Research on Three-phase Voltage Source PWM Rectifier Based on Direct Current Control

M. Deva Darshanam, R.Hariharan

ABSTRACT--- This paper is focused on the development of the rectifier for three phase voltage source to achieve unity power factor at input supply mains. The mathematical model is developed for PWM using direct current control and to apply 3-phase voltage source rectifier decoupled with feed-forward control. This method regulates the output voltage with reduced harmonics. Different PWM techniques such as Hysteresis band and Carrier based sinusoidal is applied and their performance is analysed. This work is implemented in MATLAB/SIMULINK environment. The results confirm the validity of the model and its control method.

Keywords: PWM rectifier, Direct Current Control (DCC), Hysteresis-band PWM, Carrier-based sinusoidal PWM, Space vector PWM.

I. INTRODUCTION

These days fast acting switches and their applicability in different cases is increased enormously. These devices are used as converters or rectifiers. In standard applications there are several problems posed at input side such as: Low power factor, THD values at ac line currents are high and grid harmonic pollution. The pulse width modulation (PWM) techniques are used to operate rectifier switches due to several advantages as input DC bus voltage control, power flow in either directions, maintaining power factor near to unity and line currents are sinusoidal. Synchronous reference frame is adopted for current regulating due to advantages as current response is dynamic and fast, accuracy, switching frequency is fixed for switches and sensitive to change the current variations. The DC current control scheme is widely used in implementation. The DC bus voltage can be regulated using different control strategies while enhancing the quality of input current using direct current control scheme. In day today life electric loads are growing which are controlled using power electronic devices such as Desktop computers, televisions and adjustable speed control drives (ASCD). The increased applications of electrical load lead to introduce current harmonics from the utility grid[1]. There are several technique have been proposed many researchers to mitigate current harmonics and to supply quality power. The supply is in single phase or three phase but for the single phase various harmonic reduction techniques are existed at rectifier side. However, finding the right solution for the three-phase rectifiers is still very difficult even though there are several techniques are existed may not be qualified for a grade-purpose ASCD. There are different methods are available in the literature to mitigate current harmonics as the devices used as electric loads works on DC whereas the supply is AC so an effective converter is required which not only convert from ac-dc and also supply quality power.

In conversion from ac-dc or vice versa require two or more number of converters and harmonics generated by one converter must be cancelled by another one using proper phase shift. The power has to share

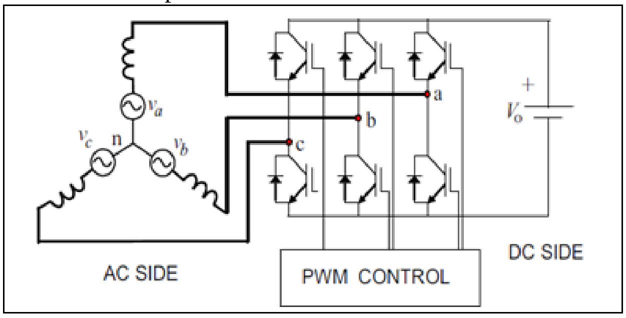

Fig.1 shows the PWM Rectifier converter

Equally between converters to attain better harmonic cancellation for which a transformer and inductor with matching inductance is used, it results into increased complexity in construction and overall cost. This methodology is applied for limited voltage and not suitable for retrofit applications. Hence this setup constitutes for limited voltage applications where complex in construction and cost is compromised. There are few harmonic reduction techniques for three-phase is found. In most the cases, ASCD is used with a rectifier with lost cost diode set up and compromise on current harmonics. Active filter or active rectifier is used an equipment for harmonic reduction but there are several problems are arose with harmonic distortion.Figure1 shows

Diode-rectifier a line side Converter with common dc link. In rectification process, the input current is highly discontinuous and contains more low frequency harmonics, due to this more total harmonic distortion (THD) at output side. The IEEE-519 limits the harmonics and power flow in only one direction that is in regenerating mode.

II. PWM RECTIFIER

PWM Rectifier is a converter and it is working on the principle of force Fig.1 shows the PWM Rectifier converter commutation techniques. In this, the output is DC voltage and it should be constant because DC Bus voltage is used for many applications. The constant DC bus voltage is achieved by using DC capacitor and a control loop.

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Agreed on the principle of maintaining the rectifier through the capacitor voltage is constant, and it was done through a feedback output voltage. The reference voltage given to the control loop must be able to block the conduction of the diodes, so that the converter operates in unit power factor mode, otherwise it will become a three-phase bridge rectifier.

DC link voltage is compared with set reference voltage under which the condition is satisfied. The switching model of the converter is produced by different control methods. These techniques will produce pulses based on the error signal generated by the comparator. Thus, the current will return to the source side using the DC link voltage.

The comparator compares the reference value of the voltage with the actual value of the voltage. If the error value of the comparator is positive, the capacitor connected in the intermediate circuit is discharged and the converter then operates in rectifier mode. Here the DC direct current will be positive. For this condition, the control block will generate six pulses for each of the power semiconductor devices. It will also provide an adequate phase shift and the current flows from the variable AC-DC sides then the capacitor voltage is restored. When the output current becomes negative, the capacitor will be overloaded and compared to the reference voltage and the control system controls the capacitor discharge in order to control the AC.

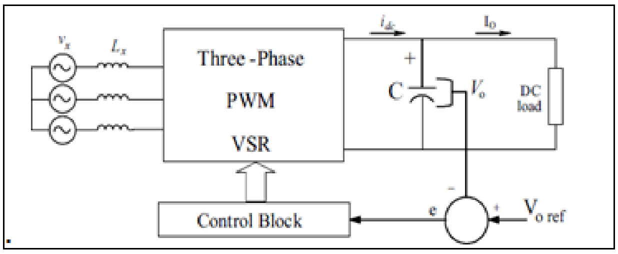

Figure 2. Operation of pwm rectifier

The pwm rectifier operation is shown in the Fig. 2 and the working procedure is explained above. From this PWM Rectifier is used for four quadrant applications[1]-[2].

The rectifier can be controlled using the supply voltage and its phase. Then, the change of the magnitude of the control voltage and phase with respect to the power supply will be established. Then operate in two quadrants, each in rectifier and inverter, that is to say the main power factor, the delayed power factor, thus obtaining four operations on four quadrants. The operation of the PWM controls the active and reactive power and allows the rectifier to absorb the current with an improved power factor. It is the input current absorbed by the source side which will be sinusoidal and therefore the harmonic distortion of the converter.

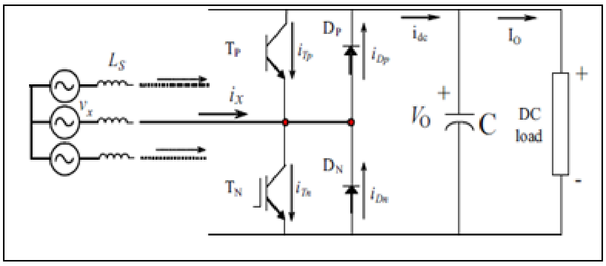

Figure 3. Single Leg Operation of PWM Rectifier.

The current flow through the semiconductors shown in Fig3. During positive cycle the current starts to flow through which is connected to the ground side of the capacitor in DC link and it is switched on in the positive half cycle. The current will come back to supply side and connected with another phase and also flows through a diode, which is connected at the ground side of the capacitor in the DC link side. The current can also flows through the constant voltage load (inversion) and again come back to the another transistor, which is connected at the high voltage side of the capacitor in the DC link. The current path is interrupted when transistor is switched OFF, and the current is ready to flow through diode , which is connected to the high voltage side of the capacitor. This current in Fig. 3, flows to the DC-link, for the production of current *idc*, which charges the capacitor *C* and will be able to generate DC power. For the conduction of Diode, inductance is used to produce induces voltage. In the negative half cycle, same operation will be occur but the thyristor and diode used for this operation, which is and . The current paths are variant in nature under inverter operation, so the currents flowing through the transistors come mainly from the capacitor C[2].

The control techniques include (a) Hysteresis-band PWM (b) Carrier-based sinusoidal PWM (c) VOC-hysteresis band PWM (d) fuzzy logic controller (e) direct current control PWM

A.HYSTERESIS-BAND PWM

It should perform three controls: 1. Source current 2. Source voltage 3. Output voltage The output of the PI controller determines the amount of current to be drawn from the source, which depends on the required set point voltage. The sinusoidal model is obtained from the source voltage and the reference current is obtained by multiplying the required amplitude of the current sinusoidal and sinusoidal model. Then, the source current of the defined value is obtained. Real-time current through the inductor is controlled by the hysteresis current controller method.

The negative side of the intermediate circuit voltage is connected to the main line when the instantaneous current exceeds the reference current. Otherwise, the source network phase will be connected to the positive side of the DC link. The same process will be performed for two other phases in a similar way.

A MATLAB simulation model will develop for the PWM rectifier with hysteresis band control. The outputs are obtained with a THD = 9.33% and a power factor of 1 on the input side.

B.CARRIER-BASED SINUSOIDAL PWM & RESULTS

The techniques which are in actual voltage from converter in real time and it compare with the reference voltage, then error is generated. The error signal is compare with high frequency carrier signal that is triangular wave. Then reference source current is obtained. This reference source current is again compare with actual current error generated and that error sent to PI controller. The output from PI

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controller gives reference source voltage which is compare with triangular carrier wave to obtain the switching sequence. This method known current controlled carrier based sinusoidal PWM.

A MATLAB simulation model will develop for the PWM rectifier with CB-SPWM control with the parameters. The outputs are obtain with THD= 3.35 % and high power factor at the input side[3].

C.VOLTAGE ORIENTED CONTROL HYSTERESIS – BAND PWM

The hysteresis band PWM method of the voltage-oriented control is based on the comparison of the actual current with the reference current obtained by the vector control method. The error of the PI regulator is considered as the reference current of the axis d, the current of the axis q is considered as zero. This reference d-q is converted into an alpha-beta reference which is again converted to abc reference signals. Here, the PWM hysteresis band is used for switching control. Since the voltage-oriented vector control is used to obtain the reference signals, this method is known as PWM with hysteresis of the voltage-oriented control[3].

The outputs are obtain with THD= 7.67 % and high power factor at the input side.

D. FUZZY LOGIC CONTROLLER:

The fuzzy logic has two different values. Fuzzy logic is a logical systems, it is enlarge of multivalued logic in narrow sense. However in wider sense fuzzy logic is synonymous with theory of fuzzy sets. The theory is relate to class of objects with unsharp boundaries of membership matter of degree[3]-[4]. This perspective, fuzzy logic in narrow sense is branch of fuzzy logic. if more narrow definition, fuzzy logic distinct both in concept and substance from logical systems.

fuzzy control system is a control system based on fuzzy logic, which is analyses input values in terms of variable that are in numerical values between 0 or 1.

The outputs are obtain with THD= 10.12% and high power factor at the input side.

DIRECT CURRENT CONTROL

E.Voltage source PWM Rectifier model

The mathematical model of three phase rectifier is , and are the phase voltages , and are phase currents, is the output voltage DC voltage. input side resistance and L input side inductance of the filter, C is capacitance of filter at input side of DC bus. , input voltages of rectifier and is Load current.

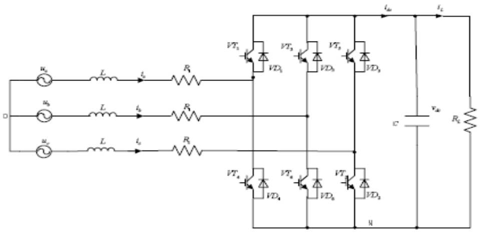

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Figure4.Boost type Rectifier

Boost rectifier parks equations are

(1)

,,

, are synchronous form voltages

, are Switch function in synchronous rotating in d-q model. Angular frequency.

, and, are voltage source, current in parks transformation in d-q model[4].

Design of current loop

The equation (1) mutual interference in control loops. The voltage and current are decoupled and feed forward control loops. feed forward voltage added to fast responses of currents. Current control loop of the converter in the system shown in Figure 5.

d - q axis voltages expressed

(2) from equation (1)

(3)

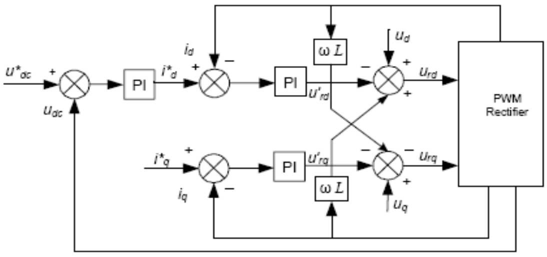

Figure 5. d-q dual closed-loop controller of rectifier

The proportional- integral controllers is adopted to current regulation.

and are controlled by the following expression:

(4)

Voltage commands are not saturated and the d-q current control loop decoupled[4]. Then d-axis current is control structure is in Figure 6.

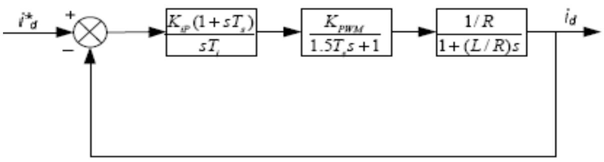

Figure 6.Equivalent control block diagram of d-q current –loop

When consider the fast current responses of the current regulator can be designed as the control system, for pole-zero cancellation, $T = L/R$.

Current transfer function for open-loop can expressed

(5)

Adjusting method for control model system, the damping ratio ξ=0.707, then we have the following equation

(6)

So PI controller value considering

(7)

G. Design of voltage loop

The equation of voltage control is

G(s)=s (8)

Where (9)

The transfer function of open system can expressed

(10)

The noise immunity must be consider into account in course design of voltage loop to maintain stability[5].

Proper choice to end the adopted control model II system So

(11)

Where is the frequency width in the voltage loop, take then (12) the results are

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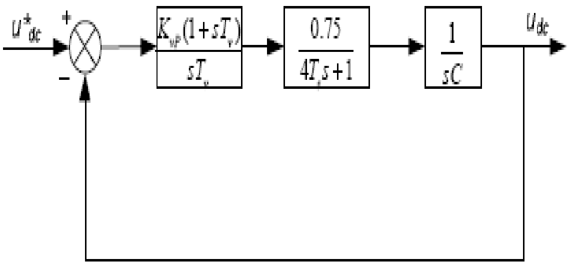

COMPARISION TABLE

Control	Fundamental current	THD (%)	Power factor
HB-PWM	4.374	9.33	0.99
CB-SPWM	4.602	3.35	0.98
VOCHB-PWM	4.395	7.67	0.99
f- control	4.47	10.12	0.98
COC-PWM	4.543	12.2	0.99

III. CONCLUSION

This article presents three different control techniques for switching the PWM rectifier. MATLAB simulations are performed and the results are obtained. The first two methods are a completely scalar control and do not require complex transformations compared to the third, a vector control technique. In any case, the third VOC HB-PWM control technique will give more accurate results than the other four methods. A comparison of these five methods presented in the table reveals that the UPF and THD controls of hysteresis control and voltage-based control are greater than 5%, whereas the CB-SPWM control has less than 5% THD, fuzzy control greater than 5%,DCC greater than 5%,almost a unit power factor but five additional PI controllers are need compared to other techniques. Therefore, by adjusting PI control more precisely, we can achieve easily and efficient switching control using the first technique, e.g. the hysteresis control.

Recently advance control techniques such as space vector control, fuzzy logic controller, feedback control have been perceived for line converter. Therefore, modern control techniques are highly appreciated to deal with variable voltage and current connected with distinct load condition and connect with different drives.

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