Implementation of Extinction Angle Control Using PWM Based Controlled Rectifier

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***Abstract*- This paper aims to correct the displacement power factor employing a modern approach that includes power electronics devices using MOSFET, rather than passive methods. The answer proposed during this paper modifies the input waveform, consequently changing the form by triggering the MOSFETs & SCRs at certain times. The action of triggering winds up in a very phase shift within the basic component of this wave and as a result power factor is improved.**

***Index terms*- power factor correction, inductive load, capacitive load, extinction angle and firing angle.**

I.INTRODUCTION

In electrical installations with an occasional power factor, significant cost savings may be made through the appliance of power factor correction. These physical phenomenon of the distribution system, raise the voltage level, and reduce the system losses. Using shunt capacitor banks for power factor correction (PFC) could be a notably established approach.

Power factor resembles how effectively the power generated is being consumed by the load .Therefore power engineers' aim for a high power factor to ensure maximum utilization of the power generated. Due to the ever growing use of inductive loads which are one of the components which lead to a poor power factor the power factor decreases to very low values. This state is bad and undesirable for consumers, power system operators and the environment.

The effects of a bad power factor can be mitigated by using capacitors- also known as reactive power compensation. This method includes calculating the negative reactive power which is consumed by the system and adding capacitors of the same value to provide positive reactive power to compensate, balance out, the effect of the inductive load. Therefore the main problem that this paper addresses is fixing a low power factor caused by an inductive load or a capacitive load. Contrary to the classical method of using capacitors, fully controlled rectifier by the extinction & firing angle switching schemes will be used. This paper will:

1. Illustrate the concept of power factor correction using extinction angle mechanism.
2. Design power factor corrector using power electronics devices (Thyristors).
3. Test the performance of the power factor corrector under different loads.
4. Illustrate the relation between the triggering schemes and their corresponding effect on the power factor.

II. THEORETICAL BACKGROUND

Several switching mechanisms are available for active power factor correction. The mechanism chosen depends on whether the load is capacitive or inductive. The load is taken as an inductive load since most of poor power factors are caused by inductive loads, therefore extinction angle control is used to improve the power factor. In extinction angle control the conduction is not delayed but waveforms are modified by forced commutation to switch off (extinction) before the half cycle, which can be seen as firing angle from the other side. Full-wave controlled MOSFETs-based rectifier is used to demonstrate the operation of the extinction angle control.

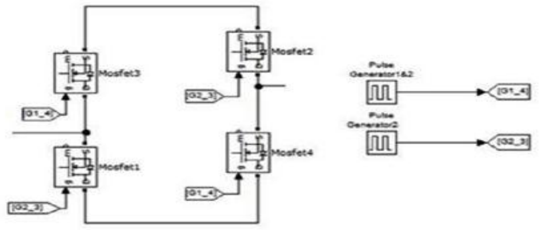


Figure 1: Full-wave rectifier including the pulse generators

Fig.1 above shows MOSFETs, 1, 2, 3, and 4, which operate in pairs after being triggered by a pulse signal. At any moment in time, only one pair will be turned on while the other pair is turned off. In this case switch, 1 and 2 are turned on at the beginning of the positive half cycle and turned off by forced commutation at *wt*=π-β while the other pair of switches are reverse- biased. In the beginning of the negative half-cycle switches 3 and 4 are turned-on, and turned off by forced commutation at *wt* = 2π - β. This switching is achieved by the pulse generators shown in fig.1.The output of the rectifier is controlled by varying the extinction angle as can be seen in fig. 2 below.

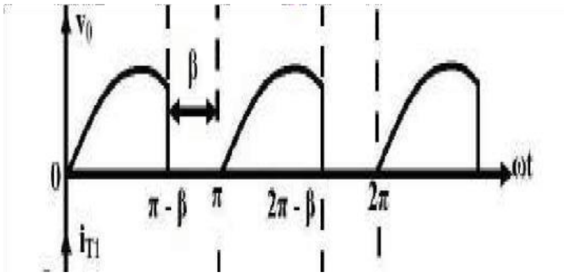


Figure 2: Extinction Angle Control

The leading power factor caused by the angle of extinction control eliminates or reduces the effect of lagging power factor caused by the inductive load, thus, it is seen as adding a capacitor compensating the phase shift at the source side. From the source the load appears purely or more resistive. The impact of the switching can be seen in fig. 3. The dotted line represents the fundamental component of the current, it's clear from the diagram that it is leading.

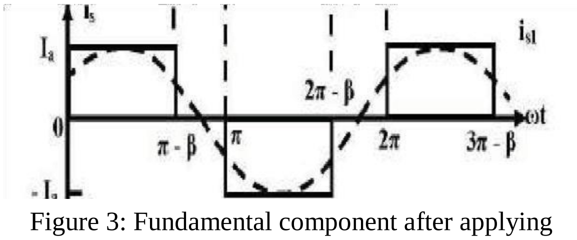


Figure 3: Fundamental component after applying extinction angle control

This mechanism provides a displacement power factor equal to the fundamental power factor which can be expressed by the following equation:

cos θ1 = *cos* β/2, leading (1)

(1) Switch selection

Due to the characteristic of the applying ability of the power MOSFET, it has been taken into consideration. A power MOSFET is especially a particularly reasonable selected kind of metal oxide semiconductor field-effect designed to handle significant levels of power. Additionally, it's simple to alter- extinction, no need for forced commutation.

III. METHODOLOGY

The voltage source supply's the load with AC voltage. The rectifier's output is connected in series with the DC load (part of the patron load) which is represented by a resistance and in parallel with an AC load therefore the energy supplied is split between both of the branches. The AC load is an R-L load which causes the source current to lag the voltage. The rectifier converts the AC voltage into DC voltage.Fig.4 is a simplified block diagram for the circuit while fig. 6 below shows a detailed Matlab drawing. The rectifier consists of controlled MOSFETs which are switched ON and OFF by a pulse as can be seen infig.5.

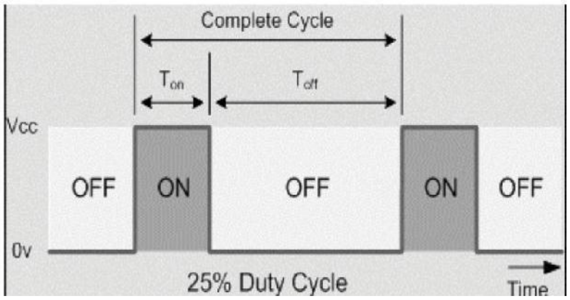
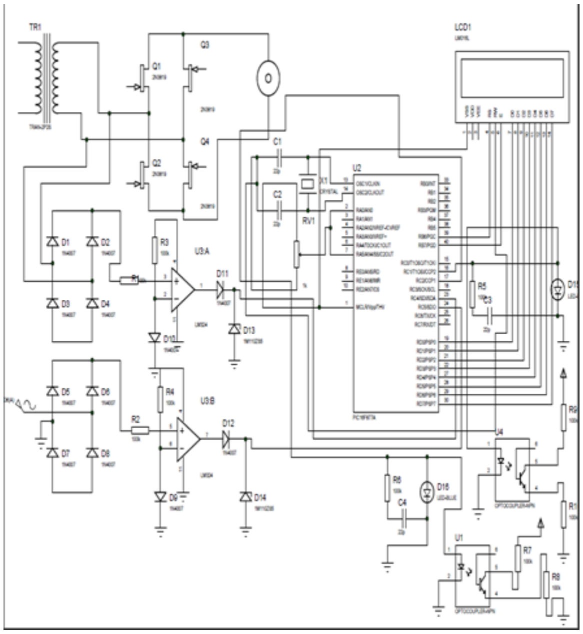


Figure 4: Duty cycle.



The pulse generator provides a pulse signal to turn the MOSFETs ON at the beginning of each half cycle for a certain duty cycle which determines the width of the pulse, at the end of the duty cycle the MOSEFTs are turned-off- before the end of the half cycle (extinction). Controlling the extinction angle causes the fundamental component of the current to lead the voltage. The source sees two phase shifts in two different directions (lagging and leading) so the correction (as seen from the source side) is obtained from the effect of the current flowing in the rectifier branch (corrected current)on the total current supplied from the source. The extinction angle control in the rectifier affects the source current waveform leading to a higher power factor.

The theory explained relates the extinction angle with the shifting of the fundamental current however MOSFETS are controlled by turning them on which is represented by the duty cycle, referred to as the pulse width in this paper. Therefore the pulse width is the complement of the extinction angle and they can be directly related using the following expression:

Extinction Angle=180-360*D (2) D= Duty ratio i.e pulse width

The relation between the power factor and extinction angle is not linear in this method since the current is divided between the two legs. Power factor correction depends on the extinction angle as well as the amount of corrected current. So a study is made to investigate the relation between the power factor and the extinction angle and the effect of the amount of corrected current on the power factor.

IV. DISCUSSION

A.INDUCTIVE

According to the theory explained in the literature review the fundamental current becomes leading when the extinction angle is changed. The results in fig. 7 and 8 clearly manifest this phenomenon. For instance in the case of the 0.94 power factor load, the phase shift was 25 degrees without any triggering and after the triggering it decreased to 10.01 and then increased to 44.83 hence the corresponding power factor value of 0.94 increased to 0.9848 and then decreased to 0.7. This represents an improvement of 50% in terms of the phase angle shift.

Similarly, the results for the 0.8 and 0.9 power factors followed the same manner. However each one had a different result for the maximum power factor that could be obtained in each case, the results are summarized in table 5. Another observation is that after the maximum power factor is reached and the pulse width is increased further, power factor decreases. For example, the 0.94 power factor load decreases from 0.9848to0.7.This is due to the fact that at very narrow pulse widths the current flowing through the DC load is relatively small compared to the current flowing in the AC load thus only the AC load has an effect on the power factor.

B. CAPACITIVE:

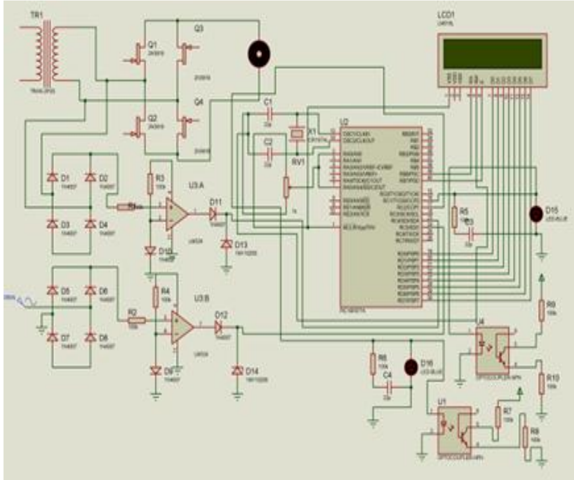
The operation of power factor correction for capacitive loads using the firing angle switching scheme follows the same manner as the method discussed earlier. With the increase of the firing angle the power factor continues to increase until a certain point where the current is small compared to the total current so the effect of the correction current will be small. This makes the AC effect more apparent to the source. The power factor will be equal to the AC load power factor when the firing angle becomes equal to 180 degree where the DC side will be open circuit so the source will only see the effect of the AC load.

Attention must be paid to the high values of power factors chosen in both designs. This is due to the effect of the DC load hence the AC load alone has a bad power factor however when the triggering values become high it starts affecting the circuit's operation. Therefore the overall power factor of both DC and AC loads is substantially high but the circuit still manages to improve it further proving its effectiveness and the effectiveness of the methodology.

Additionally it was observed that the relationship between the triggering angles and the power factor is not linear due to the fact that the current is not constant in both branches. The current is not constant because the varying values of the triggering angles lead to variable values in the average voltage in the DC branch hence the power and current change values depending on the triggering angle, drawing a variable current which creates the nonlinear behavior.

SIMULATION

The whole system is designed by using Proteus software. This contains transistors, motors, diodes, zero crossing detector, pic microcontroller, opto-oscillator etc. By using those algorithms, we have designed the program and it is built into the microcontroller. The simulation diagram of the proposed system is as shown in figure 5.



According to the requirement, we have programmed the microcontroller

V. CONCLUSION

So by this project, improving the PF can maximize current- carrying capacity, improve voltage to equipment, reduce power losses, and lower electric bills.

Most industrial processing facilities use an oversized quantity of induction motors to drive their pumps, conveyors, and other machinery within the plant. These induction motors cause the power factor to be inherently low for most of the industrial facilities. Many electric utility companies assess an influence factor penalty for lower power factor (usually below 0.80 or 0.85). Some also inducement high power factor (for instance, above 0.95). By adding power factor correction, you'll be able eliminate the power factor penalty from your bill.

Most of the electric utility companies charge for optimum metered demand supported either the most worthily registered requirement in kilowatts (KW meter), or a percentage of the most worthily registered requirement in KVA (KVA meter), whichever is bigger. If the power factor is low, the share of the measured KVA is going to be significantly greater than the KW demand. Improving the power factor through power factor correction will therefore lower the demand charge, helping to scale back your electricity bill. A lower power factor causes a better current flow for a given load. As there is increase in the line current, the voltage drop in the conductor also shows a gradual increase, which may result in a lower voltage at the equipment. With the power factor improvement, there is reduction of voltage drop in the conductor, and this gradually improves the voltage at the equipment.

REFERENCES

[1] R. W. Erickson, “Fundamentals of Power Electronics”, New YorK: Kluwer Academic Publishers, 2011.

[2] H. Daniel W, “Power Electronics”, New York: McGraw-Hill, 2011.

[3] W. S. a. P. Zand, “Energy Flow and Power Factor in Nonsinusoidal Circuits”, Cambridge: Cambridge University Press, 1979.

[4] J. A. C. O Garcia, “Power Factor Correction: A Survey,” in IEEE proceedings, PESC, 2001.

[5] R. Carbone, “A Single-Phase Controlled Rectifier with Unity Power Factor,” in 8th WSEAS International Conference on Electric Power Systems, High Voltage, Electric Machines, Reggio Calabria, 2008.

[6] V. R. Moorthi, “Power Electronics: Devices, Circuits and Industrial Applications”, New Delhi: Oxford University Press, 2005.

[7] M. H. Rashid, “Power Electronics Handbook: Devices, Circuits and Applications”, MA: Elsevier, 2011.

[8] S. Umesh, “Active Power Factor Correction Technique for Single Phase Full bridge Rectifier,” in Conference Rec. HPFC, Bangalore, 2004.

[9] W. M. Grady, “Harmonics and how they Relate to Power Factor,” in EPRIPower

[10] “Quality Issues and Opportunities Conference”, SanDiegp, 1993.