Improvement of Power Factor using the Extinction Angle Control Method

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Abstract*: Basically, the power factor (PF) is defined to be the ratio of real power (P) to the total apparent power(S). The phase shift that is found in between the current and voltage waveforms cause the changes in Power factor. This phase shift is due to the load connected on the end therefore depending on the type of load (inductive, capacitive) the phase lag and lead respectively. In this paper we have proposed an idea on improving the power factor of a system using a different approach which is done with the help of power electronic devices like MOSFET & SCR instead of using capacitor banks. Extinction angle refers to the time interval from the instant when the current through an outgoing thyristor becomes zero (and a negative voltage applied across it) to the instant when a positive voltage is reapplied. It is expressed in radians by multiplying the time interval with the input supply frequency (ω) in rad/sec. In this proposed model by controlling this extinction angle power factor is improved and this is called as extinction angle control. The input current's waveform is changed by setting on/off the MOSFETs & SCRs at certain times. The turning on/off leads to increase in phase in the fundamental current wave. This setup of power factor correction can be used as a redundant one, because in capacitor banks replacements take time and it costs more. so, this is the method through which the power factor correction is made cost efficient and easy for the users for replacements. By doing this, the power factor is improved. The above-mentioned system was executed in MATLAB Simulink software and convincing outcomes were acquired.

***Index Terms*: Extinction angle control, Inductive load, Power factor correction, Power electronic devices, Simulink (MATLAB).**

I. INTRODUCTION

Power Quality is the most important factor for an efficient working of an electrical equipment. there are many elements which helps in improving the power quality, among that which plays an important role is Power factor. Power Factor Correction (PFC) is a technique used to improve the power factor (PF) factor which increases the power quality like using capacitors bank for inductive loads (for example motors) [2]. The efficiency of power supply is increased by the use of PFC systems, which helps cost savings on electricity. Power Factor is said to the measure of how efficiently the incoming power is utilized by your electrical appliances (Loads).

Power Factor Correction is mainly wanted in the electrical system where the power factor is equal to or less than 90% (or 0.9). A low power factor can add to electrical equipment's unsteadiness and which becomes unreliable, just as essentially higher than would normally be appropriate vitality costs since it implies that increasingly current is required to play out a similar measure of work. By enhancing and improving the power factor, we improve the power quality which is the most important factor by lessening the load on the power distribution system [1].

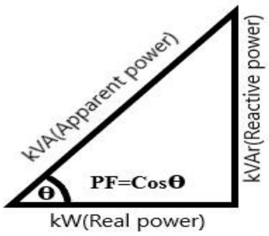

Fig.1.1

$$\text{Power Factor (PF)} = \frac{Real\ power\ (P)}{Apparent\ power\ (S)}$$

Power factor improvement is a way used to correct the lagging AC by a leading AC, by associating capacitors in the circuit. Capacitors used in improving the power factor draws current that is leading in voltage and produces a leading power factor. An adequate capacitance is associated with the goal that control factor is balanced as near to the unity i.e. PF (Cosɵ = 0) as expected [1,2]. Hypothetically, capacitors could give 100% of the required receptive power, in any case, for all intents and purposes, amending power factor much closer to solidarity may result in symphonious bending.

Methods of Power Factor Correction

1. Static Capacitor
2. Synchronous Condenser
3. Firing angle control method (α)
4. Extinction angle control method (β)

In this paper, we'll illustrate the concept of Power Factor improvement by:
1. Power Electronics devices (MOSFET)
2 Extinction Angle control Method

II. THEORY

A. Extinction Angle Control:

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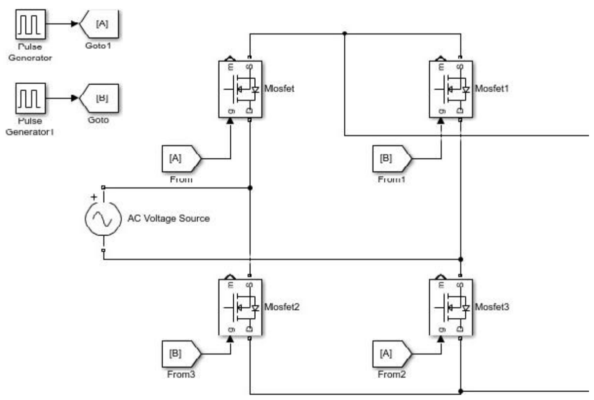

Fig.2.1

The above circuit diagram represents the single-phase full wave-controlled rectifier. This is a force commuted bridge rectifier. In the circuit diagram there are four MOSFETs which are controlled using the gate pulse. The Gate pulses are varied by changing the duty cycle. The duty cycle refers to the width of the pulse that is given in the gate of MOSFETs [1,2]. During the first half of the cycle MOSFET 1 and MOSFET 3 are triggered at ωt=0 i.e. α=0, then these MOSFETs are switched OFF at the angle ωt=π-β. The switching off the MOSFETs is done by the forced commutation which is controlled using the gate pulses here. The gate pulse Duration for the MOSFETs 1 and 3 is from 0 to π – β. The waveform of the first half cycle, triggering pulse and the second half output cycle is clearly shown in the figure 2.2.

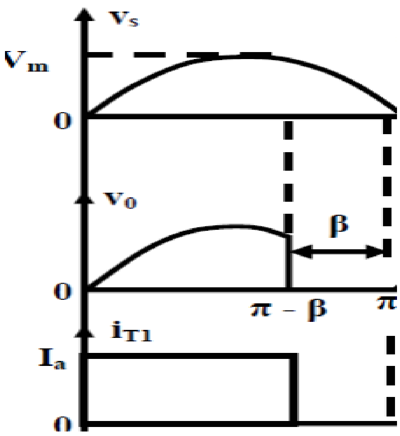

Fig 2.2

During the second half of the cycle MOSFETs 2 and MOSFETs 4 is switched ON by the gate pulse. these MOSFETs are triggered at the angle ωt=π. Then the MOSFET 2 and MOSFET 4 is switched OFF by the forced commutation at the angle ωt=2π-β. The gate pulse Duration for the MOSFETs 2 and 4 is from π to 2π – β. The waveform of the second half cycle, triggering pulse and the second half output cycle is clearly shown in the figure 2.3.

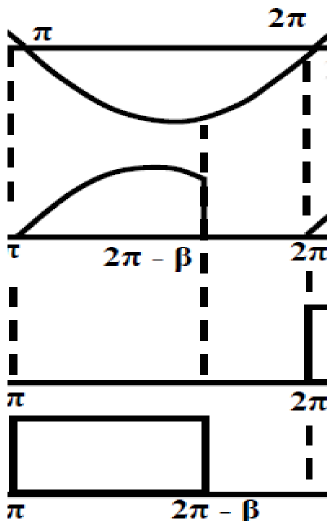

Fig 2.3

All the for coming cycles are led to this process by which the output voltage gets controlled. So basically, it is said to be that the output voltage is controlled using the extinction angle β. By this process the Input current is made to lead the input voltage which makes the displacement factor and also the power factor to be leading [2].
This circuits major aim is to convert the AC voltage to the DC voltage and provide the DC voltage to then DC load which is part of a consumer load. The output of this circuit is pulsating DC voltage or DC current which is converted into a pure DC waveform (constant voltage) by the use of particular capacitor

III. METHODOLOGY

- The load is supplied with AC voltage by the voltage source. The output from the rectifier is fed to the DC load (here it is R load) which is connected in series and the AC load is connected in parallel.
- Due to this connection the power delivered by the source is divided between two of these branches. We are using RL Load and motor (capacitor start motor) here which represents the AC load and due to the presence of the inductance in the AC load the current lags the voltage in source side and as well as in load side.
- The alternating current (AC voltage) is converted into direct current (DC voltage) by the rectifier circuit. Controlled MOSFETs are been used in the rectifier circuit.
- These MOSFETs can be controlled i.e. switched ON and OFF by the gate pulse.
- The pulse signal is provided by the pulse generator which turns ON the MOSFETs during the start of the half cycle for a particular duty cycle and by the end of the duty cycle the MOSFETs will be switched OFF before the completion of the half cycle(extinction).

- The duty cycle is determined by the width of the pulse and the extinction angle is also controlled using the width of the pulse.
- Due to the control of extinction angle the currents fundamental component leads the supply voltage.
- On seeing from the source side there are two phase shifts which are in different directions i.e. lagging and leading therefore the correction is done from then effect of the current which flows in the rectifier circuit on the total current.
- This total is current is nothing but the current supplied from the source.
- In the rectifier circuit due to the extinction angle control the source current waveform is affected and it is lead to a higher power factor.
- The figure 3.1 represents the circuit diagram with inductor as load and figure 3.2 represents then diagram with motor as load.

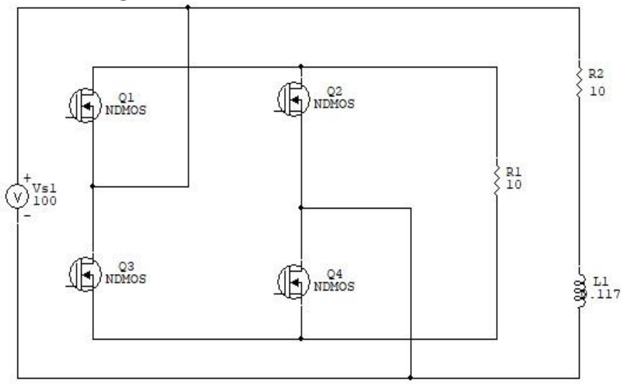

Fig 3.1

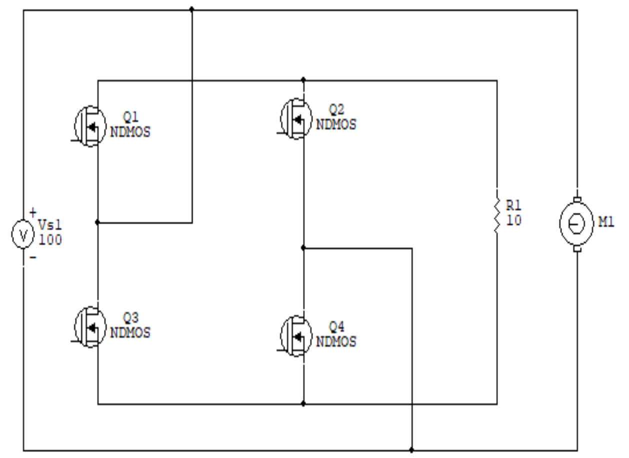

Fig:3.2

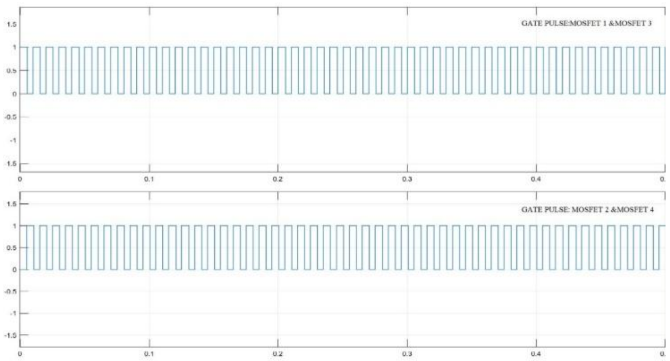

Fig 3.3

The figure 3.3 represents the gate pulse which are given to the MOSFETs for the triggering process

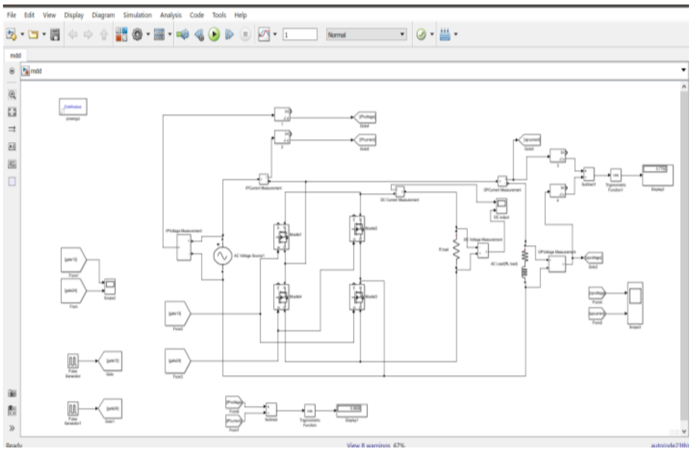

Fig 3.4

First the inductor was used as the AC load with different values. The figure 3.4 represents the simulation diagram with inductor as load. For different values of inductor, we fixed different values of duty cycle for the gate pulses which are provided to the MOSFETs.The duty cycle values were set to 45% 55% & 65% and the readings were taken.

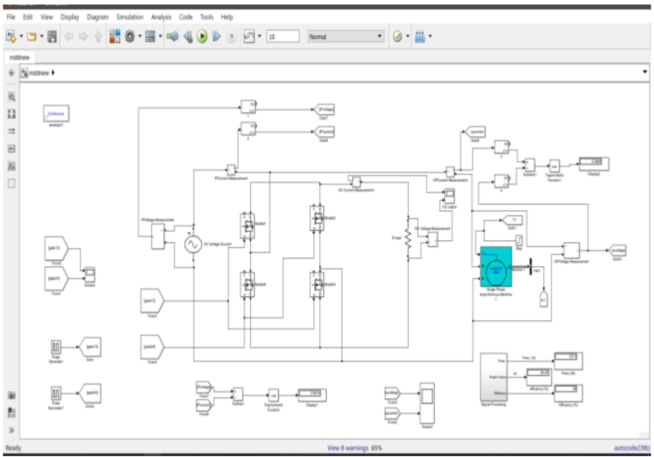

Fig 3.5

Secondly the inductor was replaced with capacitor start motor and the readings were taken. The figure 3.5 represents the simulation diagram with capacitor start motor as load. All these values were compared with the values without any compensation circuit.

IV. RESULTS

In this project the major output is the improved power factor in a circuit. Firstly, the inductor was used and the readings were taken. The inductance values of inductor were changed and the output readings were taken. And also, the readings for different values of the duty cycle were taken and observed. The relation between the duty cycle and the extinction angle is given below by a formula.

Extinction Angle= 180- 360*D

D= Duty cycle ratio i.e. pulse width

The given table 1.1 represents the outputs for different values of inductance and pulse width.

Pulse width	Inductor value	Normal power factor		Power factor after the correction	
%	(H)	Source side	Load side	Source side	Load side
45%	0.117	0.7211	0.8129	0.9847	0.8155
	0.03	0.7125	0.7777	0.9415	0.7792
55%	0.117	0.7211	0.8129	0.9897	0.8155
	0.03	0.7125	0.7777	0.9606	0.7792
65%	0.117	0.7211	0.8129	0.9926	0.8155
	0.03	0.7125	0.7777	0.9717	0.7792

Table 1.1

Secondly the inductor was replaced with motor (capacitor start motor) and then the readings were taken. The motor is a single-phase asynchronous motor and specifically it is a capacitor start induction motor. The figure 4.1 represents the specification of the motor that was used in the simulation.

Pulse width	Mutual Inductanc e value	Normal power factor		Power factor after the correction	
	(H)	Source side	Load side	Source side	Load side
45%	0.166	0.9362	0.9788	0.9571	0.9798
55%	0.166	0.9362	0.9788	0.9712	0.9798
65%	0.166	0.9362	0.9788	0.9794	0.9798

Table 1.2

At the load the above-mentioned motor was connected and for different values of the pulse width (duty cycle) the readings were taken and tabulated above in table 1.2.

V. OUTPUT WAVEFORM

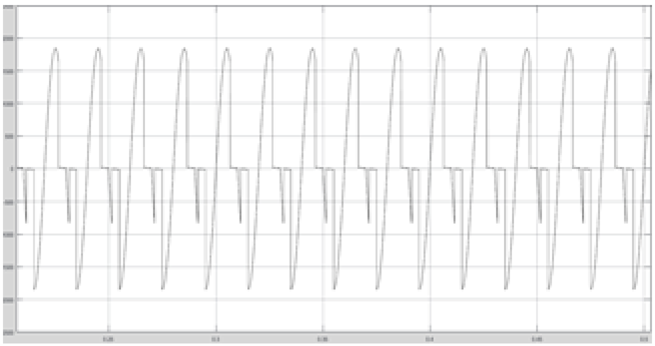

Fig 5.1 Modified input current waveform using Extinction angle control

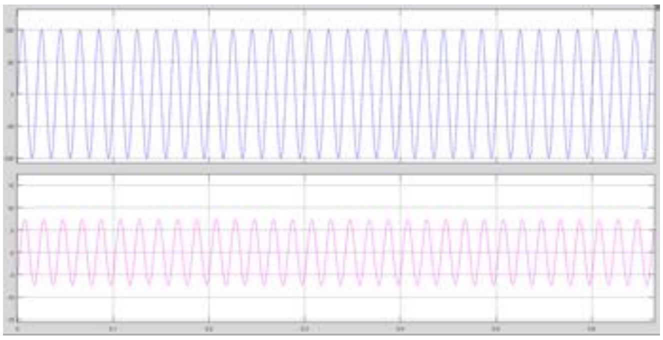

Fig 5.2 Output voltage & current waveform with improved power factor

VI. CONCLUSION

In this paper, the aim was to improve the lagging power factor using power electronic devices such as MOSFETs and SCRs. A MOSFET switch arrangement was implemented to improve the poor power factor due to an inductive load. The MOSFET switch arrangement serves two functions i.e., improving the power factor using extinction angle method and producing DC current for the DC load. Various extinction angles (β) lead to different leading phase shifts in the fundamental component of the current waveform. The whole arrangement was executed on MATLAB Simulink and the power factor has seemed to be improved. The result of this proposed model has definitely demonstrated the improvement of power factor. This setup of power factor correction can be used as a redundant one in the industries as the replacements of this setup is easy and as well as costs less. Many power electronic devices are available like IGBT, SCR, TRIAC and so on.so more experimentation can be done by replacing the devices and we can come up with a more effective method for the power factor correction. Anyway, more experimentation could be performed to study the impact of this procedure on total power factor.

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