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POWER FACTOR CORRECTION SYSTEM USING MATLAB WITH DIFFERENT LOADS

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Abstract
Energy efficiency improvements can provide significant cost savings from reduced energy consumption. These savings are often the reason why electric companies charge customers. This review of high-efficiency, state-of-the-art active power factor correction (PFC) technology for high-power, single-phase applications is now available. The advantages and limitations of many PFC technologies used to make switching efficient in modern network servers and telecommunications equipment. The technology includes a variety of zero-voltage and zero current transformers, active biasing methods to reduce back-coupled switching, and techniques to reduce losses. Finally, the impact of recent advances in semiconductor technology (mainly silicon carbide technology) on the performance and design of PFC converters is also discussed.

Keywords: Power, Filter, Rectification, Simulation, Power Factor

1. INTRODUCTION

Any end equipment powered from AC supply represents a complex load where the input current is not always in phase with the instantaneous line voltage. And so, the end equipment consumes both real power as well as reactive power from the supply. The ratio between real, usable power and the total real plus reactive power is known as Power Factor. Laptop Adapters can be the perfect example of end equipment.

PFC (Power Factor Correction) circuit intentionally shapes the input current to be in phase with the instantaneous line voltage and minimizes the total apparent power consumed. Power Factor is a parameter to measure the energy efficiency of the circuit. [15] It shows the efficiency of the circuit and power losses and power consumption of the same.

1.1 POWER FACTOR

The classical definition of Power Factor is defined as the ratio of real power measured in watts (W) consumed by a load divided by the total apparent power measured in Volt – Amperes (VA) circulating between the power source and load.

For a DC input, the input current and input voltage is always in phase and as such maintains a power factor of 1 or an electronic application that is powered from the AC supply, the input current does not naturally follow the instantaneous AC line voltage.

Power Factor (PF) defined as the ratio of Real Power to Apparent Power. Where,

$$Real\ Power(Watts) = Instantenous\ V\ \times I$$

$$Apparent\ Power\ (VA) = V_{rms} \times I$$

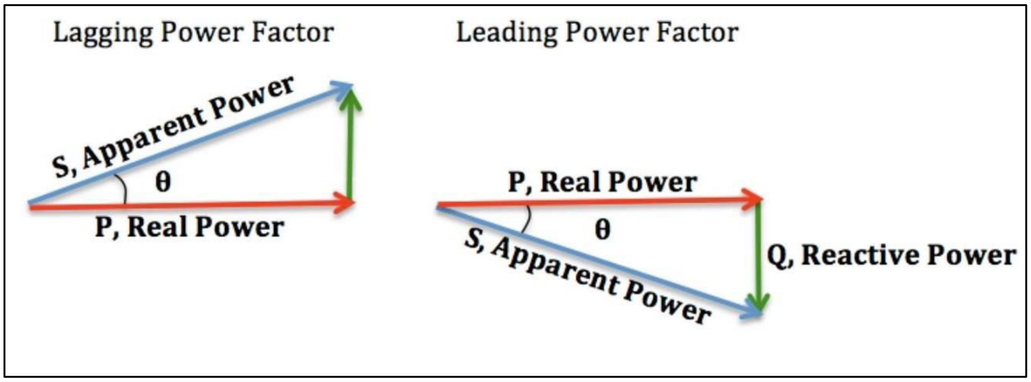

Fig 1: Power Factor

But this is only applicable to sinusoidal waveforms. Plus power factor can be leading or lagging.

1.2 BEER ANALOGY

To understand what Power Factor is, the common example used is Beer Analogy. It is used to represent the Power consumption at a site. There are different types of power present like – Reactive Power, Real Power and Apparent Power.[1]

Reactive Power which is measured in KVAR is a kind of complex power that doesn't do any work. It corresponds to storage, retrieval of energy and magnetizing.[3] Example it enables transforms to transform or generators to generate.

- Real power is the power which actually does work. It is actual power that is consumed due to the load. It is measured in Watt.
- Apparent Power is the culmination of Reactive Power and Real power in a line. Or, it is the power, the grid must be able to withstand. It is measured in VA (Volt – Ampere).

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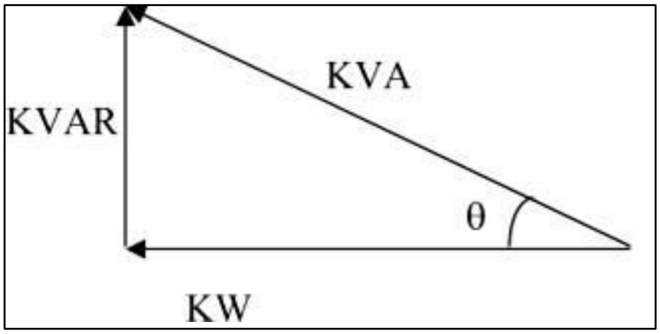

Fig 2: Ratio of Real power, Apparent Power and Reactive Power

As we can see in Fig 3, that is Beer Analogy of Power Factor.[1]f According to this figure-

1. The glass is Apparent Power. Vectorial Summation of Real and Apparent powers.
2. The Foam on the top is Reactive Power. It is wasted power, and customer additionally pays for it.
3. Beer that is actual power or we can say Real Power. The actual power used at the site.

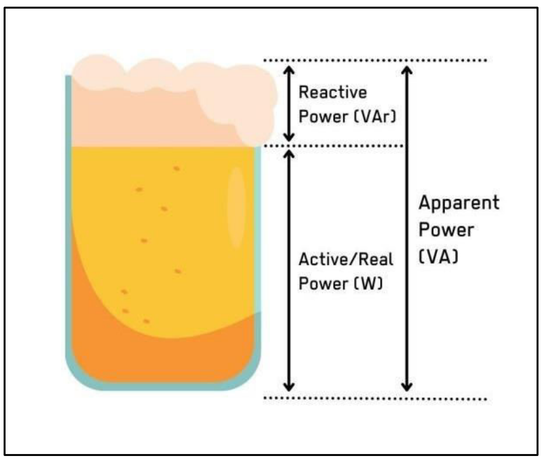

Fig 3: Beer Analogy and Power Factor

1.3 CAUSES OF LOW POWER FACTOR

When the current waveform is not sinusoidal, as is the case for switching power converters, the PF can also be less the unity. The current in a switching power converter contains a frequency element that multiplies with switching frequency. This results into distortion power factor. Low power factor means when P.F. is not equal to or near to 1. There are several causes of low power factor:

1. Induction Motors: For full load motor works at PF between 0.8 – 0.9. For small load motor works at PF lying between 0.2 – 0.3. And if no load is available the PF may come to 0.
2. Varying load in Power System: As load is varied so when there is low load period, supply voltage is increased which will increase the magnetizing current and so power factor will be decreased.

3. Electrical Discharge Lamps: High Intensity discharge lighting lamps operate at a very low power factor.
4. Transformers: It operates under no-load conditions has a low power factor because the circuit is almost purely reactive. But as the load on a transformer increases, the reactance decreases, and power factor increases.
5. Industrial Heating furnaces
6. Harmonic Currents

1.4 REQUIREMENT OF PFC

By improving the power factor one can improve the energy efficiency, reduce losses on the distribution system and also reduces cost. It improves the work output and lessens the instability and failure of the system elements.

Adding capacitor in the simple converter circuit leads into the power factor correction circuit, which will provide reactive power. Reactive power is the leading current which helps to compensate the lagging current to increase the energy efficiency.[4]

Capacitors used will also neutralize the magnetizing current. The power factor should basically the near to unity so if it even reaches the range of 0.92 to 0.95 then also it can be counted as better. There are many systems in which energy is been wasted in the distribution system itself. Power factor correction will reduce this wasted energy.

For DC Supply we calculate power as product of voltage and current for a fixed resistance, where current is proportional to the applied voltage. So power dissipated will be linear. But in AC Supply the reactance will affect the behavior of the circuit, also AC voltage us a form of line wave and it continuously keeps on changing its magnitude and direction with time at a rate which is decided by the source frequency.

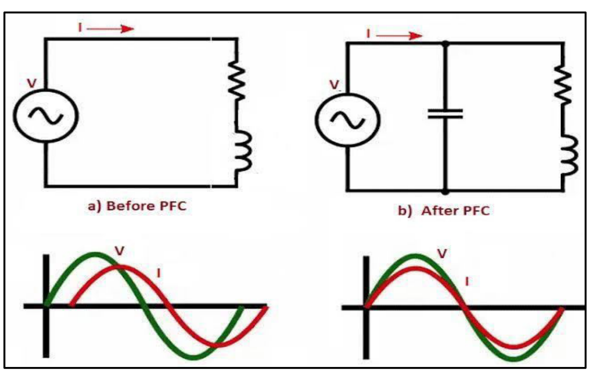

Fig 4(a): Before PFC means when no capacitor for correction is used then voltage and current are out of phase and so there will be low power factor.

Fig 4(b): After PFC means when capacitor is connected in the circuit, then both voltage and current are in phase so the power factor in the circuit will be equal to or near to 1 (unity).

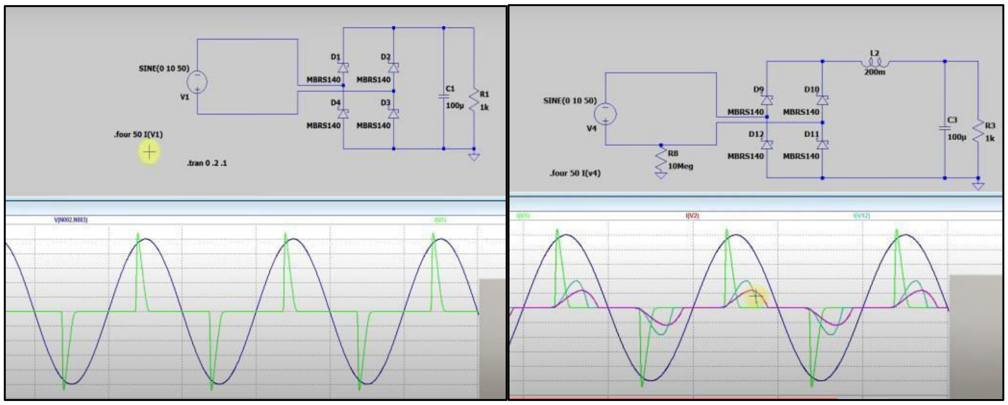

Fig 5: Resistive load PFC circuit (left) ; RL Load PFC circuit (right)

2. CORRECTION OF POWER FACTOR

The main intent of Power factor correction (PFC) is to ameliorate power factor, and also reduces the load acts on the distribution system, increases energy effectively and reduces costs of electricity. It also decreases the unstableness and failure of system constituents. Power Factor correction is nothing but connecting the capacitors which produce reactive power. [11]

Electrical Energy in opposition to the electrical energy is absorbed by loads like motors, nearly close to the load. It improves the power factor where the reactive power is connected.

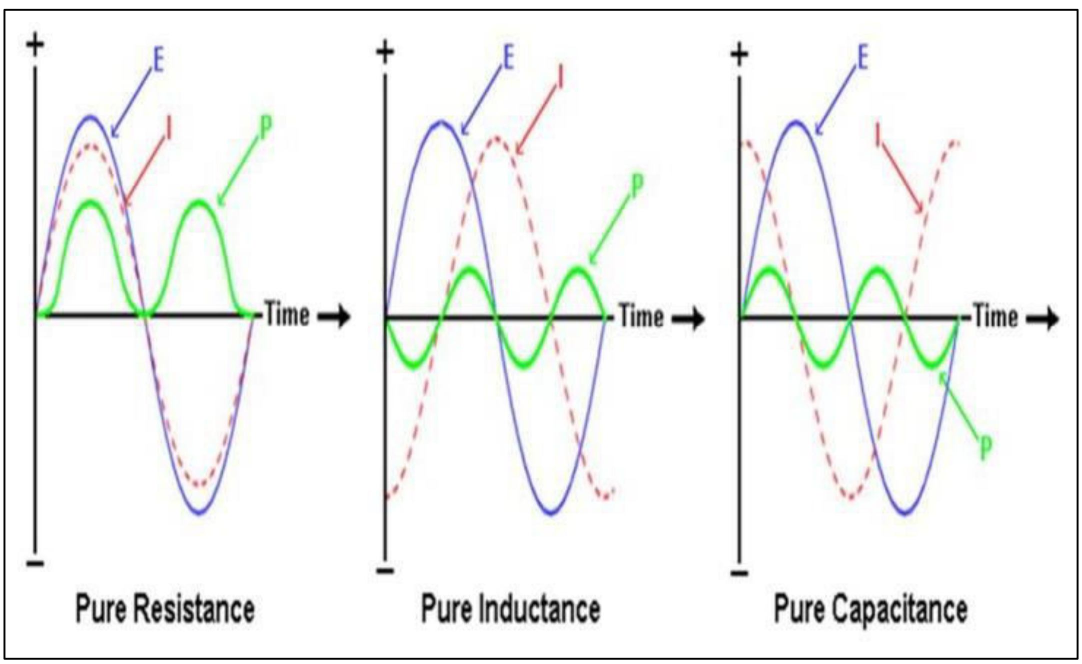

Fig 6: Waveforms of voltage and current with respect to time in different circuits

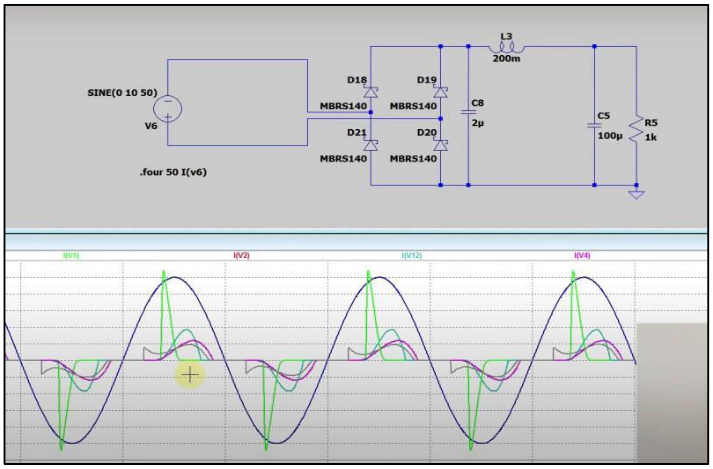

Fig 7: PFC circuit with RLC load

3. ADVANTAGES OF PFC

- Reduction in electricity bill due to reduced maximum demand.
- Improved voltage regulation in the system.
- Reduction in system losses
- Efficiency of plant increases, Overall cost per unit decreases.
- KW capacities of prime motors, alternators, transformers improve

4. ACTIVE AND PASSIVE PFC

The simplest form of PFC is passive PFC. Passive PFC uses a filter at the AC input to correct the low power factor. The Passive PFC circuitry uses only passive components – an inductor and some capacitors like in Fig 8. Although pleasantly simple and robust, a passive PFC infrequently circuit operates at the low line power frequency of 50 Hz or 60 Hz, the passive elements or components are typically bulky and big.[6]

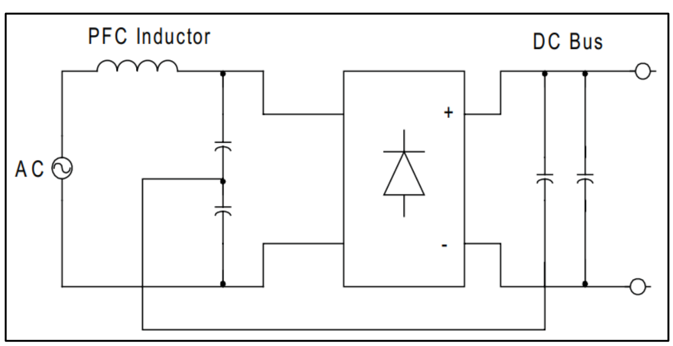

Fig 8: A passive PFC circuit requires only a few components to increase efficiency, but they are large due to operating at the line power frequency [5]

Active PFC offers better Total Harmonic Distortion (THD) and is significantly lower and lighter than a passive PFC circuit (Fig 9). To reduce the size and cost of passive filter elements, an active PFC operates at an advanced switching frequency than the 50 Hz - 60 Hz line frequency. Active PFC functions include:

1. Active wave shaping of the input current
2. Filtering of the high frequency switching
3. Feedback sensing of the source current for waveform control
4. Feedback control to regulate output voltage

Buck, boost, fly back and other converter topologies are used in active PFC circuits. The DC- DC converter input capacitor also benefits from active PFC. The capacitor can be sized to filter the high frequency ripple of the active PFC circuit rather of a much larger capacitor that would be required to smooth the 50- 60 Hz input. The regulated input of the DC- DC converter also demands a lower range of duty cycle from the DC- DC converter. Other benefits of active PFC include increased "hold-over-time." Hold over (brownout protection) benefits from always starting at the maximum voltage; the capacitor can be much lower than a capacitor in a converter without Active PFC.

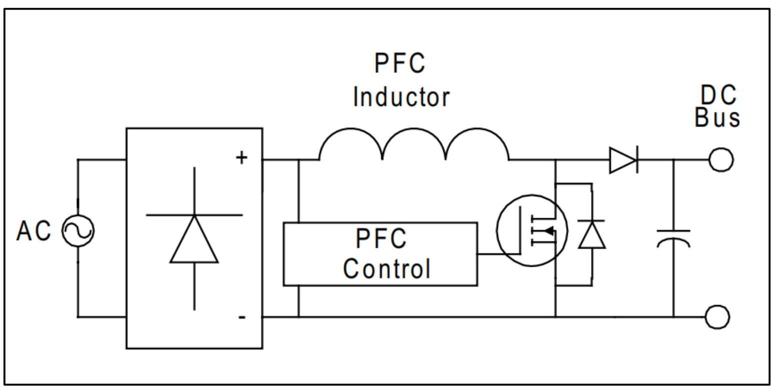

Fig 9: An active PFC circuit produces low THD and uses relatively small passive components.

5. MATLAB SIMULATION MODEL

There are two configurations of power factor correction circuit for MATLAB.[9] First circuit will not consist capacitor bank that is similar to the Before PFC section covered in Fig 4(a) and another circuit would consist capacitor bank just like the concept of After PFC, covered in Fig 4(b). The following MATLAB Simulation model consist of a block diagram and circuit implementation. It compares the circuits with and without capacitor bank usage.

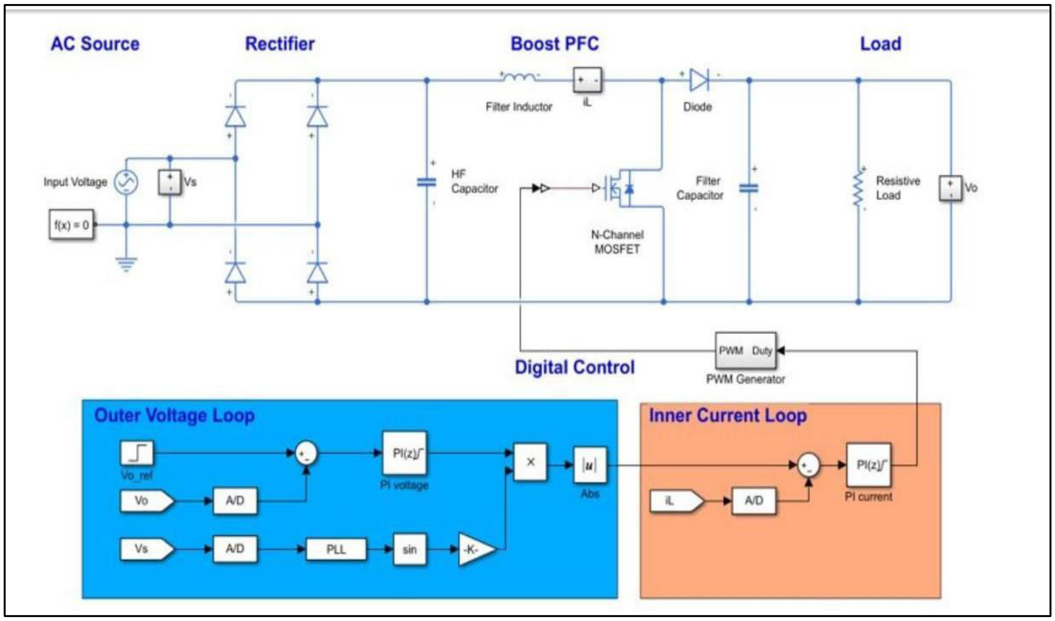

Fig 10: MATLAB Simulation Block Diagram

5.1 SIMULATION MODEL WITHOUT CAPACITOR BANK

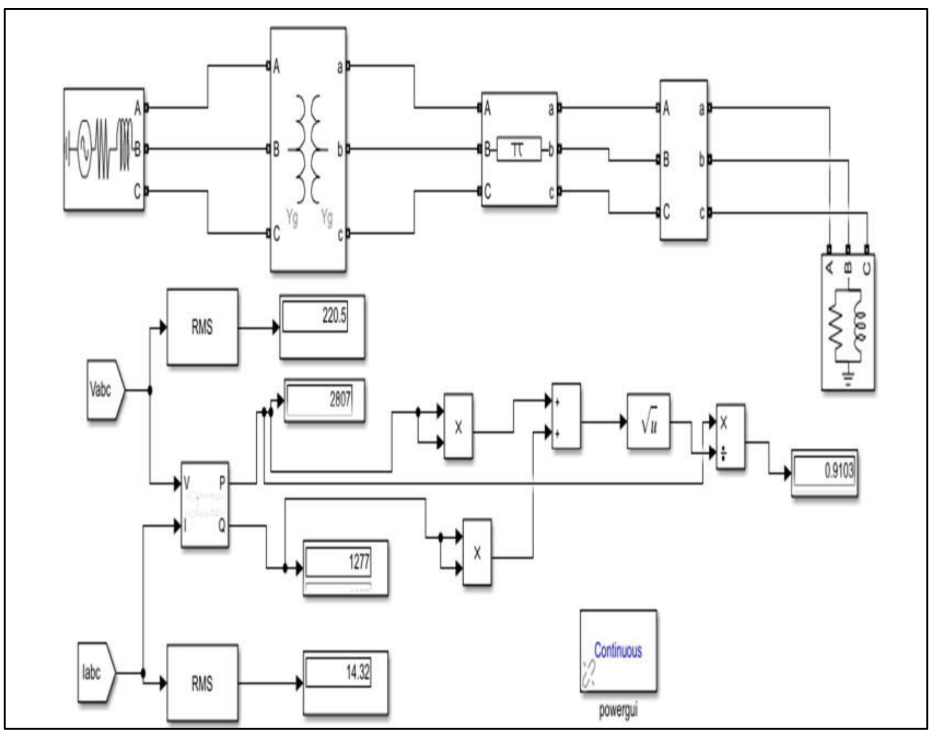

Fig 11: Simulation Model without capacitor bank

It contains generation system and output of the generator is connected to the 11kV/ 415v, 25MVA and the secondary of the transformer is transmitted through the transmission line and the output supply is connected the R- L load of 10kw, 5 KVAR which drawing the power factor the0.8944 to ameliorate the power factor of the system the computation the capacitor bank should be needed. In the below system there's no capacitor bank in between load and transmission line.

5.2 SIMUALTION MODEL WITH CAPACITOR BANK

After calculating the capacitor value it will be connected in between the line and load the power factor of the system will be improved power factor. The below numbers of filter forms will gives the values of terminal voltage and current.[9]

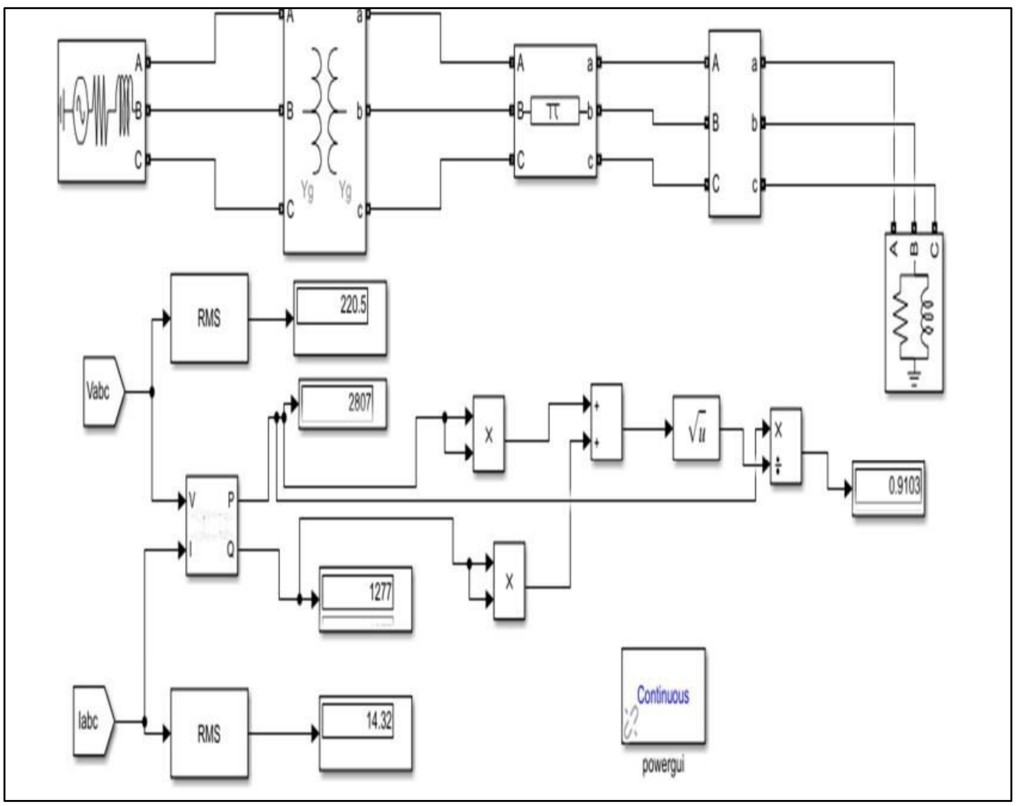

Fig 12: Simulation Model with Capacitor bank

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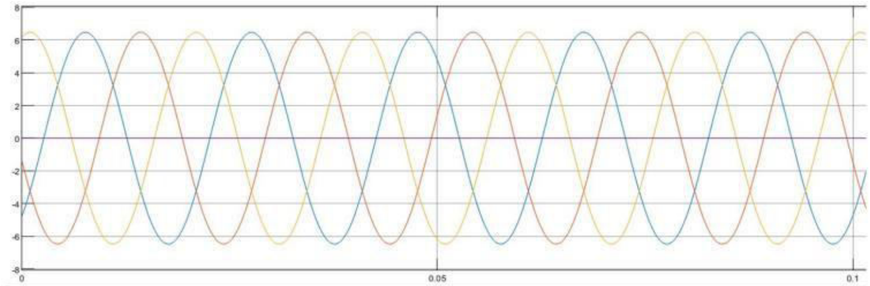

Fig 13: Input Current

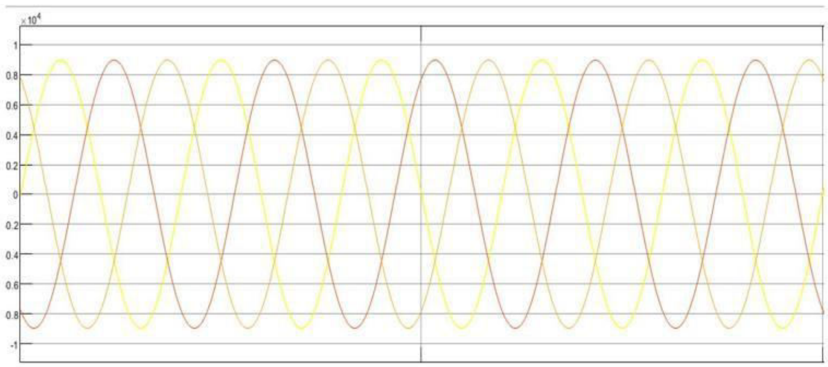

Fig 14: Output Voltage generated

6. CONCLUSION

If the input voltage is 230V, the output voltage of the regulator shall be 400V that corresponds to the desired value. Due to the bulky capacitor used between the conversion stage of the PFC to ACDC and the conversion stage of the boost regulator, the disadvantages of the double stage approach are higher costs. . This drawback is a one stage approach is available to overcoming this problem, the AC to DC and boost regulator stages of the PFC are integrated in a single stage, whereas the capacitor is replaced and exchanged by a single switch.

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