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Three-Phase Induction Motor Operation at Unity Power Factor

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Abstract—*In this paper the improvement of power factor of an induction motor by using shunt active power filter is presented. High power factor is the goal of any electrical utility company since if the power factor is low, more current is required to the user for a given amount of power used and with the low power factor more line losses occur. Induction motors are the most widely used due to their low cost, reliability and robustness. For mining and industrial applications, 3- phase induction motors are the prime movers and70% to 80% of all electricity in the world is consumed by induction motors. As we know that the power factor of an induction motor is very low at no load. Power factor is improved at increasing load from no load to full load. Power factor improvement is achieved by shunt active power filter.*

Keywords*: power factor, Three Phase Induction motor, active power filter*

1. INTRODUCTION

The objective of this paper is to design an energy saving scheme for an induction motor load. The low power factor leads to transfer more reactive power from the utility through the network. The main drawback of low power factor is that network loss is increased, voltage level is reduced and energy cost is more. The amount of power being used in a network is called real power. The combination of real power and reactive power is called apparent power. In power system load may be resistive, inductive, and capacitive. Example of resistive load is electric heater and incandescent lighting. Inductive loads are reactors, induction motors, transformers and capacitive loads are capacitor banks, motor starting capacitors and synchronous motors. Low power factor is not that much problem in domestic's area but it becomes a problem in industry where multiple large motors are used so there is requirement to correct the power factor. Thus Power factor correction (PFC) is usually achieved by adding capacitive load to offset the inductive load present in the power system. There are many benefits to having power factor correction.

2. POWER FACTOR

In an AC circuits there is a phase difference between voltage and current. The cosine of the angle between voltage and current is known as power factor of the circuit. If circuit is inductive, the current lags behind the voltage and associated power factor is lagging power factor and in case of capacitive circuits the current leads to voltage and power factor is called leading power factor.

The average power is expressed as

P= VI cos$

Where current and voltage are RMS values. Power factor of a purely resistive loads (incandescent lights, electric heating elements) are 1.0 (unity).

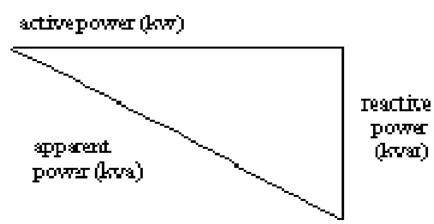


Fig. 1: Power triangle in terms of power

From the figure,

$$(KVA)^2 = (KW)^2 + (KVAR)^2$$

$$\text{Power factor } \cos\phi = \frac{\text{active power}}{\text{apparent power}} = \frac{KW}{KVA}$$

The source of excitation in an induction motor is the stator input. The induction motor operates at a lagging power factor. The power factor is very low at no load and increases to 85 to 90 percent at full load, the power factor improvement being caused due to increment in real-power requirements with increasing load. The air-gap between the stator and rotor of an induction motor increases the reluctance of the magnetic circuit. Consequently, an induction motor draws a more magnetizing current (Im) to produce required field flux in the air-gap.

(i) At no load, an induction motor draws a more magnetizing current and less active component to meet the no-load losses.

Therefore, the induction motor takes large lagging no load current. Therefore the power factor of an induction motor on no load is low i.e., about 0.15 lagging.

(ii) As the load increases on induction motor the active component of current is increased while the magnetizing current remains about the same. Consequently, the power factor of the motor increases. The power factor of an induction motor at full load improves to 0.9 lagging [10].

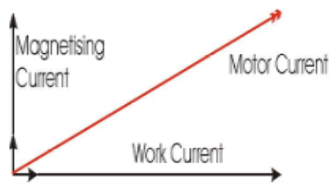


Fig. 2: Current components of an induction motor.

The magnetizing current establishes the flux in the iron core and it is very necessary for the motor to be operating. The magnetizing current does not contribute to the actual work of the motor. It is necessary that allows the motor to work properly.

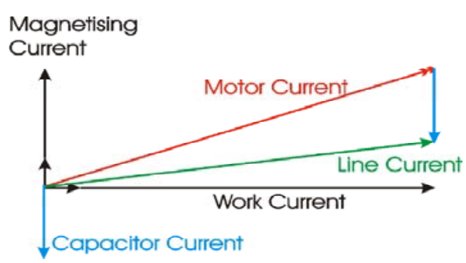


Fig. 3: Current components after adding capacitor.

3. SIMULATION MODEL AND RESULTS:

Using Simulink toolbar and its respective library, a sequence of models can be created to meet the requirements.

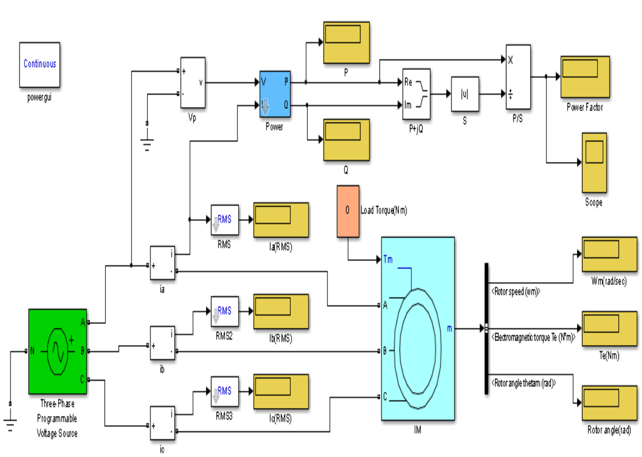


Fig. 8: Simulink model of a 3-Phase Induction Motor

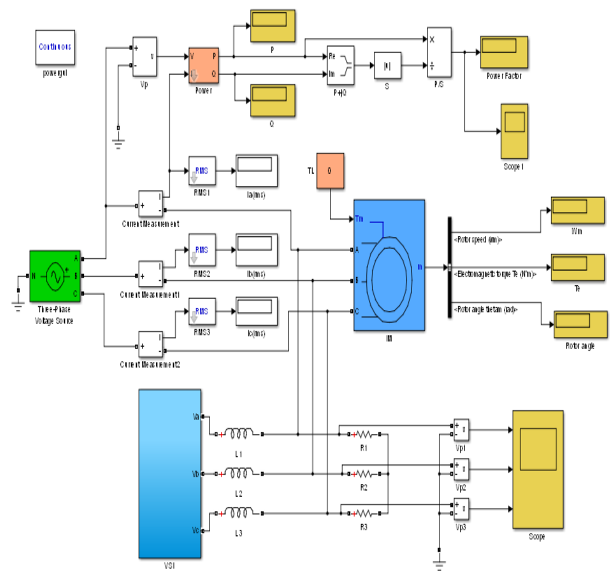
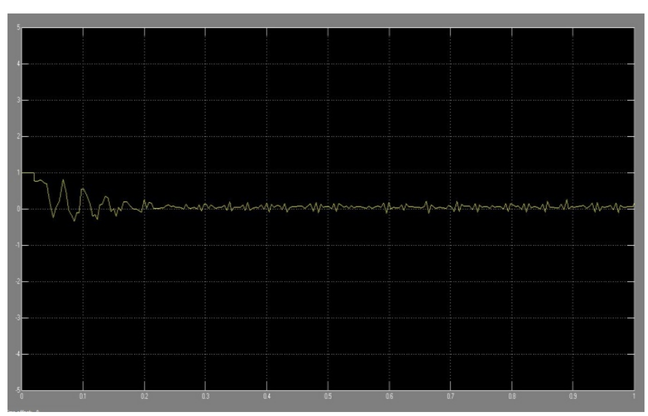


Fig. 9: Simulink model of a 3-Phase Induction Motor Using Active Power Filter

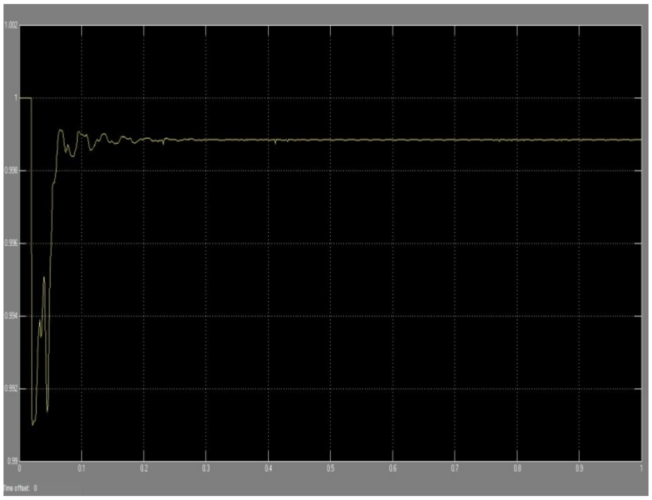
Table 1: Comparison of Power Factor without any compensation and with Active Power Filter

Sr. no	Motor Load Factor	Power Factor without compensation	Power Factor with active power filter compensation
1	Unloaded	0.15	0.998
2	¼ loaded	0.62	0.998
3	½ loaded	0.82	0.998
4	¾ loaded	0.86	0.998
5	Full loaded	0.89	0.998
6	Overloaded	0.91	0.998

In the table 1, it shows that power factor is improved by using active power filter. Power factor is very low at no load it can be improved from 0.15 to the 0.91 at full load. By using active power filter the power factor is near to unity at different loads Simulation results are given above.



Graph 1: Plot of pf without compensation



Graph 2: Plot of pf with active power filter compensation

4. CONCLUSIONS

In this paper a power factor improvement system for three-phase induction motor has been presented. The system has employed a shunt active power filter to be connected to the supply with induction motor directly. The performance of two-loop control strategy is analyzed through transfer function. The system is modeled and simulated to provide theoretical reference. Experimental results show that motor will operate with unity power factor, at the same time, the ac supply provides only active current and transmission loss of electrical wire is decreased.

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