. The aim of this equipment is the elimination of harmonics in the system and reduction in reactive power flow. Depending on application type, series or parallel configurations or combination of active and passive filters are used. Active power filters can be used in conjunction with passive filters improving compensation characteristics of the passive filter and to avoid the possible occurrence of the generation of series or parallel resonance. If the passive filters are not connected, the active power filter could compensate only voltage regulation and voltage unbalance. The best method is to combine the compensation characteristics of passive and active power filters, as shown in Fig. 1 which is Hybrid Filter. In this way, the compensation characteristics of the passive filter is significantly improved since the active scheme generated voltage harmonic components across the terminal of the primary windings of the series transformer, forcing current harmonics generated by the load to circulate through the passive filter instead of the power distribution system. By controlling the amplitude of the voltage fundamental component across the coupling transformer, the power factor of the power distribution system can be adjusted. However, the control of the load power factor imposes a higher voltage across the filter capacitor. This effect has to be considered when the filter capacitors are specified. This type of configuration is very convenient for compensation of high power medium voltage non-linear loads, such as large power ac drives with cycloconverters or high power medium voltage rectifiers for application in arc furnaces.

3. SIMULATION RESULTS

The simulation is carried out using MATLAB software. Fig. 2 shows the SIMULINK diagram of 3-phase system without Hybrid filter and non-linear load. At T = 2 sec. the additional load is connected to increase the total load. Voltage sag occurs due to load variation. The non-linear load produces higher harmonics in the system. Fig. 3 shows the load current and voltage with the voltage sag due sudden application of load. Fig. 4 shows the RMS load current. Fig. 5 shows the RMS load voltage with load variation conditions.

Fig. 6 shows the Total Harmonic Distortion, THD, in load voltage. The THD is 13.60% for load voltage with non-linear load conditions.

The SIMULINK diagram of 3-phase system with hybrid filter and non-linear load is shown in Fig. 7. The Cascaded seven level active filter is connected in series with the source and passive LC filter is shunted across the load. The combination of this active and passive filters is a hybrid filter. Simulation diagram of a cascaded seven level inverter for 3-phase system is shown in Fig. 8. The detailed simulation circuit diagram for each pahse using a cascaded multilevel inverter is shown in Fig. 9.

Cascaded multilevel inverter has three H-bridge inverter swhich forms seven level (Phase Voltage) inverter. Output voltage has seven levels as shown in Fig. 10. Fig. 11 shows the multilevel inverter output voltage for one leg. Fig. 12 shows the three phase output current.

At T = 2 sec., the additional load is connected to increase the total load. Voltage sag occur due to load variation. The non-linear load produces higher harmonics in the system. At T = 2.06 sec., the active filter is connected to the system so that voltage sag is compensated and harmonics also reduced. Fig. 13 shows the three phase source voltage which is 11KV. Fig. 14 shows three phase voltages with voltage sag and compensation using hybrid filter. Fig. 15 shows the RMS load current.

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Fig. 16 shows the RMS load voltage with load variation conditions. Fig. 17 shows the THD in the load voltage. The THD is 2.03% for load voltage with non-linear load conditions. After Filter insertion the THD is reduced considerably and is within the range defined by IEEE & IEC.

4. CONCLUSION

As observed from the simulation results the following conclusions are arrived. In the absence of hybrid filter, whenever the non-linear loads are present, there is a voltage sag at T = 2 sec. (Fig. 3). This voltage sag is compensated by connecting the proposed novel hybrid filter at T = 2.06 sec. As observed from FFT analysis (Fig. 6 and Fig. 17), after Filter injection the THD is reduced from 13.60% to 2.03%. Therefore, the proposed hybrid filter ensures reduction of harmonic content.

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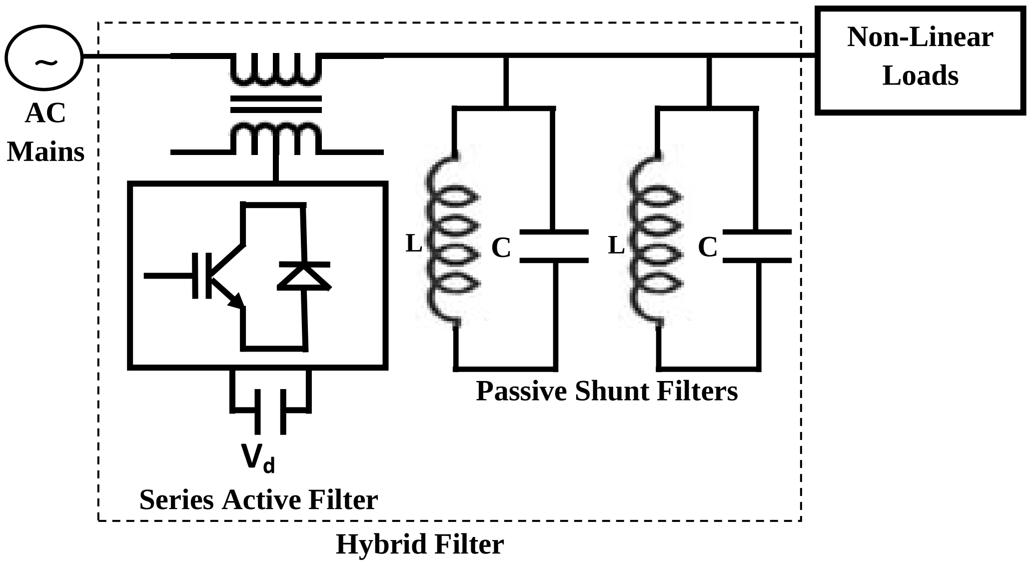

Fig. 1 One-Line Diagram representation of Hybrid Filter with Source and non-linear Loads

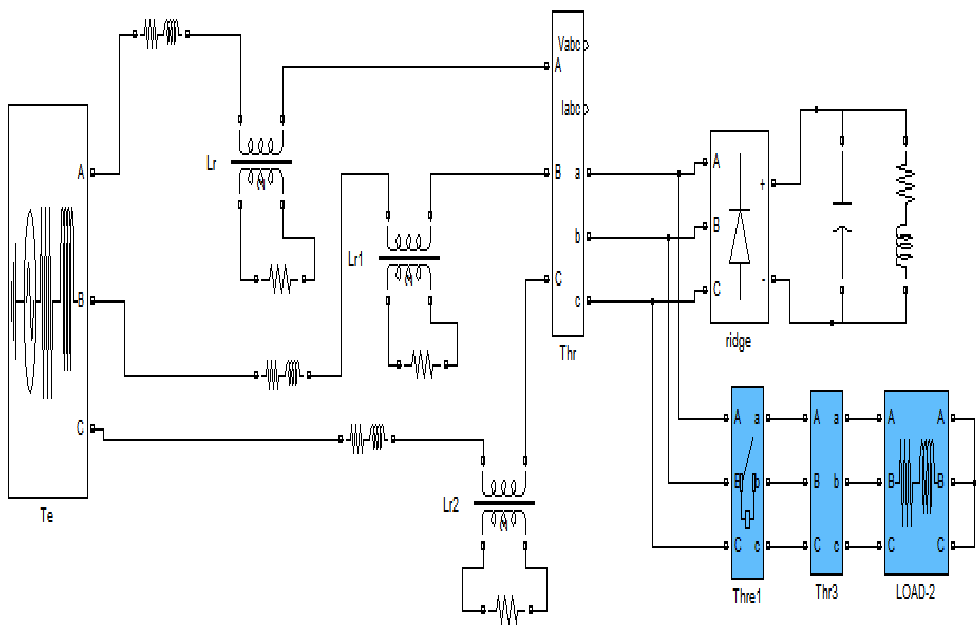

Fig. 2 Line Model with Non-Linear Load

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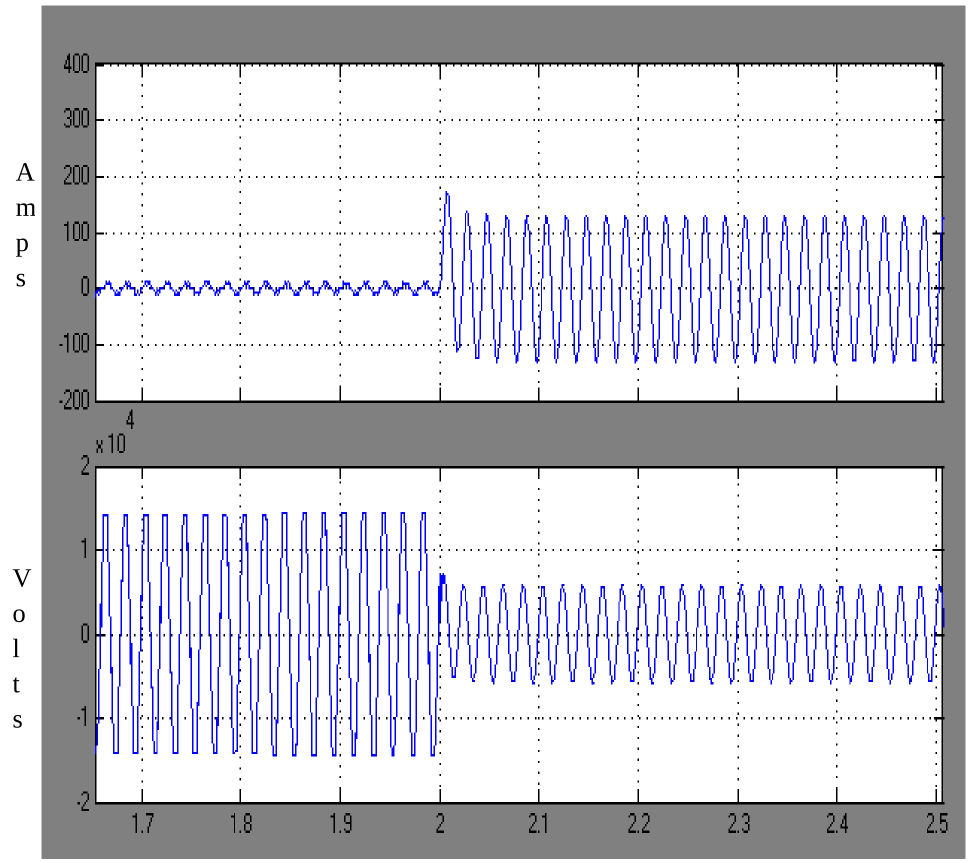

Fig. 3 Load Current and Voltage with Sag Time (s)

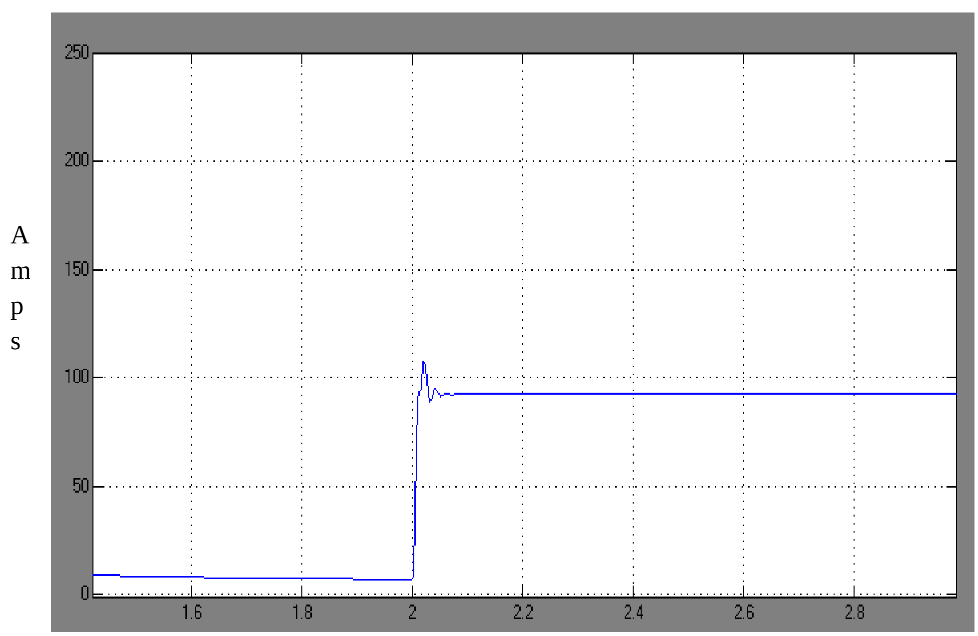

Fig. 4 RMS Load Current Time (s)

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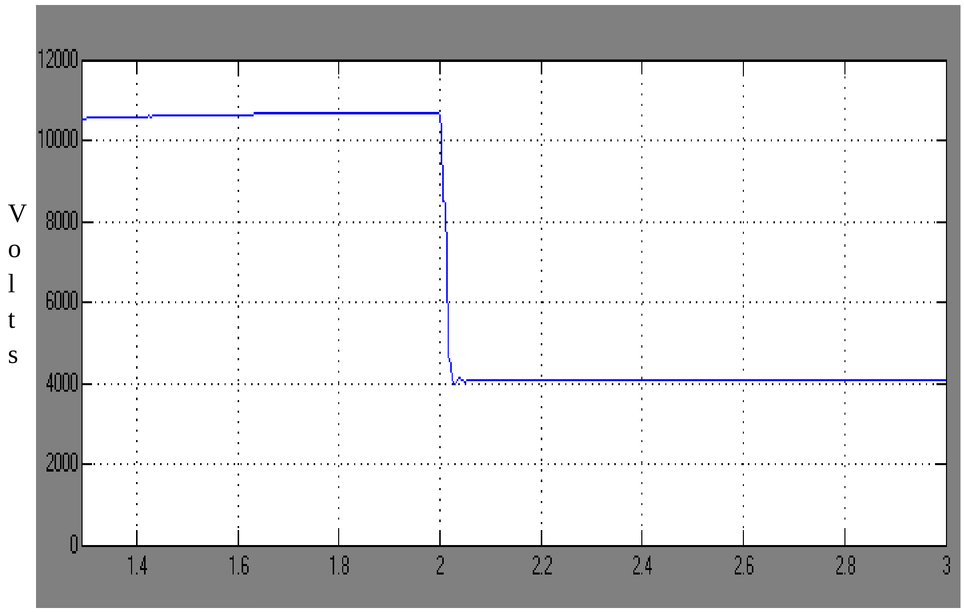

Time (s)

Fig. 5 RMS Load Voltage

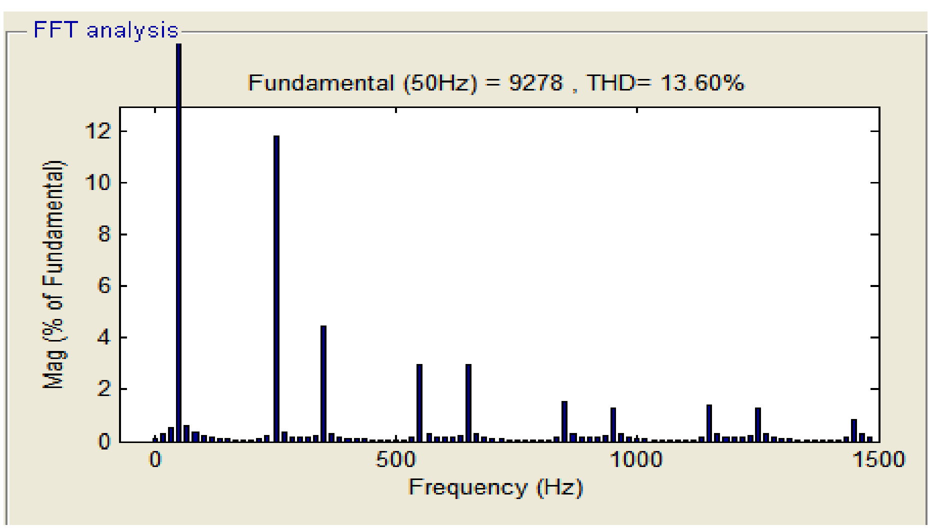

Fig. 6 FFT analysis for Load Voltage

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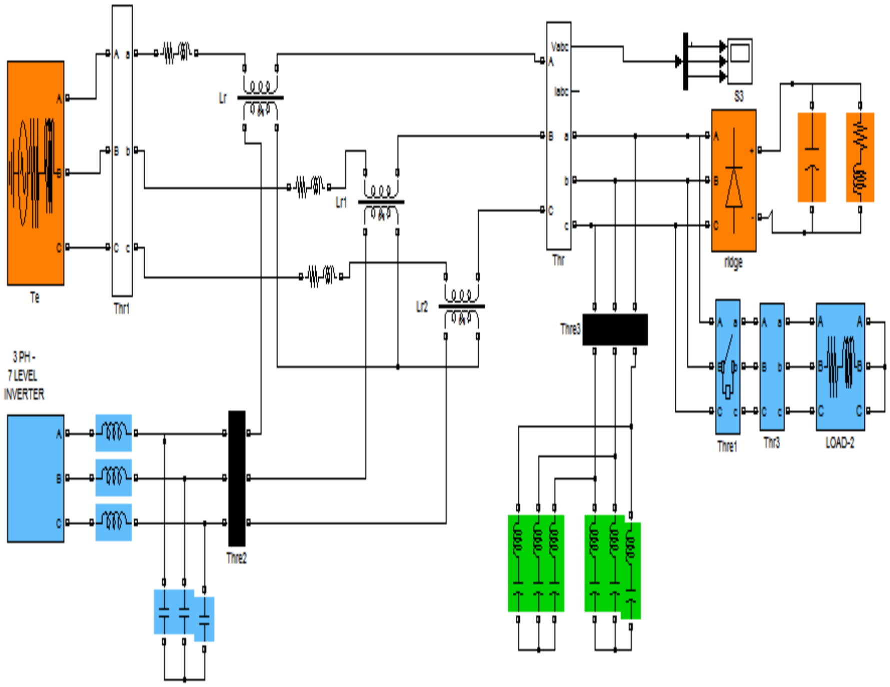

Fig. 7 Line Model with Hybrid Filter

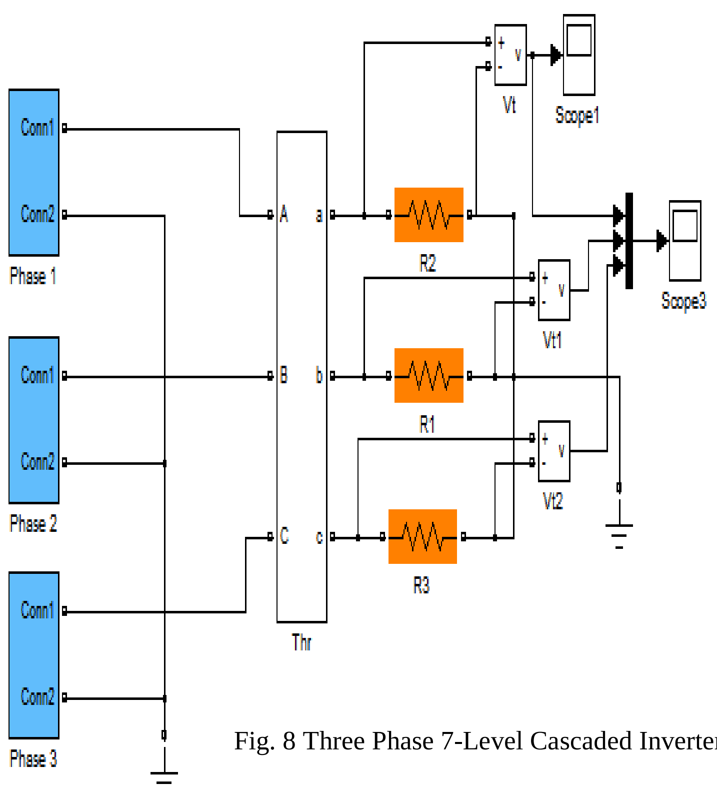

Fig. 8 Three Phase 7-Level Cascaded Inverter

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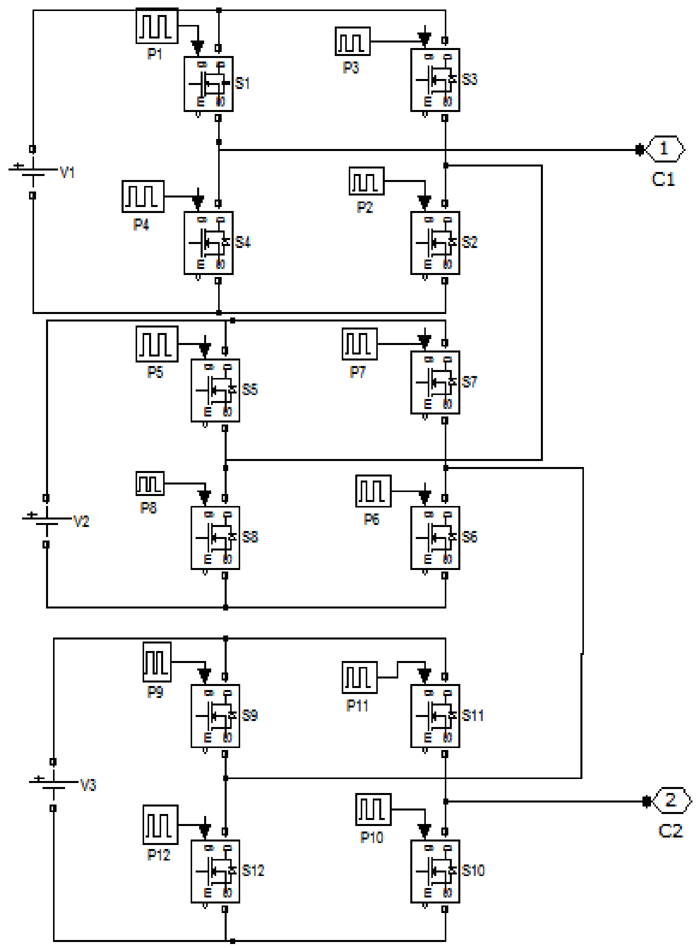

Fig. 9 7-Level Cascaded Multilevel Inverter Circuit Diagram for One Phase

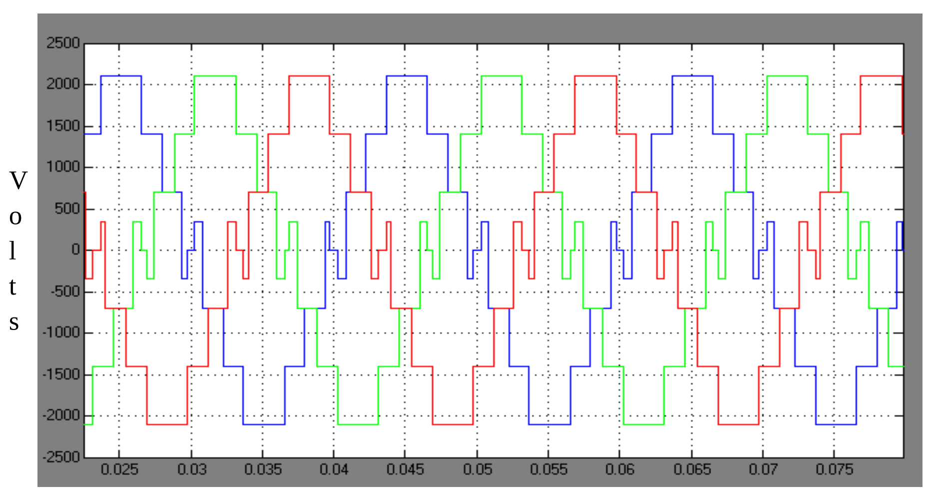

Fig. 10 7-Level Inverter Output Voltage in three phases

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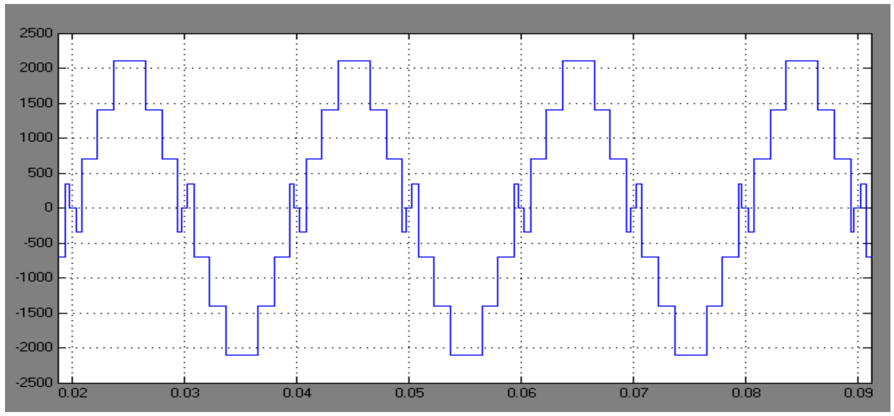

Fig. 11 7-Level Inverter Output Voltage in one phase

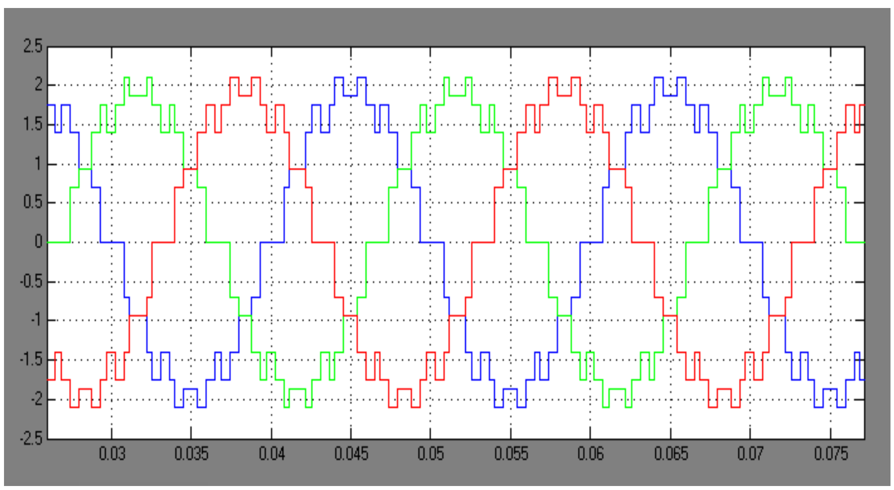

Fig. 12 7-Level Inverter Output Current

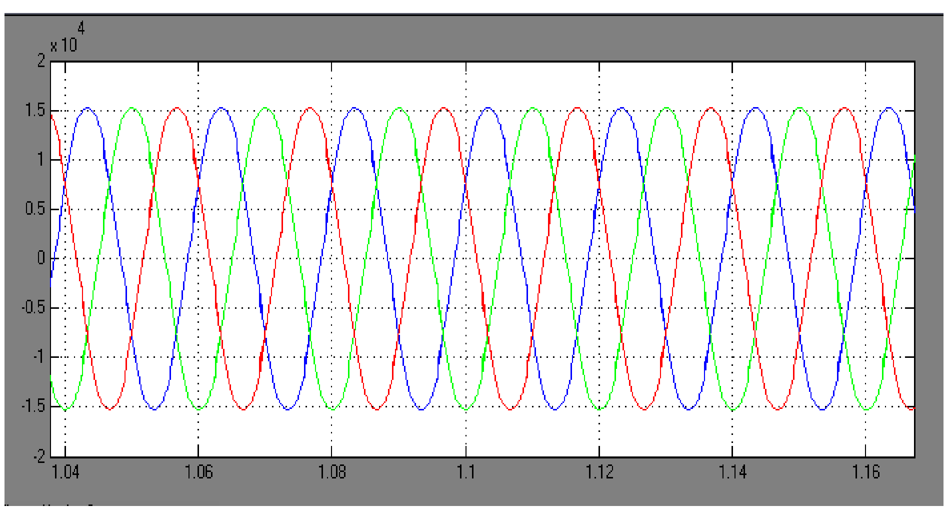

Fig. 13 Three Phase Source Voltage

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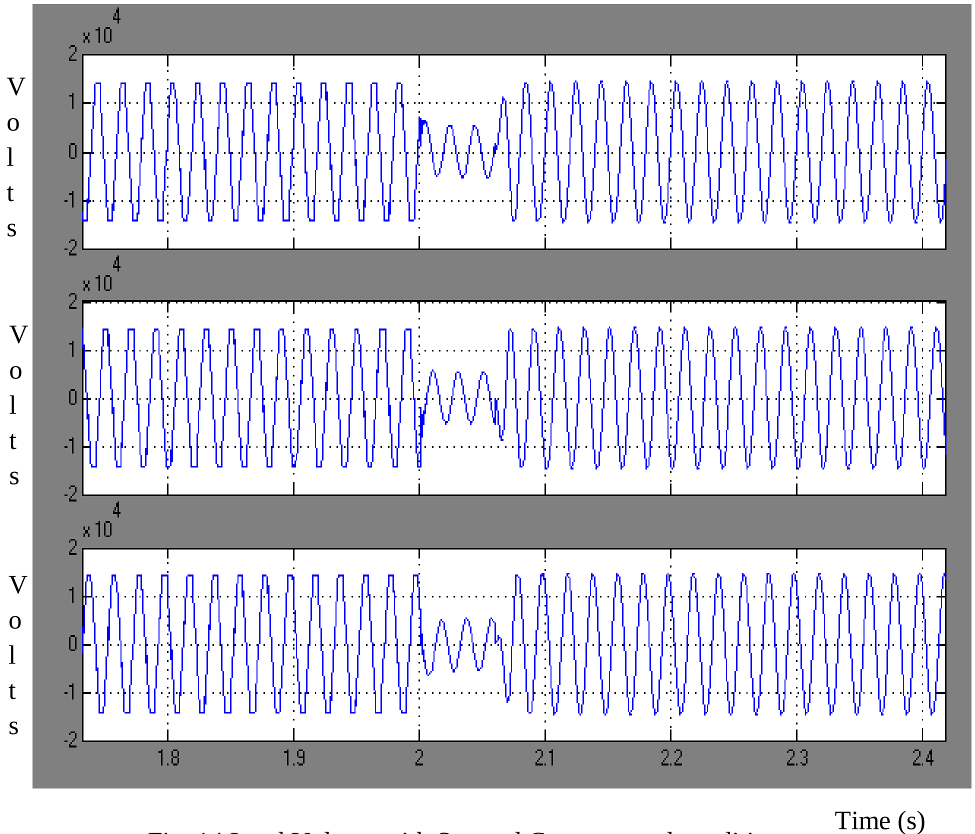

Fig. 14 Load Voltage with Sag and Compensated condition

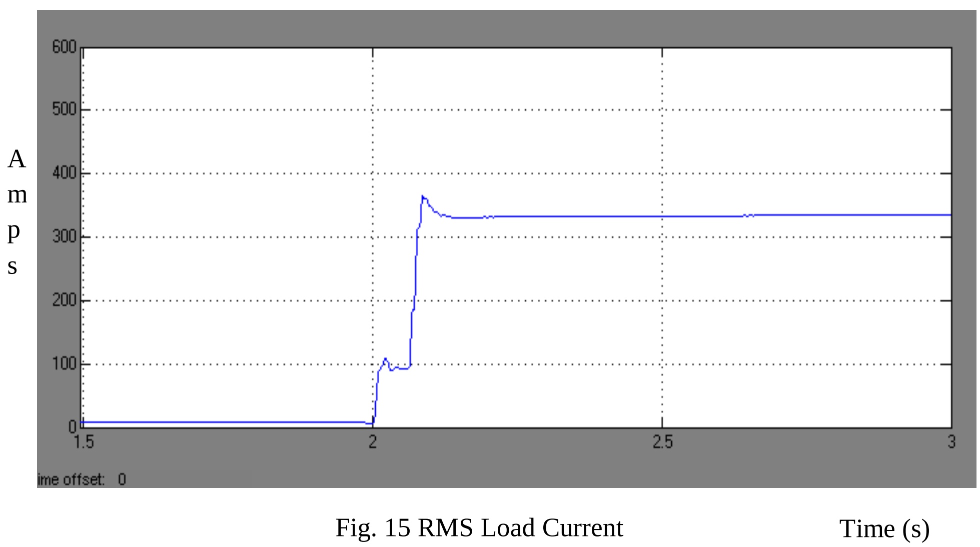

Fig. 15 RMS Load Current

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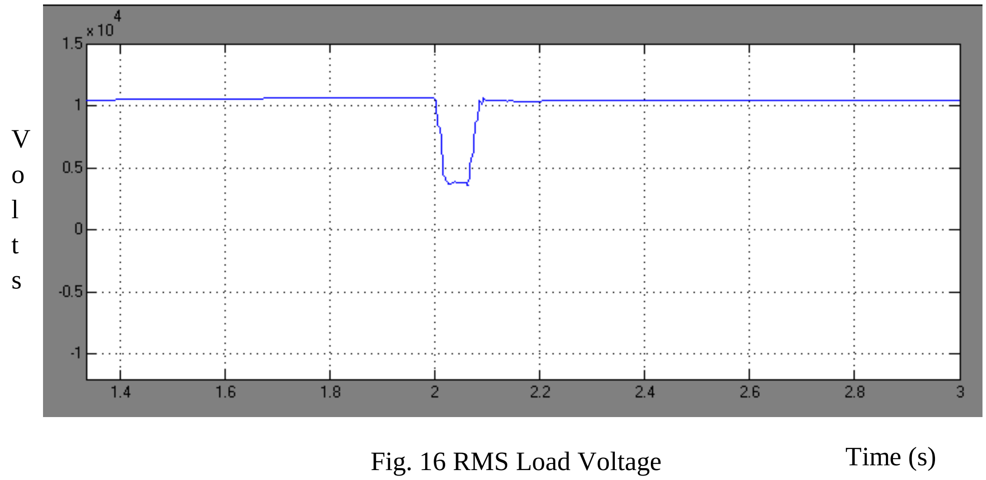

Fig. 16 RMS Load Voltage

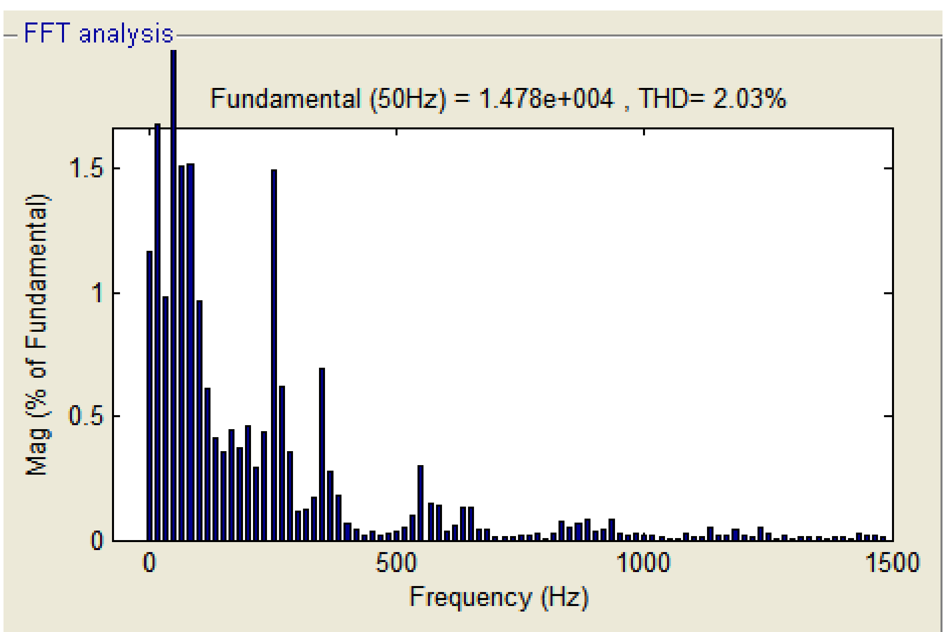

Fig. 17 FFT Analysis for Load Voltage with Hybrid Filter