A COMPARATIVE STUDY & DESIGN OF PWM RECTIFIER USING DIFFERENT CONTROL SCHEMES

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Abstract: - To solve the problem of harmonic pollution to the power grid that caused by traditional diode rectifier and phase controlled rectifier, the unit power factor PWM rectifier is designed. This paper presents the modeling, simulation and analysis of an AC-DC converter based PWM rectifier. It provides a suitable control algorithm for a pulse width modulation rectifier which reduces ripple from the DC voltage at output side as well as shapes the input current as sinusoidal as possible. The basic objective of a PWM rectifier is to regulate the DC output voltage and also ensure a sinusoidal input current and unity power factor operation. This is implemented by high speed IGBT / MOSFET switches connected in VSI topology. The output voltage is controlled by switching these IGBTs / MOSFETs and higher order ripples at the output can be easily eliminated with the help of passive filters. Lower order harmonics are eliminated using PWM technique. The control subsystem generates gating pulse to the VSI converter by passing the output voltage and input currents through a network consisting of comparator, discrete PI controller and discrete PWM generator. The outputs of this generator are the gating pulses to be applied to the PWM rectifier. By this control method, we have tried to reduce the input current harmonic distortion and bring the input current and voltage in same phase as well as make it sinusoidal. The control of modulation index (m) and phi has been shown in the closed loop system. The influence of the discussed modulation methods on the line current distortion and the switching frequency has been examined. The simulation results of the presented techniques have been demonstrated and concluded for various load.

Keywords: - PWM, Rectifier, IGBT/MOSFET,Matlab-Simulink etc.

1. INTRODUCTION

The AC-DC conversion is used increasingly in a wide diversity of applications: power supply for microelectronics, household-electric appliances, electronic ballast, battery charging, DC-motor drives, power conversion, etc.

The rectifiers take a number of forms, including vacuum tube diodes, wet chemical cells, mercury-arc valves, stacks of copper and selenium oxide plates, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motors have been used. Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal of galena (lead sulphide) to serve as a point-contact rectifier or "crystal detector". AC-DC converters can be classified between topologies working with low switching frequency (line commutated) and other circuits which operate with high switching frequency. For AC-DC conversion we have three types of switches available, uncontrolled switches (Diodes), semi-controlled switches (SCR / Thyristors) and, fully controlled switches (IGBTs / MOSFETs). Harmonics are present in uncontrolled and semi-controlled AC-DC converters, they are called conventional rectifiers. Other disadvantages of conventional rectifiers are non-sinusoidal AC current, poor power factor and ripple in output DC voltage.

Conversion of three phase AC to DC by means of an AC-DC power converter (Fig. 1) finds it application in various areas of power electronics such as Electric drives, UPS systems, Battery management systems and Telecom power supplies to name a few. Conventionally, the diode bridge or the Thyristor Bridge has been the most commonly used AC-DC power converter for obtaining DC power from the AC grid. The use of these bridge topologies is mainly motivated due to their advantage in size, control, reliability, structural simplicity and economics.

Figure 1: AC-DC Power Converter

However, usage of such bridge circuits is quite disadvantageous from the viewpoint of the AC grid, as they inject unwanted current harmonics (Fig. 2) of relatively high amplitudes (depending on the power level of the bridge) into the grid. Consequently, this
results in the distortion of the grid voltage, which can cause undesirable disturbances and hence poor power quality in the neighboring loads connected to the grid. In view of limiting this utility pollution due to power converters, standards (IEEE 519, IEC 61000-3-6)[1] have been drafted limiting the direct use of diode and thyristor bridges, with more emphasis being laid on the use of power converters which have lesser harmonic influence on the grid.

2. MODELING OF THREE PHASE BOOST RECTIFIER

As rectifiers are power electronic systems that convert input ac power to output dc power. Rectifiers come in many types and can be classified variably as:

- Single-phase vs. three-phase
- Half-wave vs. full-wave
- Phase controlled vs. pulse width modulated

Single-phase vs. three-phase rectifiers is a classification based on the type of ac input to the rectifier. The rectifiers shown in Figure 3(a) and 3(b) are diode rectifiers. The third classification relates to the type of semiconductor device used in the rectifier; uncontrolled rectifiers comprise of diodes as the switches, phase-controlled rectifiers comprise of SCR (silicon controlled rectifiers) and in pulse-width modulated rectifiers, IGBTs (insulated gate bipolar transistors) or power MOSFETs (metal oxide field-effect transistors) are used. The rectifier is switched using pulses that are generated using sine-triangle or space vector

The pulse-width modulated rectifiers can be further divided on the basis of the relationship between the ratios of the input and output voltages. Some examples of the pulse-width modulated rectifiers are buck, boost, and buck-boost rectifiers. In buck rectifiers, the dc output voltage is lower in magnitude than the peak value of the ac input. Similarly, the boost rectifier has an output dc voltage that is higher in magnitude than the peak value of the ac input voltage. The buck-boost rectifier can have an output voltage, either lower or higher in magnitude when compared to the ac input, with the duty ratio of the switches determining the nature of the output.

Operation of Three-Phase Boost Rectifier

The topology of the three-phase boost rectifier is shown in Figure 4.

The three-phase boost rectifier comprises of six switches that are switched using sinusoidal pulse width modulation technique. In general, the operation of a converter can be explained in terms of the input quantities, output quantities, and the switching pattern used to obtain the desired output. The switching pattern of the switches in the converter is obtained in accordance with Kirchoff’s voltage law (KVL) and Kirchoff’s current law (KCL). The ON and OFF states of a single switch are assumed to have values 0 and 1, respectively; i.e. if the device is ON, the switch is assigned a value = 1. If the device is OFF, the switch is assigned a value =0.

In a three-phase rectifier, the input ac voltages are defined and the output dc voltage is dependent on the input quantities as well as the switching pattern of the rectifier. The switching pattern for any converter can be expressed as a function, which is a mathematical representation of the switching pattern, called an existence function.

3. SWITCHING MODES OF THREE-PHASE BOOST RECTIFIER

For the three-phase boost rectifier, the restraints on the possible modes of operation that also satisfy KVL and KCL can be mathematically expressed as

The application areas of the boost rectifier are varied and exhaustive due to the efficient utilization of power in the rectification process, and the boosting of the output voltage.
Equations (3.1) to (3.3) shows that at no instant of time can the top and bottom devices of the same leg be ON simultaneously, as the condition would violate KVL. Assuming one switch in the top leg and one switch in the bottom leg to be ON, the boost rectifier Figure 4 can be simplified as shown in Figure 6. The six active states as shown in Table 2 can be graphically represented in Figure 7. For each state illustrated, the switches ON are specified, and a red line, indicating the switches ‘ON’ and thereby each active state, depicts the path of flow. Figure 7(a) illustrates the mode of operation where the top switch G1 and bottom switch G6 are ON. The switches that are ON therefore determine the path of flow of current. The second possible mode of operation is shown in Figure 7(b) where the switches G1 and G2 are ON.

4. SIMULATION AND RESULT DISCUSSION

Hysteresis current control with resistive load

Simulation Results

Results of three phase PWM rectifier are divided in to four parts

Figure 11: Waveform of source voltage (Vsa) and source current (Ia)

Figure 12: Waveform of source currents (Isabc) – without control

Figure 13: FFT analysis of source current and current THD = 73.34%
As discussed above, load current is increasing at 1 sec that effect is observing.

5. CONCLUSION
This paper presents the modeling, simulation and analysis of an AC-DC converter based PWM rectifier. It provides a
suitable control algorithm for a pulse width modulation rectifier which reduces ripple from the DC voltage at output side as well as shapes the input current as sinusoidal as possible. The basic objective of a PWM rectifier is to regulate the DC output voltage and also ensure a sinusoidal input current and unity power factor operation. This is implemented by high speed IGBT / MOSET switches connected in VSI topology. From this work of dissertation Power quality issues are discussed and three phase PWM rectifier model is proposed to mitigate current harmonics with hysteresis current control and dq based theory. Voltage and current waveforms are made in phase and sinusoidal by proposed three phase PWM rectifier model for different loads as well as in different loading conditions. Total Harmonic Distortions are diminished with the help of FFT analysis.

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