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A Novel Strategy for Total Harmonic Reduction using EMI Filter and Boost Converter Stage for Capacitor Charged Power Supply

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Abstract:
This paper deals with the mitigation of issues of the higher EMI and harmonics in the high power Capacitor Charged power supply. The supply is fed by the 12V batteries, a PWM based Inverter integrated with EMI filter and output Boost converter stage for THD reduction. Our work deals with the issues generated in the power supplies due to electromagnetic interference generated by various sources. Thus, we have integrated the EMI Filter and isolated power supply rectifier stage followed by the active boost converter. The overall result of the proposed configuration helps in reduction of the THD from 15.6% without use of the filter and boost converter to the 2.86%. The models have been developed using MATLAB-SIMULINK with the 3-Phase PWM based VSI stage for better THD performance as compared to the conventional strategies of voltage doubler circuit. The results show the EMI performance and thus the THD has been reduced. The various simulation results have been added for the validation of the proposed model.

Keywords: EMI, THD, VSI, Boost Converter, rectifier, PWM based Inverter

I. INTRODUCTION

The power supply design for high power and higher voltage application has always been challenging due to various issues. The power supply finds the wide application for various devices and utilities that requires variety of the design requirement. This various configurations of the power supplies has been designed and implemented in the previous works. The major challenges that can be observed in the nature of source and loads can be presence of the EMI and harmonics that causes loss of the power and interfere with the proper transmission of the desired power. The harmonics and the EMI introduce extra loss of the total input power and thus hamper the power quality of the transmission and also the efficiency of the power distribution schemes. The harmonics introduces the extra heat that adds another design constraint and thus requires additional hardware components. Thus, it increases the cost and total hardware requirements. With the advent and exploitation of the power electronics, the design for power supply has been more efficient. Thus, it has caused increase in carrier frequency of the PWM that is used for driving the IGBTs, MOSFETs rated for very high voltage (< 1200V) and up to several KHz (~40 KHz) range. But however, we need to deal with the issues in these devices like higher leakage current, reverse EMF, spikes, harmonics etc. Thus, the issues of EMI and harmonics arise and need to be mitigated very efficiently. In our work, we have designed the Capacitor charged power supply. In this supply, the two batteries of 12V, 16Ah has been connected in series to generate 24V DC as source voltage. Similarly we have used the 3-phase MOSFET based VSI inverter. The VSI inverter is fed by the PWM of carrier frequency 1 KHz. The inverter output is then fed to the EMI filters. The Inverter supply is then isolated using the 3-phase transformer and followed by the diode bridge circuit for the rectification. The output DC is then fed to the capacitor using boost conversion stage. We have compared the two designs implemented in MATLAB-SIMULINK. The first design consists of the supply without EMI Filter and boost stage. The second proposed design consists of the supply design with the EMI filter and boost converter stage. The various control pulses, voltages and current simulation results has been presented. The simulation results have been then analyzed using FFT analysis for THD analysis. The results show that the THD without EMI filter and boost converter stage is 15.6%. After the introduction of the EMI filter and the boost converter stage, the THD has been reduced to the 2.86%. Thus, the reduction of 81.67% has been reported in THD using our proposed design.

II. INTROCUTION TO DC-DC CONVERTER DESIGN

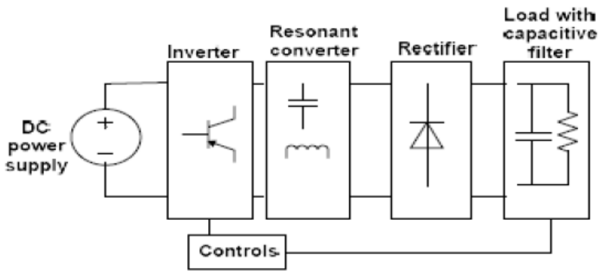

Figure. 1. Basic Block Schematics of the DC-DC Converter

Here, in this design, the source of the power supply is the voltage source generated by the 12V Batteries. The voltage is then fed to the 3-phase VSI Inverter, followed by the EMI filter, rectifier and the load. The inverter operated with very high frequency, which converts constant DC voltage in to a square wave with a frequency equal to switching frequency. The input source to the inverter may be either constant voltage or constant current source. Resonant converter followed by inverter, the output of resonant converter is sine wave whose frequency equal to resonant frequency, then once again it rectified and given to the load. Before delivering to the load a high value capacitor is connected across the load to filter out ripples. A voltage source in series with large inductor makes a constant voltage source into a constant currents source and is feeds to the resonant network. Voltage source fed inverter followed by series resonant converter is a popular DC-DC converter for industrial heating applications. Parallel resonant inverter with current source as an input source with a resonant capacitor connected in parallel with resonant inductor makes the constant current source for industrial heating applications.

III. REFERENCE POWER SUPPLY DESIGN

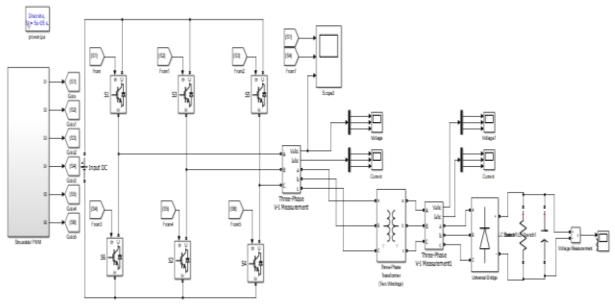

Figure.2. Reference design of the DC-DC converter for capacitor charge power supply

In the figure 2, the reference design of VSI based DC-DC converter has been presented for feeding the capacitor load in DC output. The design has been implemented in the MATLAB-SIMULINK using SIMPOWERSYSTEM toolbox. All the simulation has been done using the MATLAB R2013a. Here, the design has been implemented for 12V/ 16Ah as DC source. The power supply has been designed for the 30kV/ 15mA DC power supply. The switching frequency of 1 KHz has been used for the PWM generation. The 3-Phase VSI inverter has been implemented driven by the sinusoidal PWM pulses generated by the controller source. The 3-phase supply has been isolated using the 3-phase transformer that provides the necessary step up for the generated 3-phase voltage signals. The diode based bridge rectifier has been used for the rectification of the signal fetched by the transformer and thus, the capacitor load has been fed. The THD for the above design has been shown to be 15.6 %. And thus, it verifies the EMI has been present and harmonics has been generated in the power supply due to non-linearity of the conversion.

IV. PROPOSED DESIGN & METHODOLOGY

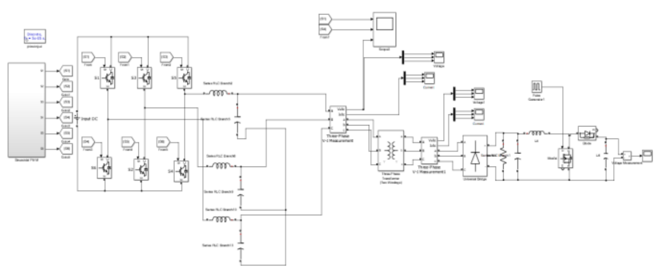

Figure. 3. Proposed design of the CCPS

The figure 3 shows the SIMULINK model of the proposed design. The design introduces the EMI Filter in the voltage signal generated from the VSI using sinusoidal PWM. Also, the output consists of the boost conversion stage. The proposed design has been shown to reduce the THD and EMI from 15.6% to 2.86%. Thus, total reduction of 80% has been shown using the EMI filter and boost converter stage. The model has been verified by the simulation analysis using the MATLAB-SIMULINK. The simulation results have been shown to verify the THD% and the interference in the VSI signal fetched to the 3-phase transformer.

V. SIMULATION PARAMETERS & RESULTS

EMI Filter:
L1 = 4.4mH
C1 = 6uF

The EMI Filter consists of the series inductor and shunt capacitor. Here, the series inductor of 4.4 mH is used and Capacitor of the 6uF has been used.

Power supply design:

Table.1. Design & Simulation parameters

SN	Parameters	Ratings/ Values
1	Battery Voltage	12V
2	Battery Capacity	16Ah
3	PWM Type	SPWM
4	Transfomer Power Rating	10KVA
5	Output Voltage	30KVA
6	Output Current	25mA
7	Load Capacitor	10uF
8	Load Resistance	100K
9	Diode PIV Rating	16kV
10	Transformer primary current	25A
11	Transfomer Seconday current	20mA

In the table 1, the design and simulation parameters have been presented. The various design parameters including battery source voltage, VSI design and transformer design has been presented.

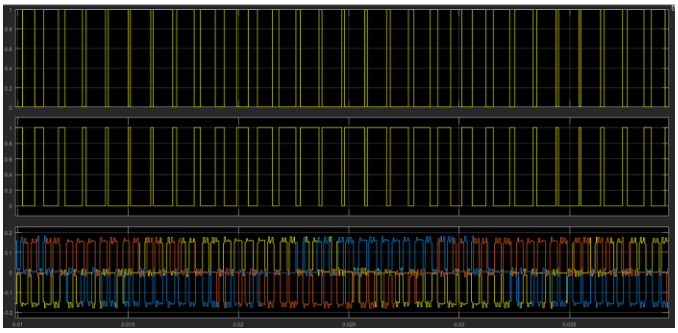

Figure.4. SPWM for VSI

In figure 4, the PWM wave of 1 KHz has been shown. The carrier wave has been generated and compared with the sine wave of 50Hz. Thus, the figure shows the SPWM wave generated for the production of the sine wave of 50Hz frequency.

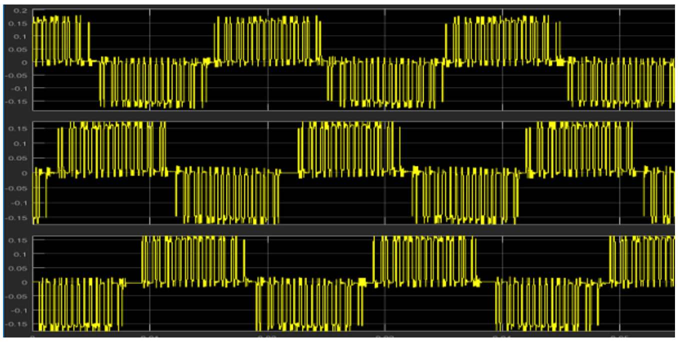

Figure.5. Output voltage signal generated by the VSI (3-phase)

In figure 5, the output waveform of the voltage generated from the VSI has been shown. Here, the 6 MOSFETs has been used in the h-bridge configuration and thus fed to the EMI filter. The output waveform shows the PWM generated sine wave signal for further processing.

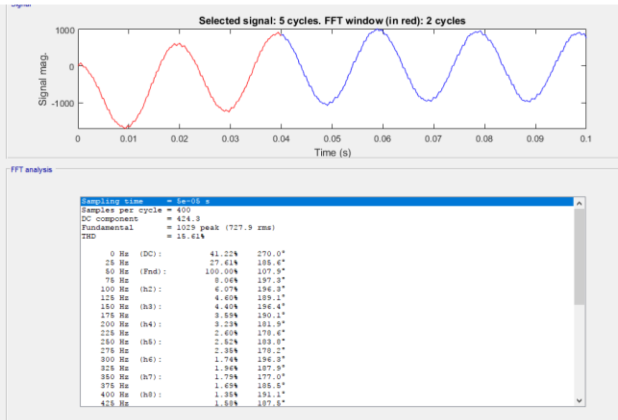

Figure.6. FFT Analysis of the design without EMI filters and Boost converter stage

In figure 6, the FFT analysis of the VSI output has been shown. Hence, the THD% has been analyzed using simpowersystem toolbox in MATLAB-SIMULINK. Here, after the analysis, if we do not use the EMI filter and the boost converter scheme, the THD has been found to be 15.61%.

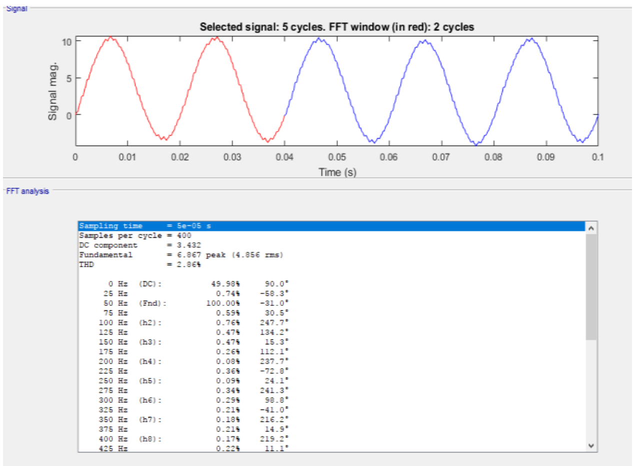

Figure.7. FFT Analysis of the proposed design with EMI filters and Boost converter stage

In figure 7, the FFT analysis of the VSI output has been shown when the EMI filter and boost converter has been introduced... Hence, the THD% has been analyzed using simpowersystem toolbox in MATLAB-SIMULINK. Here, after the analysis THD reduces to 2.86%. Thus, reduction of over 80% has been achieved.

VI. CONCLUSION

In this work, the power supply for capacitor charging has been proposed. The proposed design reduces the THD% and EMI generated within the circuit. The proposed scheme consists of the VSI fed by the SPWM and EMI filter have been introduced. The proposed design shows the reduction in the THD% and EMI of the overall power system. Thus, here the presented simulation results have been obtained by the MATLAB-SIMULINK and FFT analysis by the Simpowersystem toolbox in the SIMULINK. The results show the reduction in the THD from 15.6% to 2.86%.

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