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Wave Shaping Of Current Using PWM Rectifiers

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***Abstract*— The paper presents the modeling 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 output side as well as shapes the input current properly. 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. The simulation results of the presented techniques have been demonstrated and concluded accordingly.**

***Index Terms*— PWM rectifier, power factor.**

I. INTRODUCTION

Rectification is a process of converting an alternating current (A.C.) or voltage into a direct current (D.C.) or voltage. This conversion is possible with the aid of a variety of circuits based on and using switching devices which can be diodes, thyristors, and power transistors and so on. These circuits which act as a rectifying circuit along with other passive elements are commonly called as rectifiers.
The rectifier circuits can be broadly classified into three classes-

- Uncontrolled
- Fully-controlled
- Half-controlled

An Uncontrolled rectifier uses only diodes and the D.C output voltage is fixed in amplitude by the amplitude of the A.C. supply. The Fully-controlled rectifier uses thyristors as the rectifying elements and the D.C. output voltage is a function of the amplitude of the A.C. supply voltage and the point on wave at which the thyristors are triggered. The Half-controlled rectifier consists of a mixture of diodes and thyristors allowing a more limited control over the D.C. output voltage-level than the fully-controlled rectifier circuit.

A. BRIDGE RECTIFIERS

When one pair of SCRs is replaced by diodes in single phase fully controlled bridge circuit, the resultant circuit obtained is called as a half controlled bridge circuit. With this type of circuit it is possible to provide a continuous control of the mean D.C. terminal voltage from maximum to virtually zero but reversal of the mean voltage is not possible. Therefore only a one-quadrant operation can be obtained. Half controlled converters are also called semi-converter. In symmetrical configuration, the cathodes of two SCRs are at the same time potential so they can be connected and a single gate pulse can be used for triggering either SCR. The SCR which is forward biased at the instant of firing will turn on. In asymmetrical configuration separate triggering circuits are to be used on the other hand.

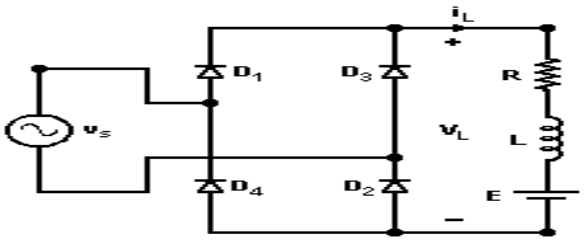

Fig.1. Diode Based Full wave rectifier

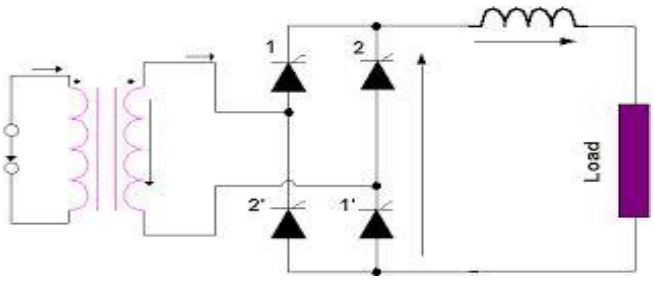

Fig.2. SCR based Full wave rectifier

II. UNCONTROLLED RECTIFIER- SIMULATION, WAVEFORMS

Simulation model of uncontrolled Rectifier:-

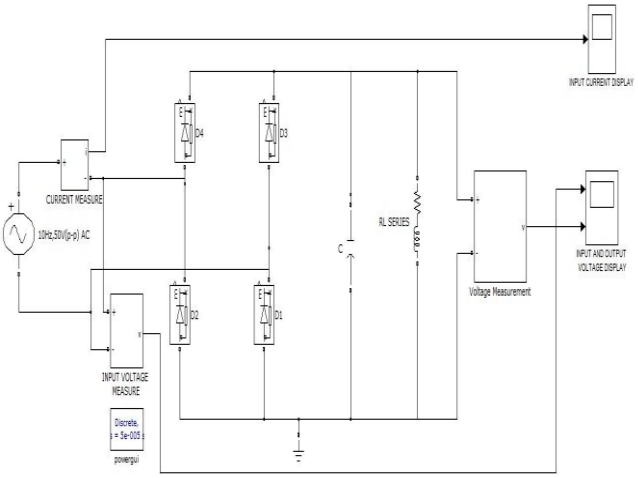

Fig.3. Simulation model

Operation:-

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- Diodes D1,D2,D3 and D4 connected in bridge configuration.
- AC voltage of 50 Hz frequency and 50V amplitude applied at input.
- In +ve half, D1 and D4 on. Conduct current.
- In –ve half, D2 and D3 on. Conduct current.
- Load has RL in series connected in parallel with C.
- C acts as a filter.
- A pulsating DC voltage with AC ripples produced at the output as shown.

A. Waveforms

The following figure shows the input and output waveforms for the full wave rectifier:-

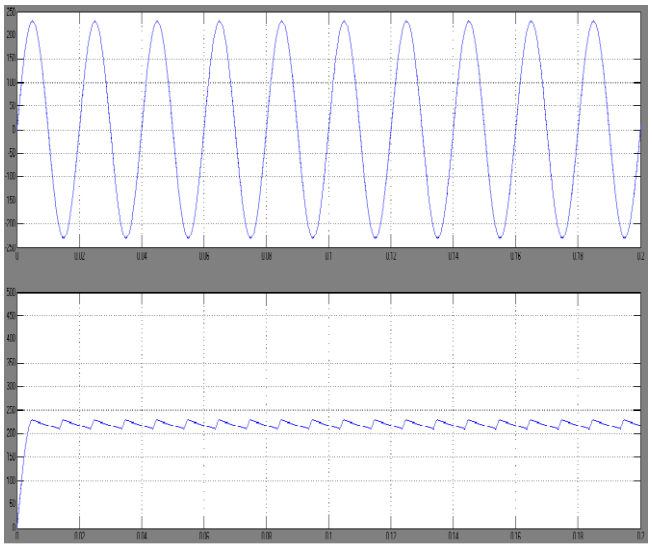

Fig.4. Input and Output Waveform

Characteristics Of Input Current

Parameters:
R=1Kohm,L=10mH,C=100microFarad

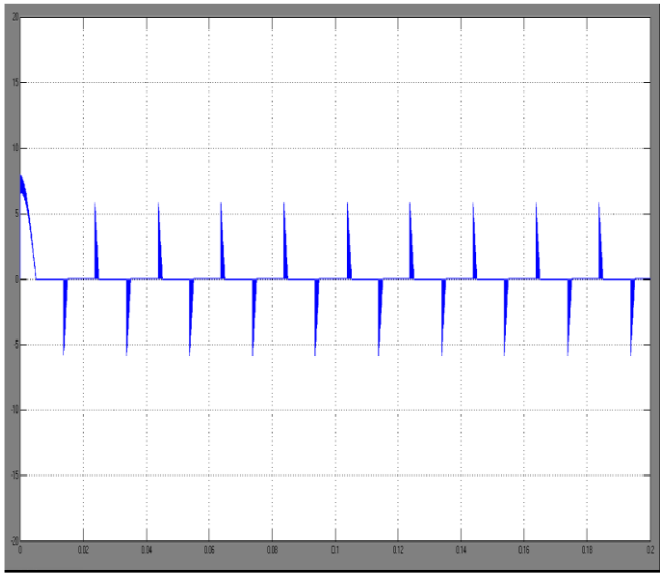

Fig.5. Input Current Waveform

B. PROBLEM IDENTIFICATION

Pollution of the supply source due to extensive use of power electronic equipments which involves continuous switching of devices often leads to disturbance of power, i.e., to be more technically accurate distortions are found at the input power due to uncontrolled rectification which portrays its distortions at the output power supply- the main cause of which is the presence of harmonics and voltage dips. Thus the problems are:-

- Input Current characteristics change with change in load.
- Keeping other parameters constant, increase of R changes the input current from a sinusoid to a pulse form.
- The change in input current is unwanted as it changes output voltage across load to an undesired value. Thus we get an **uncontrolled rectifier**.
- Thus variation in load will force to change the entire circuit which is undesirable.

C. Reasons for problems

The main reason behind the problem is due to the charging effect of the capacitor. Due to the charging and discharging effect of capacitor the input current is a pulse and not a sinusoid. With increasing capacitor the pulse width of the input current reduces thus giving sharp pulses. Thus with parameter variation the input current characteristic changes which in turn effects the output voltage and this leads to the fluctuation of voltage at load which is unwanted. Here lies the need of regulating this output voltage to mitigate fluctuations.

III. PROPOSED WORK

In order to suppress these negative phenomena caused by the power rectifiers, use is made of rectifiers with a more sophisticated control algorithm. Such rectifiers are realized by semiconductors that can be switched off IGBT transistors. The rectifier is controlled by pulse width modulation. A rectifier controlled in this way consumes current of required shape, which is mostly sinusoidal. It works with a given phase displacement between the consumed current and the supply voltage. The power factor can also be controlled and there are minimal effects on the supply network. Thus in general the remedial measures are:-

- The operation of the diode can be performed in a controlled manner.
- This can be done by the use of switches.
- Switches across the diodes working on a specific control logic controls the diode operation.
- Using switches we can make a controlled rectifier.
- Several switching devices used in general are Thyristor, IGBT etc.
- For our remedial purpose we will be using IGBT.

- IGBT has the following characteristics thus making it a suitable switching device.

A. ACTIVE CURRENT SHAPING AND VOLTAGE REGULATION

- Our primary requirement is to minimize the change of input current from sinusoid to pulse.
- This requires the regulation of voltage at the output.
- By proper voltage regulation input current characteristic can also be regulated.
- Two methods of voltage regulation:
  a. Uncontrolled rectifier with step up chopper having unidirectional power flow.
  b. Switched Mode Converters (bidirectional power supply).

B. Wave Shaping

We can shape the wave by the use of step up chopper (DC-DC converter).

- A chopper is a static device.
- Converts constant DC voltage to variable DC voltage.
- A step up chopper has output voltage more than input voltage.
- Fig. 6 below shows how a chopper can be connected in the uncontrolled rectifier circuit for the purpose of voltage regulation and input current shaping.

DC-DC converter

The block diagram and the working principle have been explained below:-

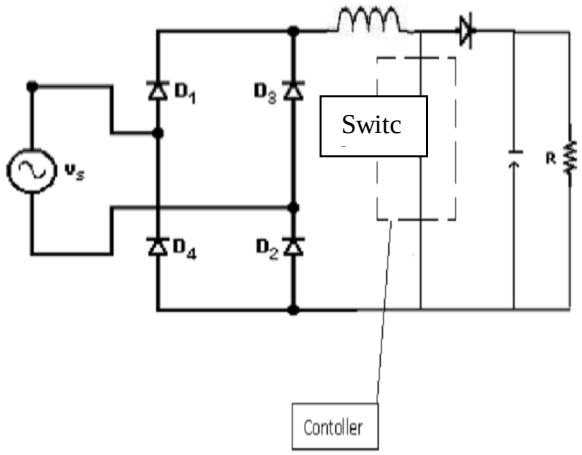

Fig.6. Step-Up Chopper

Working principle:-

- Step-up chopper gives V_0 higher than V.
- L and C are chosen depending on V_0 and I.
- When chopper is ON,L is connected across supply. I rises and L stores energy during ton.
- When chopper is OFF, I flows through D and load for toff. I tends to decrease resulting in reverse polarity in EMF in the L.
- C provides continuous output voltage.
- D prevents current flow from C to source.
- Unidirectional power flow occurs from AC to DC.

PWM RECTIFIERS

- THEORY

The main features of PWM rectifiers are:
• Bi-directional power flow,
• Nearly sinusoidal input current,
• Regulation of input power factor to unity,
• Low harmonic distortion of line current (THD below 5%),
• Adjustment and stabilization of DC link voltage (or current),
• Reduced capacitor (or inductor) size due to the continuous current,
• Properly operated under line voltage distortion and line frequency variations.

PWM rectifiers can be divided into two groups according to power circuit connection:

- BOOST RECTIFIERS (increases voltage)

It requires higher voltage on the DC side than the maximum value of the supply voltage. The rectified voltage on the output is smoother than the output voltage of the current type rectifier. They also require a more powerful microprocessor for their control. Output voltage lower than the voltage on input side can be obtained only with increased reactive power consumption.

- BUCK RECTIFIERS (decreases voltage)

In these rectifiers the maximum value of the supply voltage must be higher than the value of the rectified voltage. The main advantage is that the rectified voltage is regulated from zero. They are suitable for work with D.C. loads (D.C. motors, current inverters). The PWM rectifier aims to consume sinusoidal current and to work with given power factor.

The PWM single phase rectifier consists of 4 IGBTs connected in full bridge. The simulation of the circuit and result has been explained in the proposed scheme part.

We have proposed a design of PWM rectifier which consists of 4 IGBT's which have diodes connected to them for the control. The circuit diagram is shown below:-

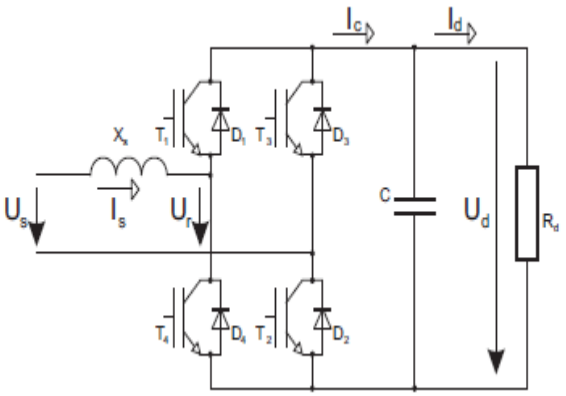

Fig.7. PWM Rectifier

The rectifier consists of 4 IGBT transistors, which form a full bridge, the input inductance and the capacitor at the output. It is controlled by pulse width modulation. Supply voltage *Us* and the voltage at the rectifier input *Ur* are sinusoidal waveforms separated by the input inductance. The energy flow therefore depends on the angle between these two phasors. The phasor diagram is shown in Fig 8,

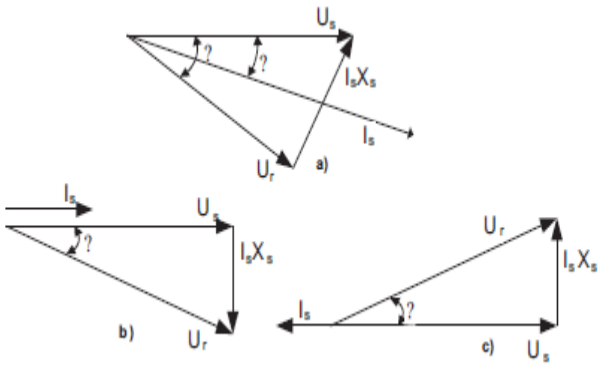

Fig. 8. Phasor Diagram

Working operation: It can be seen that two states alternate. First, the current flows into the load (D1 and D2 conducts), and second, the input of the rectifier is short-circuited (D1 and T3 conducts). The grey areas mean that the transistor conducts. The white areas mean that the passive element conducts. The transistor is turned off and the current flows through the anti-parallel diode. The switching of devices must be precisely synchronized with the supply voltage. The output voltage of the rectifier *Ud* is usually controlled to a constant value by using another converter e.g. an inverter. It is therefore possible, at a given current *Id* at the converter output, to assign to output voltage *Ud* a particular value of *z* and δ.

C. *Switched Mode Converters*

The rectification can be controlled using Switched Mode Converter. The circuit diagram has been shown in fig. 6.

Now we need to control the current across switch using Tracking method. By tracking the path we can control the current. As the current increases above certain value switch is closed and now as it falls then suddenly switch gets on to keep it in the required range. The switch takes the help of the controller which works on the control logic that uses the sinusoidal input voltage as reference and keeps the input current within that maergin. Thus in this way by tracking the current we can control the current flowing.

D. *Control*

The control includes a voltage controller, typically a Proportional-Integrative (PI) controller, which controls the amount of power required to maintain the DC-link voltage constant. The voltage controller delivers the amplitude of the input current. For this reason, the voltage controller output is multiplied by a sinusoidal signal with the same phase and frequency than *vs*, in order to obtain the input current reference, *Isref* .
The fast current controller controls the input current, so the high input power factor is achieved. This controller is a bilinear hysteresis controller.

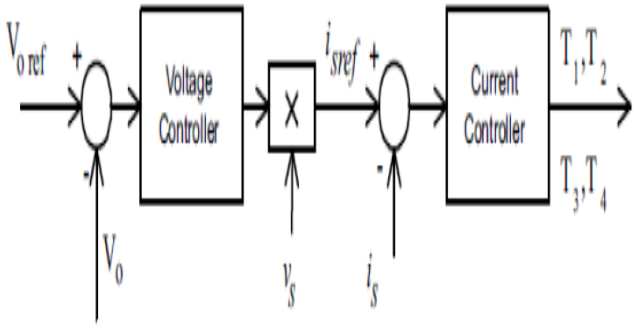

Fig. 9

a) Hysteresis Controller

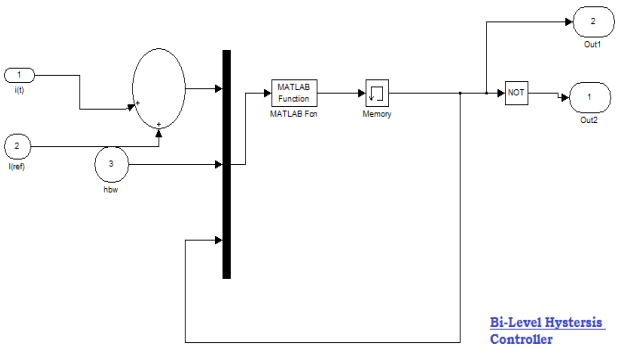

Fig.10

In the control algorithm we have basically used hysteresis controller, which helps us to meet with our objectives. The bandwidth of the hysteresis current controller determines the allowable current shaping error. By changing the bandwidth the user can control the average switching frequency of the active power filter and evaluate the performance for different values of hysteresis bandwidth. In

principle, increasing the inverter operating frequency helps to get a better compensating current waveform.

IV. CONCLUSION

The use of PWM control in rectifiers eliminates the problems caused by using phase controlled rectifiers. We have designed a PWM rectifier using IGBT and diode in combination which has various advantages.

The PWM rectifiers can perform well in many applications, for example as an active filter, or as an input rectifier for an indirect frequency converter. This application is useful mainly in traction, where the A.C. voltage from the trolley wire is first rectified, and the traction inverters and also other auxiliary converters are fed from the output of the rectifier. A traction vehicle equipped with a PWM rectifier which does not consume reactive power will not load the supply network with harmonics and can recuperate. Another possible application of the converter is as an active filter where an active front-end will have the capacitor at the output.

V. FUTURE SCOPE

The main challenge of this particular project lies in the use of IGBT or more specifically converters along with controllers teaming up with PWM bridge rectifiers for the reduction of pollution which are basically instance interruptions, voltage dips, flicker or harmonics of the supply source due to extensive use of power equipments which requires continuous switching of devices or in other words reduction of power flickering with effective use of converters which for one can act as a bidirectional wave-shaper for the input current source and finally interfacing with microcontrollers coupled with fuzzy logic algorithms to produce an ultimate utility technical solution for the recurring problem which is caused by amplitude modulation of the feeding alternating voltage.

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