

Power Factor Improvement of Induction Motor by Using Capacitors

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Abstract— This paper describes the improvement of power factor of an induction motor by using capacitor bank. When power factor is improved, automatically energy will be saved. A power factor is the goal of any electrical utility company since if the power factor is less than one, they have to supply more current to the user for a given amount of power use. In so doing they occur more line losses. Induction motors are the most widely used electrical motors due to their reliability, low cost and robustness. For industrial and mining applications, 3-phase AC induction motors are the prime movers for the vast majority of machines. It has been estimated that 70% to 80% of all electricity in the world is consumed by these motors. At no load induction motor has very low power factor. It improves at increasing load from no load to full load. Power factor correction is achieved by the addition of capacitors in parallel with the connected motor circuits and can be applied at the starter, or applied at the switchboard or distribution panel.

Keywords— Induction motor, simulation, power factor, power factor correction etc.

I. INTRODUCTION

The main objective of this study is to design an energy saving scheme for an industrial distribution network. This can be achieved by decreasing the network losses and improving the main electric load operation to a better efficiency level. The designed scheme is concerned with improving the power factor of the distribution network by adding shunt capacitors to the network at optimal size and location. Industrial power distribution networks encounters increase in power losses and increase in the type of load is accompanied with low power factor which leads to huge transfer of reactive power from the utility through the network. The main drawback of this problem is increase in the network losses and reduction in the voltage level. It can result in poor reliability, safety problems and higher energy costs. The lower our power factor, the less economically our system operates. The actual amount of power being used or dissipated in a circuit is called true power. Reactive loads such as inductors and capacitors make up what is called reactive power. The linear combination of true power and reactive power is called apparent power. Power system loads consist of resistive, inductive, and capacitive loads. Examples of resistive loads are incandescent lighting and

electric heaters. Inductive loads are induction motors, transformers, and reactors and capacitive loads are capacitors, variable or fixed capacitor banks, motor starting capacitors, generators, 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.

II Power factor

In an ac circuits there is generally a phase difference between voltage and current. The term $\cos \phi$ is known as power factor of the circuit. If the circuit is inductive, the current is lags behind the voltage and the power factor is called lagging power factor and if the circuit is capacitive then current leads to voltage and power factor is said to be leading power factor.

The average power in an ac circuit is expressed in terms of rms current and voltage

$$P = VI \cos \phi$$

A purely resistive load (incandescent lights, electric heating elements) would have a power factor of 1.0 (unity).

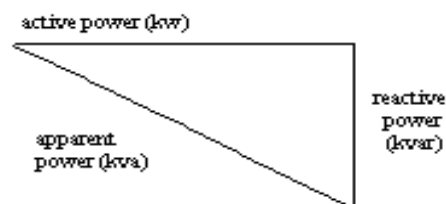


Fig 1 Power factor triangle in terms of power

From the figure

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

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

Thus, power factor may also be defined as the ratio of active power to the apparent power. This is perfectly general definition and can be applied to all cases.

Power factor correction is a technique of counteracting the undesirable effects of electrical loads that create a power factor that is less than one. Power factor correction may be applied either by an electrical power transmission utility to improve the stability and efficiency of the transmission network or correction may be installed by individual electrical customers to reduce the cost charges to them by their electricity suppliers.

Low power factor is an issue, which can be solved by adding power factor correction capacitors to the plant distribution system. Capacitors work as reactive current generators "providing" needed reactive power (KVAR) into the power supply. By supplying their own source of reactive power, the industrial user frees the utility from having to supply it, and therefore the total amount of apparent power supplied by the utility will be less. Power factor correction capacitors reduce the total current drawn from the distribution system and subsequently increase the system's capacity by raising the power factor level.

A. POWER FACTOR OF AN INDUCTION MOTOR

The only possible source of excitation in an induction machine is the stator input. The induction motor therefore must operate at a lagging power factor. This power factor is very low at no load and increases to about 85 to 90 percent at full load, the improvement being caused by the increased real-power requirements with increasing load.

The presence of air-gap between the stator and rotor of an induction motor greatly increases the reluctance of the magnetic circuit. Consequently, an induction motor draws a large magnetizing current (I_m) to produce the required flux in the air-gap.

- (i) At no load, an induction motor draws a large magnetizing current and a small active component to meet the no-load losses. Therefore, the induction motor takes a high no-load current lagging the applied voltage by a large angle. Hence the power factor of an induction motor on no load is low i.e., about 0.1 lagging.
- (ii) When an induction motor is loaded, the active component of current increases while the magnetizing component remains about the same. Consequently, the power factor of the motor is increased. However, because of the large value of magnetizing current, which is present regardless of load, the power factor of an induction motor even at full load seldom exceeds 0.9 lagging[10].

Induction machine may become self-excitation when a sufficiently heavy capacitive load is present in their stator circuits. The capacitive current then furnishes the excitation and may cause serious overvoltage or excessive transient torques.

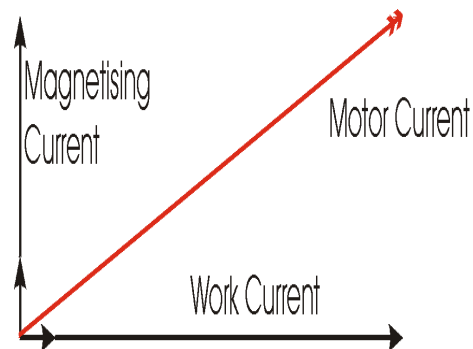


Fig 2 Current components of an induction motor [22]

- The magnetizing current is the current that establishes the flux in the iron and is very necessary if the motor is going to operate. The magnetizing current does not actually contribute to the actual work output of the motor. It is the catalyst that allows the motor to work properly.
- The magnetizing current and the leakage reactance can be considered passenger components of current that will not affect the power drawn by the motor, but will contribute to the power dissipated in the supply and distribution system.

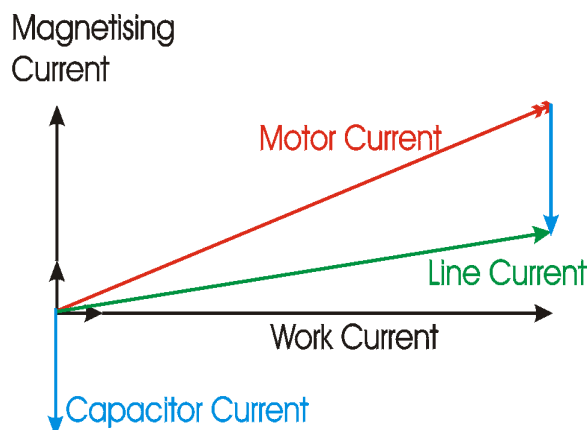


Fig 3 Current components after adding capacitor current

In the interest of reducing the losses in the distribution system, power factor correction is added to neutralize a portion of the magnetizing current of the motor. Typically, the corrected power factor will be 0.92 - 0.95 some power retailers offer incentives for operating with a power factor of better than 0.9, while others penalize consumers with a poor power factor. There are many ways that this is metered, but the net result is that in order to reduce wasted energy in the distribution system, thus the consumer will be encouraged to apply power factor correction [22].

III. SIMULATION AND RESULTS

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

SIMULATION MODEL AT NO LAOD WITHOUT CAPACITOR

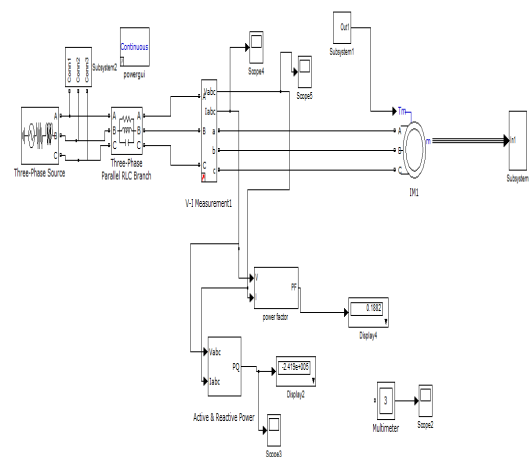


Fig 4 Simulink model of 50 hp induction motor at no load

TABLE I

POWER FACTOR AT DIFFERERNT LOAD CONDITIONS

Sr. no.	Motor load factor	Power factor
1.	Unloaded	17 % (0.17)
2.	¼ loaded	55% (0.55)
3.	½ loaded	73% (0.73)
4.	¾ loaded	80% (0.80)
5.	Full loaded	84% (0.84)
6.	Overloaded (25%)	86% (0.86)

SIMULATION MODEL AT FULL LAOD WITH CAPACITOR

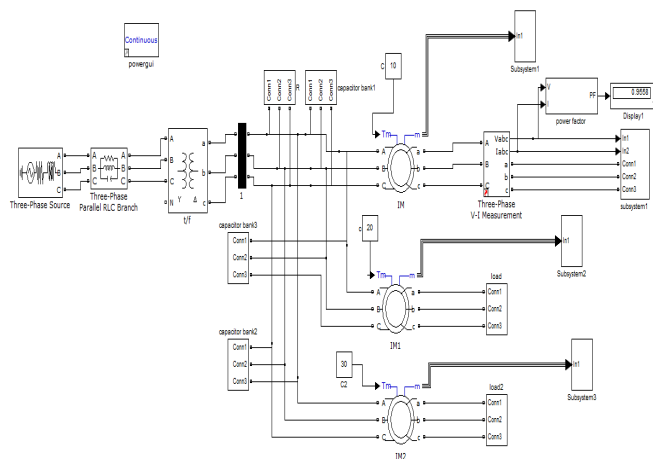


Fig 5 Simulation model of three IM connected in parallel with capacitor bank (after PFC)

TABLE III
AFTER POWER FACTOR CORRECTION

LOAD	CAPACITOR VALUE (micro farad)	POWER FACTOR
200	4	0.9300
200	5	0.9311
200	6	0.9345
200	7	0.9558
200	8	0.9766

In the table II, it shows that power factor is improved by using capacitors. Power factor is very low at no load it can be improved from 0.17 to the 0.95 at full load. Simulation results are given below. Here rotor current, speed and torque of induction motors at full load is shown in fig 6, fig 7 and fig 8.

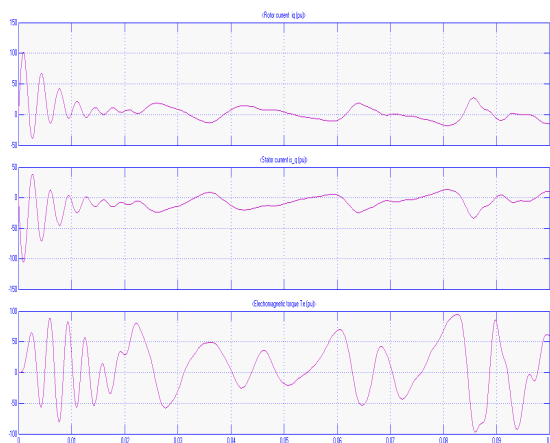


Fig 6 Rotor current, stator current and torque of first motor at load 200 KW

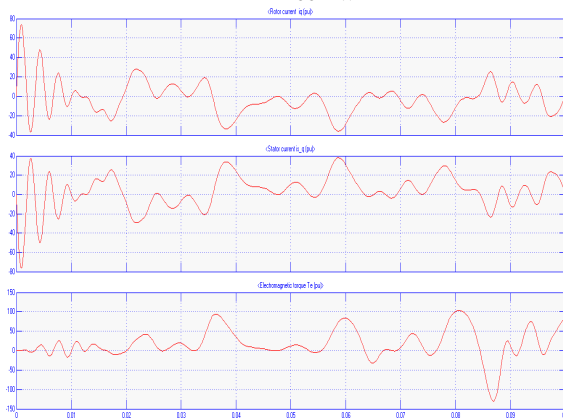


Fig 7 Rotor current, stator current and torque of second motor at 200 KW load

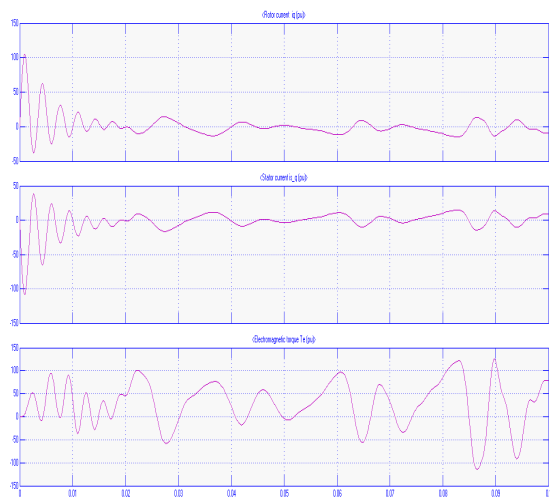


Fig 8 Rotor current, stator current and torque of third motor at load 200 KW

IV. CONCLUSIONS

After measurements and results obtained measuring the electrical characteristics of induction machine we have come to the following conclusions:

A reduction in the overall cost of electricity can be achieved by improving the power factor to a more economic level. The supply will be able to support additional load which may be of benefit for an expanding company. Reducing the load on distribution network components by power factor improvement will result in an extension of their use. It can also be installed in a shorter period of time and is not subject to environmental considerations such as shading or weather.

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