

Fpga Based Power Factor Improvement Using Single Phase Matrix Converter

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Abstract: This project presents a new approach for converting three phase AC power to single phase using a simple circuit topology with bidirectional switches that are triggered by logically generated gating pulses. Power Factor of the system get improved by controlling the SPWM and IGBT switching control through FPGA control with help of XILINX system. The phase converter chosen in this work involves single stage power conversion principle and is capable of providing a variable voltage, variable frequency but constant v/f single phase output voltage from available three phase source using Matrix Converter (MC). The performance of the chosen phase converter is evaluated in MATLAB/SIMULINK environment for different types of load. This implementation of SPMC based phase converter is also carried out using low cost but powerful FPGA and the experimental results obtained are compared with those obtained through simulation. The significant application of this phase conversion technique is simplified feeder mechanism for electric locomotives.

Index terms: FPGA, Transformer, Rectifier, Regulator, Detector(XILINX Software).

I. Introduction

A single phase using a simple circuit topology with bidirectional switches that are triggered by logically generated gating pulses. The performance of the chosen phase converter is evaluated in MATLAB/SIMULINK split phase induction motor of load. This implementation of SPMC based phase converter is also carried out using low cost but powerful FPGA and the experimental results obtained are compared with those obtained through simulation. The results obtained validate the strategy developed. Power factor of this single phase matrix converter improved by controlling the ON and OFF time period of IGBT switches and controlling PWM switching period with help of FPGA and Xilinx 13.2 Software. In many instances, the single phase load is supplied by one phase of three phase service when single phase service is not available. Supplying high power density single phase load like electric traction becomes prohibitive due to occurrence of higher negative sequence currents in the power grid which causes over heating of all devices 2 connected to the grid.

Therefore three phase to single phase converters are excellent choice for situations where negative sequence currents are expected to be kept at minimum value. Hence TPSPC are used to energize the single phase feeder used for electric traction. The cost of TPSPC can be made economical as the cost of power semiconductor switches are decreasing and converter topologies with high device count are starting to draw more attention. The most important and valuable characteristic of these new topologies is that even under unbalanced and significantly disturbed input voltage waveforms, the output waveforms turn out to be reasonably clean and balanced.

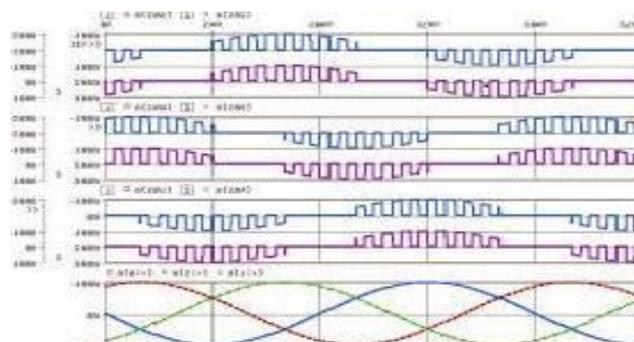


Fig1:On/Off Control strategy.

The essential information regarding the transfer characteristics of the proposed single stage TPSPC can be obtained by simulation using MATLAB/SIMULINK model developed for different types of load. The most common single phase inverter is the H .Bridge inverter. Since most loads contain inductance, feedback rectifiers or ant parallel diodes are often connected across each semiconductor switch to provide a path for the peak inductive load current when the semiconductor is turned off. Microcontroller is used to obtain the gate signal of the booster switch and to drive the inverter switches using SPWM. 8051 microcontroller is used to perform a single set of functions which provides high performance and reliability. MOSFETs are preferred in this work because it has applications with high frequency (<50Hz), zero voltage switch (ZVS) circuit (>200 KHz), wide line or load variations, low voltage applications (<250V) and lower output power (<500W).

II. Proposed Block Diagram

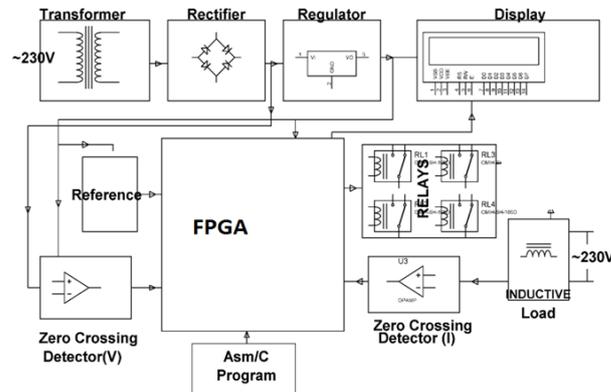


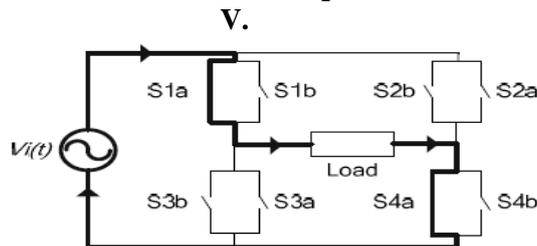
Fig2: Power Factor Correction using FPGA.

The phase converter chosen in this work involves single stage power conversion principle and is capable of providing a variable voltage, variable frequency but constant v/f single phase output voltage from available three phase source using Matrix Converter (MC). The proposed circuit topology is capable of operating a single phase AC motor under constant v/f mode eliminating the occurrence of negative sequence currents in the power system network as it tends to create balanced loading of all three phases.

III. Technical Description

The mathematical model of the proposed converter , which is supplied by a three-phase ac source and the phase voltages are denoted as v_{an} , v_{bn} , and v_{cn} , respectively. A three-phase to single-phase matrix converter, which composes of three boost inductors (L_a , L_b , and L_c) and six bidirectional switches (S_{a1} , S_{b1} , S_{c1} , S_{a2} , S_{b2} , and S_{c2}), inserts between the ac source and a conventional N/2-stage CWVM circuit, where N is an even integer. Two anti-series Insulated Gate Bipolar Transistors (IGBTs) form one bidirectional switch as shown in the left-bottom part in Fig. 2. The six bidirectional switches are divided into two parts, the upper part (S_{a1} , S_{b1} and S_{c1}) and the bottom part (S_{a2} , S_{b2} , and S_{c2}). According to the first subscripts of the switches, the left terminals of the switches connect to the relative ac sources through three boost inductors. The three right terminals of the upper-part switches connect to upper terminal D of the CWVM, while the three right terminals of the bottom-part switches connect to the bottom terminal E of the CWVM. For simplicity, the derivation of the mathematical model is divided into two parts, the ac-side part and the CWVM, which are separated by the terminals D and E.

IV. Modes Of Operation



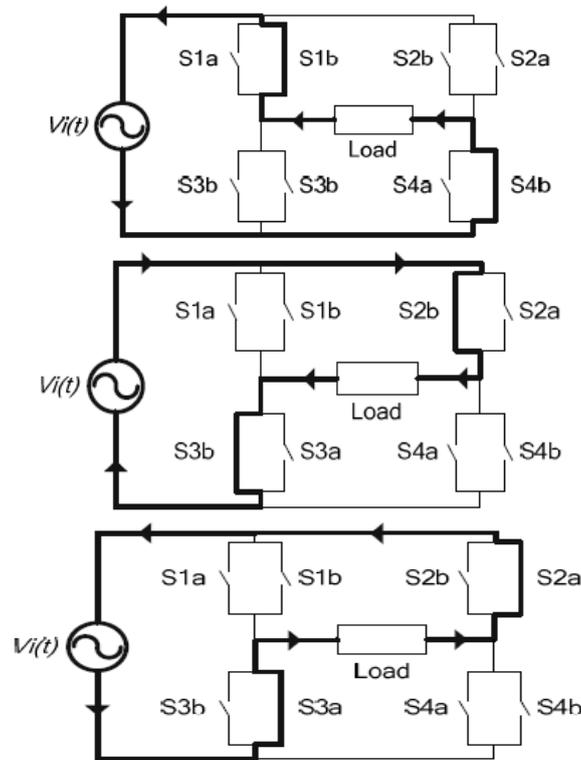


Fig3: Modes of operation Matrix converter.

A. Software Analysis:

Simulation has become a very powerful tool for industrial application as well as in academics, nowadays. It is now essential for an electrical engineer to understand the concept of simulation to study the system or circuit behaviour without damaging it. The tools for doing the simulation in various fields are available in the market for engineering professionals. Many industries are spending a considerable amount of time and money in doing simulation before manufacturing their product. In most of the research and development (R&D) work, the simulation plays a very important role. Without simulation it is quite impossible to proceed further. It should be noted that in power electronics, computer simulation and a proof of concept hardware prototype in the laboratory are complimentary to each other. However computer simulation must not be considered as a substitute for hardware prototype. The objective of this chapter is to describe simulation of impedance source inverter with R, R-L and RLE loads using MATLAB tool.

B. Role of Simulation

Electrical power systems are combinations of electrical circuits and electro mechanical devices like motors and generators. Engineers working in this discipline are constantly improving the performance of the systems. Requirements for drastically increased efficiency have forced power system designers to use power electronic devices and sophisticated control system concepts that tax traditional analysis tools and techniques. Further complicating the analyst's role is the fact that the system is often so nonlinear that the only way to understand it is through simulation. Land-based power generation from hydroelectric, steam, or other devices is not the only use of power systems. A common attribute of these systems is their use of power electronics and control systems to achieve their performance objectives.

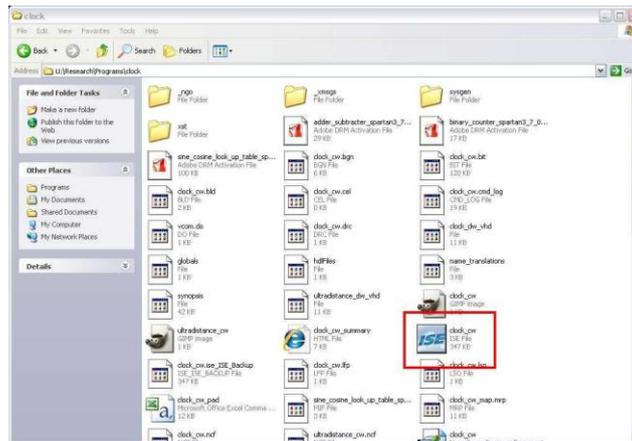


Fig4: XILINX ISE 13.2 document.

Once the file is open, only thing that needs to be done is to assign the pins to the output ports on the FPGA board. So click to expand (+) the user constraints in the processes window and double click on create area constraints. This will start to assemble the program, but will ask to add a UCF file halfway through implementing the design. After clicking yes, the PACE window will open as follows.

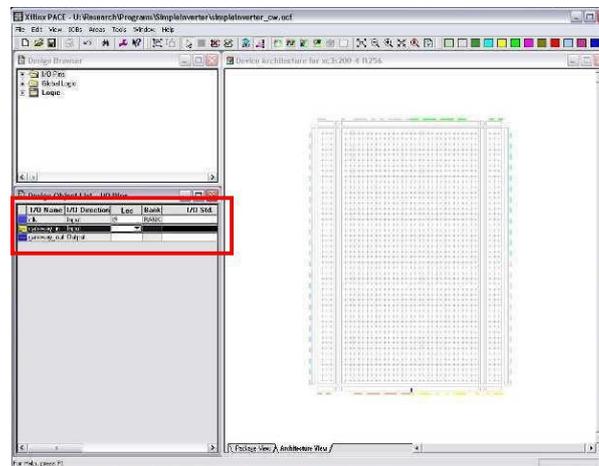


Fig5: Design of FPGA.

In this window, all the pins from the Simulink gateways show up as I/O pins. To route them out of the board, all that needs to be done is type in the I/O pin number (the pins numbers can be found written on the board for switches and LED's and in the users guide pg 49-51 for the I/O connectors). Set the input pin to K13 and the output to K12.

From this point, the project is complete and ready to be assembled and implemented as a normal Xilinx program. 34

To do this expand „Generate Programming File“ under the Processes tab and double click on „Configure Device (impact).“ Click FINISH on the pop-up „Welcome to IMPACT.“ Two Xilinx icons appear on the screen along with the „Assign New Configuration File“ pop-up..For the next pop-up just cancel. Now highlight the first Xilinx icon and right click and Program. This should download your program to the Xilinx board. Demonstration the operation of your program with SW7 and LD0.

VI. Simulation

A) Design of Compensator

The performance of the proposed control methods was evaluated first using a detailed simulation model representing the Three-phase to single MC, and additional blocks to simulate the control system using MATLAB/ Simulink SimPowerSystems tool-ox. MC semiconductors were simulated as SimPowerSystem switches with appropriate snubbers. The Single phase Matrix PFC converter is designed with the following specifications: ac input voltage range from 400V to 440V, output voltage equal to 200 to 230V, output power up to 650W, line frequency (f) equal to 60 Hz, switching frequency (f_s) equal to 130kHz. The CCM current

compensator is designed in MATLAB SISO tool to achieve the desired response characteristics, and the designed continuous-time transfer function of the average current compensator is given by The current compensator is implemented using the Xilinx block set, the compensator is designed based on the direct form-2 structure of transfer function (4) as shown in below.

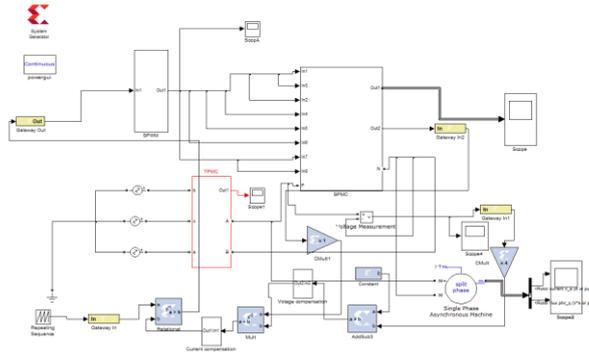


Fig6: Proposed TPSPM with FPGA Control.

B).Three phase Converter Input Waveform:

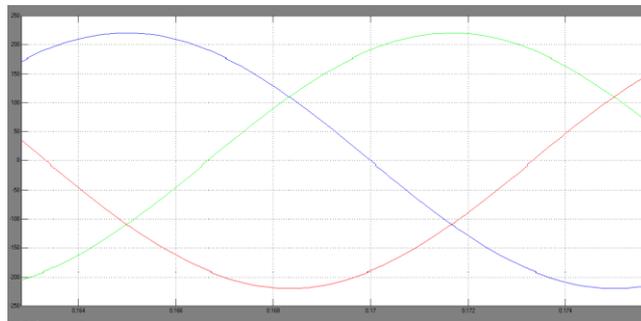


Fig7: Three phase input Voltage.

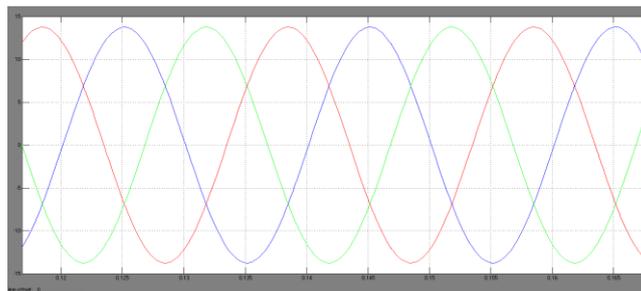


Fig8:Three phase input current.

C) Matrix converter Output Waveform:

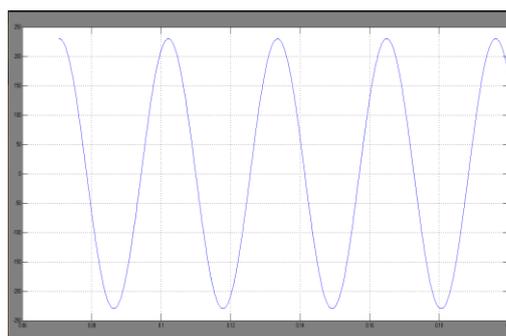


Fig9:Sinusoidal Output Waveform.

Output Values:

Referrence Values	Carrier values	Current	Voltage	Power Factor
10	10	116.5	6.613X10 ⁴	0.9
2	1	381.1	0.3359	1
5	1	381.1	0.03377	1

VII. Conclusion

A FPGA system used to improve power factor and also give the sinusoidal output waveform by controlling the SPWM and IGBT switching control with help of XILINX SYSTEM. This work also facilitates to monitor the power factor changes in system.. The system control strategy is fully developed and all the simulation results are presented. Because of the decrease in the switching time, the rating of switches decreases in converter circuit of proposed configuration which may helps in reducing cost of the system. Simulations of digital controller for TPSPMC PFC converter have been done on the platform of MATLAB Simulink environment and Xilinx System generator. Both voltage and current compensators have been generated from Xilinx System generator to control PFC converter. The FPGA based digital controller can be synthesis using Xilinx ISE design tools resulted in the above simulation results for as target FPGA.

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