

Three-Phase Three-Switch Two-Level Unidirectional PWM Rectifier Using Artificial Neural Networks

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Abstract:

This work presents a methodology to apply space vector modulation to a three-phase three-switch two-level Y-connected unidirectional pulse width modulation (PWM) rectifier. Converter switching stages are analyzed to determine switch control signals for space vector modulation. A switching sequence is proposed in order to minimize the number of switch commutations and to reduce the switching losses. PWM rectifiers have been implemented in many applications like vector controlled drives for control of induction motors, traction, interface for renewable energy sources etc., PWM rectifiers are also used in distributed power generation applications such as micro turbines, fuel cells and wind mills. Conventional PWM converters are used for wind turbines that have a permanent Magnet alternator. The three phase current controlled voltage source boost type PWM rectifier is commonly used due to following advantages. Low total harmonic distortion of the input current, Regulation of output DC voltage, Bidirectional power flow. The major advantages of using the pulse width modulation technique is the reduction of higher order harmonic. It also makes it possible to control the magnitude of the output voltage and improve the power factor by forcing the switches to follow the input voltage waveform. Artificial neural networks is used for pulse width control.

Index Terms: Rectifier, ANN, PWM

INTRODUCTION:

When bidirectional power flux is not necessary, high power factor unidirectional rectifiers present some advantages as the decrease of the number of power

switches, natural protection of short-through and smaller processing of energy for the active switches. If output voltage is not so high, two-level topologies become attractive because they do not need to control midpoint voltage of the dc bus, reducing the number of sensors and controllers. In this work, space vector modulation will be applied to a three-phase three-switch two-level Y-connected unidirectional pulse width modulation (PWM) rectifier in order to minimize the number of switch commutations as well as reduce converter losses. This structure presents as main drawback a high number of semiconductors when compared with other topologies. Other characteristics of this topology are presented in further chapters [1].

The proposed application methodology of this modulation technique is based on sub-sectors definition, on rectifier operation stages analysis and on duty cycles determination. Therefore, it is not necessary to identify the present vector sector, just impose adequate current sector in phase with line voltages. Chapter 2 presents the main characteristics of a two-level unidirectional PWM rectifier and in Chapter 3 the basic steps are described in order to apply space vector modulation to this converter. Vector control concepts used with the proposed modulation techniques are shown in Chapter 5. Chapter 9 conclusions and analysis results are discussed [2].

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THREE-PHASE THREE-SWITCH TWO-LEVEL UNIDIRECTIONAL PWM RECTIFIER:

The three-phase three-switch two-level Y-connected unidirectional PWM rectifier, showed in Fig. 1, presents high power factor and output voltage regulation. Eight topological stages may be performed from switches states, according to Table I [3]. This structure presents six symmetrical operation intervals , where six current sectors are defined in one line period: A+, B- , C+, A-, B+ and C-, as shown in Fig.2.

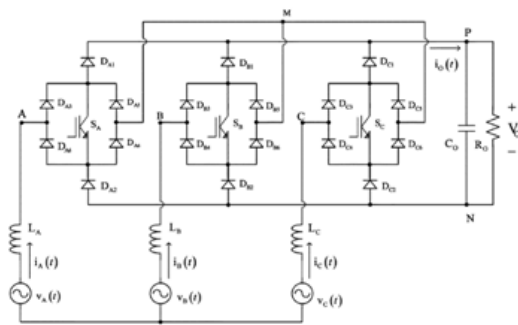


Fig. 1. Three-phase three-switch two-level unidirectional PWM rectifier.

TABLE I
SWITCHING STAGES

	Switch A	Switch B	Switch C
Stage 1	On	On	On
Stage 2	On	On	Off
Stage 3	On	Off	On
Stage 4	On	Off	Off
Stage 5	Off	Off	On
Stage 6	Off	On	On
Stage 7	Off	On	Off
Stage 8	Off	Off	Off

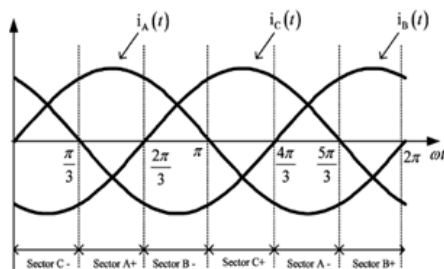


Fig. 2. Current sectors.

Each sector has an interval of 60 and it is defined by the current that has the greater value and its respective signal.

Specific sector analysis, described below for sector A+, can be extended for each other sectors considering the adaptation of the direction of input currents. In sector A+,(where phase A current is positive with higher value) five equivalent topological stages are verified in stages 4, 5, 6, 7 and 8 of Table I. When current is flowing from one phase to another, without circulate in the load, two switches must be turned on and in order to obtain null line voltages all three switches should be turned on [4].

SPACE VECTOR MODULATION:

From the analysis of structure showed in Fig. 1, seven available vectors are defined as shown in Table II. Non null vectors are represented by the potential of points A, B, and C, and the

TABLE II
AVAILABLE VECTORS

Vector	Point A	Point B	Point C	V _{AB}	V _{BC}	V _{CA}
\vec{V}_0 (0 0 0)	M	M	M	0	0	0
\vec{V}_1 (1 0 0)	P	N	N	+V _O	0	-V _O
\vec{V}_2 (1 1 0)	P	P	N	0	+V _O	-V _O
\vec{V}_3 (0 1 0)	N	P	N	-V _O	+V _O	0
\vec{V}_4 (0 1 1)	N	P	P	-V _O	0	+V _O
\vec{V}_5 (0 0 1)	N	N	P	0	-V _O	+V _O
\vec{V}_6 (1 0 1)	P	N	P	+V _O	-V _O	0

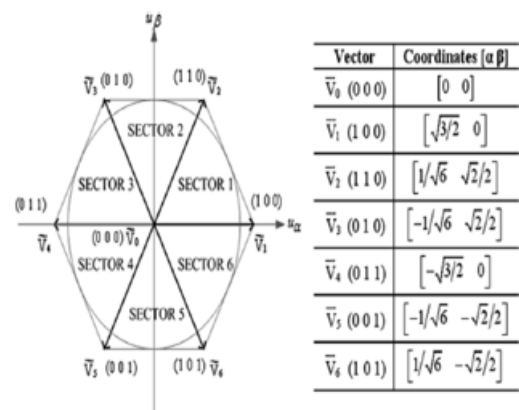


Fig. 3. Space vector coordinates.

Null vector represents the situation where the three points are connected. In this notation, used for unidirectional converters, the available vectors representation does not agree with the switching states because the potentials of points A, B and C depend on

the input currents direction. By the application of Clark transformation (1) space vector representation is made with a regular

Vector Control:

Vector control structure is shown in Fig.5.1. In the control system, input currents are sampled, Clark and Park transformations are applied to these variables and dq0 currents are obtained. For a system with high power factor, the q axis current must be zero. Therefore, the reference for the controller of this current is also zero and the reference for d axis current comes from the voltage controller. The outputs of current controllers are the duty cycles for d-axis and for q-axis. These duty cycles are decoupled and inverse Park transformation is applied to these variables. The duty cycles for α axis and for β axis are the result of this transformation, and these signals are used in space vector modulation. In digital control of the PWM rectifier, the TMS320LF2407A DSP is used. For current loops, the sample rate is the switching frequency and for voltage loop, the sample rate is the line frequency.

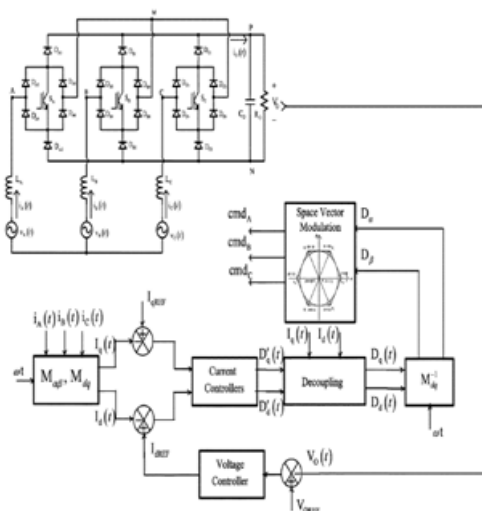
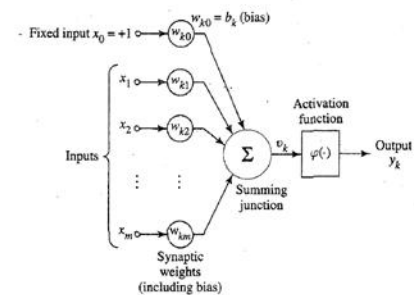


Fig.5.1 . Vector Control Structure

ARTIFICIAL NEURAL NETWORKS:

Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experiences.

It is natural proof that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modeling also promises a less technical way to develop machine solutions. These biologically inspired methods of computing are thought to be the next major advancement in the computing industry. Even simple animal brains are capable of functions that are currently impossible for computers. Computers do rote things well, like keeping ledgers or performing complex math. But computers have trouble recognizing even simple patterns much less generalizing those patterns of the past into action of the future.



Artificial Neural Networks.

SIMULINK DIAGRAMS

7.1.SIMULATION MODEL AND DISCUSSION

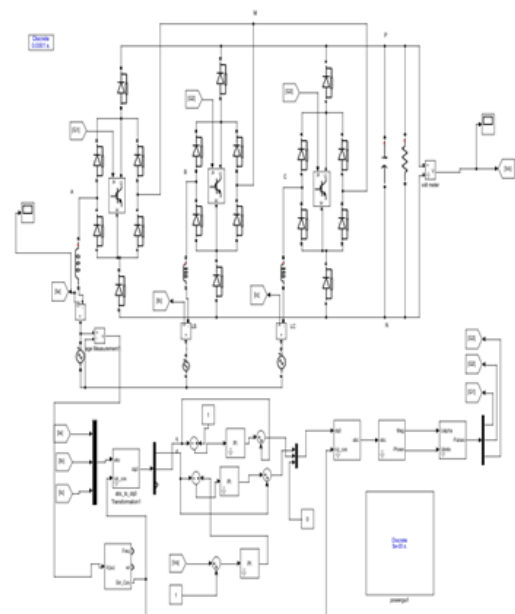


Fig 7.1: Simulation Model of Three-phase Three-switch Two-level Unidirection PWM Rectifier

Three-Phase Three-Switch Two-level Unidirection PWM Rectifier:

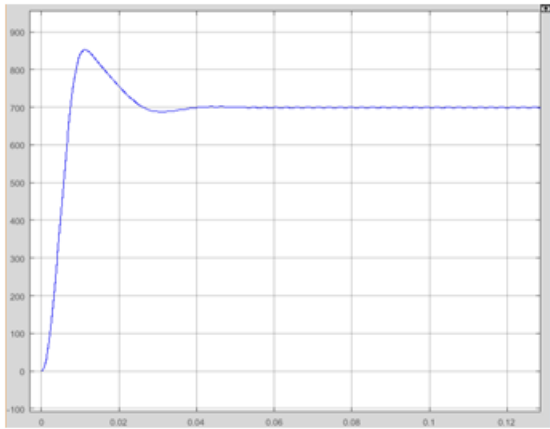
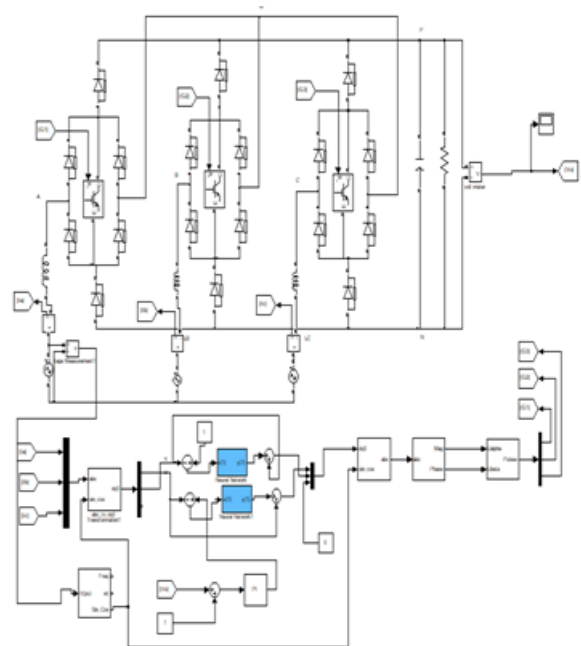


Fig.8.1.1: Output DC Voltage of Three-Phase Three-Switch Two-level Unidirection PWM Rectifier



Simulation Model of Three-phase Three-switch Two-level Unidirection PWM Rectifier using ANN

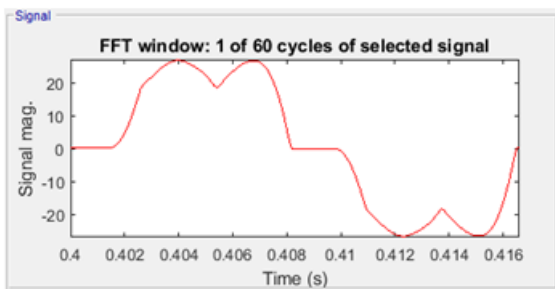


Fig.8.1.2: 1 of 60 cycles of selected input signal.

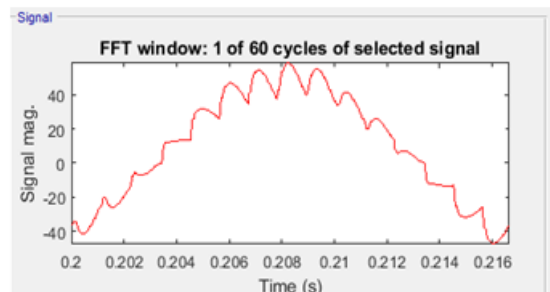


Fig.8.4.2: 1 of 60 cycles of selected input signal

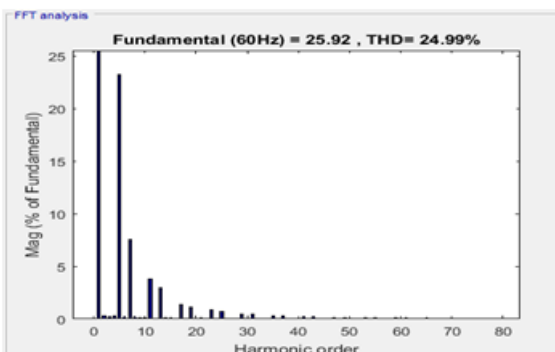


Fig.8.1.3: FFT Analysis for the selected input signal . The THD for the signal with frequency of 60Hz is 24.99%.

Conclusion:

With the help of this model, we can get the pure DC Output with reduced number of power switches and also it acts like a converter with some changes in control strategy. Unidirectional two-level PWM Rectifier presents regulated output voltage, high efficiency, high power factor, and low input current THD. From the above table we come to know that the multi-pulse Rectifier with less number of switches have the more THD in the input current and vice versa., Comparing to these topologies the PWM Rectifier gives the pure DC output and low THD in input current with less switches, where as with

increase in the number of switches the dc output will look like pulsating but the pulses for 1-cycle increases gradually. (ie.,6,12) and the THD in the input current decreases. Compared with the 12-pulse rectifier we get the THD in the input current nearer value for the model ie., we get the same THD in input current for only 3 switches and Pure DC output. Hence, we can replace the multi-pulse Rectifiers with the Two-level PWM rectifiers to have more efficiency, regulated output voltage, and low THD in input currents. With Artificial neural networks the THD is improved at the source end.

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