A Review of Pioneer Fiction Realization of Embedded Core FPGA Based Control of Single Phase to Three Phase SVPWM Converter for Electrical Drives

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Abstract

This review focuses on state-of-art in Pioneer Fiction Realization of real-time digital feedback control of single phase to three phases Converter (SPTTPC) for electrical drives. This SPTTPC has consist of an single phase alternative current source is connected to controlled single leg rectifier unit, and the output of rectifier unit is fed into controlled two leg inverter unit, in addition the capacitor bank is clamped between rectifier unit and inverter unit, the capacitor bank is manage the neutral -point of SPTTPC. Finally the inverter output is fed into electrical drives. SPTTPC unit is build up by gate controlled solid state devices, which gate pulses are generated by SVPWM technique through embedded core field programmable gate array (FPGA)-Xilin sparton behind that migrate with very high speed integrated circuit hardware description language (VHDL). Intension of this survey is to develop for the fully automated integrated circuit (IC) for electrical drive system based on VLSI technologies in addition predictable to comprehensive review of converter for electrical drives, control methodologies, various converter topologies and selection of component ratings, cost, real time application also providing a broad perspective on the status of electrical drives.

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1. Introduction

The Electrical Drives are universally bringing into play the workhorse of the motion of the electrical world due to they are most widely used in domestic and industry. They are flexible, trouble-free, economical, robust and available in all power ratings however the electrical drives are not met the electrical requirement for domestic as well as industry application. Most of the applications are required variable speed, constant speed motor. The role of the electrical drive is to control the speed of the motor as per the requirement in the application. The speed control of alternating current motor is fully depends on switching of the solid state devices [1, 2]. Because to the progress in the field of solid state switching field i.e. power employ with three legs (six-switch three-phase voltage source inverter or SSTPI), with a pair of balancing power switches each phase. A reduced switch voltage source inverter are rectifier unit single arm and inverter unit two arm (SPTTPC) [12,13].

The numerous survey report on four switch three phase inverter (FSTPI) structure is available. The proposal Pioneer Fiction Realization of Embedded Core FPGA [6] Based Control of Single Phase to Three Phase SVPWM Converter for Electrical Drives is based on FSTPI technique. The advantages of SPTTPC is the reduced economical factor of the inverter, lesser switching losses, lower EMI and less complexity of the control algorithms and interface circuits to generate SVPWM logic signals. This approaches use SVPWM strategies based on the concept of voltage space vectors that are capable to produce high fundamental output current with low harmonic distortion. The learning capability characterizing such control algorithms enables the use of. The pioneer embedded core FPGA sparton-6 controller combines the predictive SVPWM current control strategy with VLSI technology based control approach. The controller design is performed using VHDL [19] so that a versatile reusable design module (a Digital controller core) is obtained. This manuscript deals with seven parts based on single phase to three phase converter for electrical drives. Starting with an introduction, the subsequent sections cover the state of the art of the inverter and rectifier part, the different configurations, the control methodologies, harmonic analysis, fault diagnosing the economic and technical considerations, and the concluding remarks. Xilinx sparton-6 field programmable gate arrays (FPGA) are standard integrated circuits that can be programmed by a user to perform a variety of complex logic functions. The high levels of integration available with large number of logic devices are available, that can be used to implement complex electronic systems [20]. This survey presents Xilinx FPGA based SVPWM control of SPTTPC fed electrical drive. Xilinx software ISE 9.2i is used to generate controlled SVPWM pulses by using VHDL programs. The final design is a Field-Programmable Gate Array (FPGA), a type of logic chip that can be programmed and implemented to drive the system.

2. State of the Art

The converter technology has been developed at a reasonably full-grown level for single phase to three phase conversion with reduced harmonic currents, high power factor, low electromagnetic interference (EMI) and radio frequency interference (RFI) at source ac mains and well-regulated [14] good quality dc output to feed loads ranging from fraction of Watt to several hundred kilowatts power ratings in large number of applications. It has been revolutionized in the last couple of decade with varying configurations, control approaches, solid-state devices, circuit integration, varying magnetic, etc., Hardware implementation of electrical drives control and drive systems is an important issue in industrial and domestic applications. Nowadays FPGA technology received much attention by industrial researchers for designing and implementing high-performance ASIC digital controller with out-and-out structural design for induction motor control. Unlike traditional solutions based on microprocessors and digital signal processing (DSP) devices, the FPGAs introduce hardware parallelism by breaking the paradigm of sequential execution. A field programmable gate array is a set of digital logic gates and configurable logic
blocks which can be reprogrammed to meet the desired motor-control features [1, 6, 11]. While the assembly and high level languages like C are used by microcontrollers and DSPs, the technology independent hardware description languages including VHDL [19] and Verilog are used to program FPGAs. The digital FPGA-based solutions have been successfully employed for motor control applications [20]. The primary contribution of this survey is to design and implement a FPGA-based digital controller for three phase induction motor drives.

3. Analysis of PWM Technique

This analysis evaluates the state of the art in pulse width modulation [9] for ac drives fed from three-phase voltage source inverters. Feed forward and feedback pulse width modulation schemes having relevance for industrial application are described and their respective merits and shortcomings are explained. Secondary effects such as the influence of load current dependent switching time delay and transients in synchronized pulse width modulation schemes are discussed, and adequate compensation methods are presented in Table-1.

Table 1: Comparison of Different Modulation Techniques

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Modulation Technique</th>
<th>Narrow Pulses</th>
<th>Voltage Impedance</th>
<th>Losses</th>
<th>Hardware Complexity</th>
<th>DC Bus Utilization</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Multiple carrier method</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>No</td>
<td>Medium</td>
<td>Drives</td>
</tr>
<tr>
<td>2</td>
<td>Bipolar Modulation</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>No</td>
<td>Medium</td>
<td>Drives</td>
</tr>
<tr>
<td>3</td>
<td>Carrier phase variation</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>No</td>
<td>Medium</td>
<td>Drives</td>
</tr>
<tr>
<td>4</td>
<td>SVPWM Algorithm</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>No</td>
<td>Higher</td>
<td>Drives</td>
</tr>
<tr>
<td>5</td>
<td>Hysteresis control</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Higher</td>
<td>Higher</td>
<td>Drives</td>
</tr>
<tr>
<td>6</td>
<td>Soft switching Algorithms</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Higher</td>
<td>Drives</td>
</tr>
</tbody>
</table>
The survey provides a guideline and quick reference for the practicing engineer to decide which methods should be considered for an application of a given power level, switching frequency, and dynamic response. The survey has presented the space vector approach to the study of both stationary and synchronous current controllers. Even if each solution is worth a deeper analysis, here the main stress has been given to the method, rather than on the details of the schemes. Conventional regulators that have been selected as an example for effective and simple technique that deserves larger attention by the electric drive designers. Indeed, some of the new control schemes proposed in this survey have been directly prompted by the space vector approach [14] itself. The next research challenge will be the systematic study of Input - Output loop decoupling and antiwind-up action by the proposed space vector approach [10]. According to the scheme of switching status is represented by binary variables S1 to S4, which are set to “1” when the switch is closed and “0” when it is open. In addition, the switches in one leg of an inverter are controlled complementary, therefore S1+S2 = 1; S3+S4 = 1; Phase to common point voltage depends on the turning off signal for the switch.

\[ V_{ao} = (2S1 - 1) \cdot \left( \frac{V_{dc}}{2} \right); \quad V_{bo} = (2S3 - 1) \cdot \left( \frac{V_{dc}}{2} \right); \quad V_{co} = 0; \]

A combination of switching S1-S4 results in four general space vectors V1 to V4

\[ \bar{V}_1 = \left( \frac{V_{dc}}{3} \right) e^{j2\pi/3} \]

\[ \bar{V}_2 = \left( \frac{V_{dc}}{3} \sqrt{3} \right) e^{j\pi/6} \]

\[ \bar{V}_3 = \left( \frac{V_{dc}}{3} \right) e^{j\pi/3} \]

\[ \bar{V}_4 = \left( \frac{V_{dc}}{3} \right) e^{j5\pi/6} \]

\( \alpha \beta \) component of the voltage vectors are gained from a, b and c voltages by using Clark’s transformation

\[
\begin{bmatrix}
V_a \\
V_b \\
V_c
\end{bmatrix} = \frac{2}{3} \begin{bmatrix}
1 & -1/2 & -1/2 \\
0 & \sqrt{3} & 0 \\
-1/2 & -1/2 & \sqrt{3}
\end{bmatrix}
\begin{bmatrix}
V_a \\
V_b \\
V_c
\end{bmatrix}
\]

Where V_a, V_b, V_c phase voltages on the load (Y connection), defined by

\[ V_a = \frac{1}{3} \left( 2V_{ao} - V_{bo} \right); \quad V_b = \frac{1}{3} \left( 2V_{bo} - V_{ao} \right); \quad V_c = \frac{1}{3} \left( V_{ao} + V_{bo} \right) \]
In order to form the required voltage space vector $V_{ref}$, 3 or 4 vectors in one sampling interval $T_s$ are considered. The Constant value 0 (zero) vectors can be formed by dividing $t_0$ (duration of zero vector) [7] among two opposite vectors $V_1$, $V_3$ or $V_2$, $V_4$.

Fig. 1. (a) Four switch inverter; (b). Current Distortion vector; (c). Conventional SVPWM methods

the fig.1.(a) and (b) represented the four switch inverter [3] model and corresponding phase vector Current Distortion vector, similarly the fig.1.(c) represented the conventional SVPWM methods and fig.2.(a) represented the Space Vectors in Six Switch Inverter and fig.2.(b) proposed Space Vectors for Four Switch Inverter.

4. The Different Configuration of Converter Topology

This survey proposes the different configuration of rectifier with inverter (converter) circuit based on the switching activity of the solid state devices. The different configurations are uncontrolled two leg rectifier with three leg controlled inverter, controlled two leg rectifier with three leg controlled inverter, uncontrolled two leg rectifier with two leg controlled inverter, uncontrolled single leg rectifier with two leg controlled inverter and controlled single leg rectifier with two leg controlled inverter.

5. The Control Methodologies

The different digital control methodologies to analysis the control techniques for SPTTPC available are FPGA Control, PIC Microcontroller, FUZZY logic control and DSP based control etc.

5.1. Method-1

This method proposes the FPGA based control scheme of single-phase- to-three-phase space vector pulse width-modulation (SVPWM) converters for SPTTPC fed electrical drives. The novel Xilinx FPGA
is used to develop the SVPWM based control signals for the SPTTPC fed electrical drives. In this proposed experimental work, Xilinx FPGA program is used to generate the controlled PWM pulses for SPTTPC to drive the 3-phase Electrical drives. The complete XILINX FPGA [1, 2.11, 20] based SPTTPC fed electrical drive is implemented in real-time using SPARTAN-3 processor for a 3-phase electrical drives.

5.2. Method-2

This method proposes the DSP based control scheme [21] of single-phase- to-three-phase space vector pulse width-modulation (PWM) converters for SPTTPC fed electrical drives, where a single-phase single Arm rectifier and a two-Arm inverter are used. With this converter topology, the number of switching devices is reduced to six from ten in the case of full-bridge rectifier and three-leg inverter systems. In addition, the source voltage sensor is eliminated with a state observer, which controls the deviation between the model current and the system current to be zero. Although the converter topology itself is of lower cost than the conventional one, it retains the same functions such as sinusoidal input current, unity power factor, dc-link voltage control, bidirectional power flow, and variable-voltage and variable-frequency output voltage. The experimental results for the V/f control of electrical drives controlled by a digital signal processor TMS320C31 chip have verified the effectiveness of the proposed scheme.

5.3. Method-3

This method proposes the PIC microcontroller based control scheme [3] of single-phase- to-three-phase space vector pulse width-modulation (PWM) for SPTTPC fed electrical drives, where a single-phase single Arm rectifier and a two-Arm inverter are used. The advantage of this inverter that uses of 4 switches instead of conventional 6 switches which results in lesser switching losses, lower electromagnetic interference (EMI), less complexity of control algorithms and reduced interface circuits. PIC microcontroller is used to generate the SVPWM pulses for SPTTPC to drive the low power electrical drives.

5.4. Method-4

This method proposes the neural network based control scheme [18] of single-phase- to-three-phase space vector pulse width-modulation (PWM) converters for SPTTPC fed electrical drives, where a single-phase single Arm rectifier and a two-Arm inverter are used. With this converter topology, the number of switching devices is reduced to six from ten in the case of full-bridge rectifier and three-leg inverter systems. A simple scalar voltage modulation method is used for a two-leg inverter, and a new technique to eliminate the effect of the dc-link voltage ripple on the inverter output current is proposed.

5.5. Method-5

This method proposes the fuzzy logic based control scheme [11, 15] for SPTTPC fed electrical drives. In this method, PI controller is used to monitor the performance of the drive. It is based on three selected PI controllers in fixed sampling time intervals, high, medium and low-speed, and combined by simplified fuzzy logic. The experimental results are provided to show this controller is efficient and workable.
5.6. Method-6

This method proposes the FPGA with DSP scheme for SPTTPC [21] fed electrical drives. The advantage of this method is to reduce high switching loss, high stress, electromagnetic interference and total harmonic distortion. The performance of the drive is controlled by DSP controller itself.

5.7. Method-7

This new method presents the FPGA based deadbeat control scheme [20] for SPTTPC fed electrical drives. The switching pulse generated for solid state device circuits to write assembly languages. This method is a common and complex method as the hardware development for this method is complex.

6. Harmonic Analysis

A novel concept of application of power electronics networks for generating the optimum switching functions for the voltage and harmonic [5] control of converter is presented. In many research, the network is trained off line using the desired switching angles given by the classic harmonic elimination [16, 17] strategy to any value of the modulation index. This limits the utilisability and the precision in other modulation index values. In order to avoid this problem, a new algorithm is developed without using the desired switching angles but it uses the desired solution of the elimination harmonic equation.

7. Fault Diagnosis

This analysis presents a fault diagnostics for electrical drives. A normal model and an extensive range of faulted models for the inverter-motor combination were developed and implemented using a generic commercial simulation tool to generate voltages and current signals at a broad range of operating points selected by a machine learning algorithm. A structured power electronics network system has been designed, developed and trained to detect and isolate the most common types of faults single switch open circuit fault [17], short circuits fault and gate misfiring fault. Extensive simulation experiments were conducted to test the system with added noise, and the results show that the structured neural network system which was trained by using the proposed machine learning approach gives high accuracy in detecting whether a faulty condition has occurred, thus isolating and pin-pointing to the type of faulty conditions occurring in power electronics inverter based electrical drives.

These analyses have presented an intelligent system based diagnostic approach for the detection and isolation of a broad range of faults in electric drive inverters in closed-loop systems. A model of the electric drive inverter with a three-phase electrical drives and a control mechanism was developed that successfully simulates the normal operations of the power electronics inverter, six single switch open fault conditions, three post-short-circuit conditions, and six short circuit conditions under closed loop field oriented control. Three important sets of signals, namely torque, voltages and currents in different phases were used for the fault diagnostics. These signals were segmented simultaneously and diagnostic features were extracted from signal segments. Three neural networks were developed under the framework for the detection and isolation of single switch open faults, post-short circuit faults, and short circuit faults. The accuracy of the diagnostic results has reached more than 99% in average.

This survey presented a structured power electronics network system that is trained to detect and isolate any of the 15 faults in a three-phase electrical drives in real-time [8]. The system performance is evaluated on the basis of time elapsed to detect a fault after it occurs. The simulation results show that the
proposed system takes less than 20 ms on an average to successfully detect and isolate a fault. In conclusion it can be said that the proposed model-based fault diagnostic approach combined with machine learning techniques is effective in reliably detecting and isolating faults occurring in power electronics inverter based electric drives in real-time.

8. Conclusion

This survey has reviewed past, present and future trends with respect to electrical drive economics, architecture, control schemes, performance, power device, and power topology aspects pertinent to the industrial and domestic purposes. Its support to develop the fully digitalized embedded core FPGA, computation time allows obtaining much higher throughput and overcoming the typical bottleneck of FPGA sequential algorithms mentioned at the beginning. Applying FPGA for SPTTPC control seems to be an interesting alternative for the other control method. This is also assist to reduce the high switching loss, high stress, electromagnetic interference and total harmonic distortion of power switching devices.

References


