Electric Machines Laboratory
(EE2P003)

EXPERIMENT-3

POWER FACTOR IMPROVEMENT OF 3 PHASE INDUCTION MOTOR

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Aim:

TO STUDY THE POWER FACTOR IMPROVEMENT OF A 3-PHASE LOAD BY CAPACITOR BANK.

APPARATUS:

INSTRUMENTS / EQUIPMENTS

SL.NO	INSTRUMENTS /EQUIPMENTS	TYPE	SPECIFICATION	QUANTITY
1	3-$\varnothing$ VARIAC	IRON CORE	10A, 415 V	1 NO.
2	WATTMETER	LPF	5A, 600V, 0.2 P. F	2 NO. S
3	VOLTMETER	MI	(0-600 V)	1 NO.
4	AMMETER	MI	(0-10 A)	2 NO. S
5	WATTMETER	UPF	10A, 600V	2 NO. S
6	3-PH. CAPACITOR BANK		440V, (0-40) μF	1 NO.
7	CONNECTING WIRES	Cu	1.5 sq.mm	AS REQUIRED

MACHINES REQUIRED

SL.NO	MACHINE	SPECIFICATION	QUANTITY
1	3-ΦInduction Motor	3.7 kW / 5 HP, 1430 RPM 415 V, 7.8 A, Delta connection.	1 No

Theory:

In power systems, wasted energy capacity, also known as poor powerfactor, is often

Overlooked. It can result in poor reliability, safety problems and higherenergy costs. The lower your power factor, the less economically your system operates.

Power factor is the ratio between the real power and the apparent powerdrawn by an electrical load. Like all ratio measurements it is a unit-lessquantity and can be represented mathematically as

P.F. = $\frac{(APPARENT\ POWER\ (kVA)}{TRUE\ POWER\ (kW)}$.

Where, pf is power factor, kw is the real power that actually does the work,kva is the apparent power and kvar (not included in the equation) is the reactive power. In an inductive load, such as a motor, active power performs the work and reactive power creates the electromagnetic field.

For the purely resistive circuit, the power factor is 1 (perfect), because the reactive power equals to zero. Here, the power triangle would look like ahorizontal line, because the opposite (reactive power) side would have zerolength.

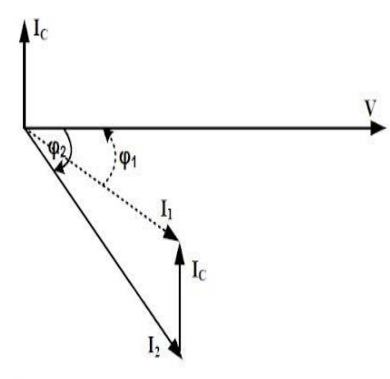
For the purely inductive circuit, the power factor is 0, because true powerequals zero. Here the power triangle.

Would look like a vertical line, because the adjacent (true power) side would have zero length. The same could be said for a purely capacitive circuit. If there are no dissipative (resistive) components in the circuit, then the true power must be equal to zero, making any power in the circuit purely reactive. The power triangle for a purely capacitive circuit would again be a vertical line (pointing down instead of up as it was for the purelyinductive circuit).

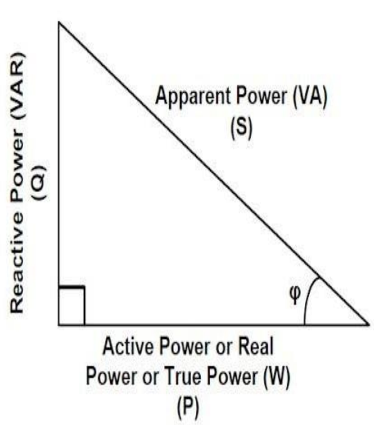
Power factor can be an important aspect to consider in an ac circuit, because any power factor less than 1 means that the circuit's wiring has to carry more current than what would be necessary with zero reactance in the circuit to deliver the same amount of (true) power to the resistive load. The poor power factor makes for an inefficient power delivery system. Poor Power factor can be corrected, paradoxically, by adding another load to the circuit drawing an equal and opposite amount of reactive power, to cancel out the effects of the load's inductive reactance. Inductive reactance can only be canceled by capacitive reactance, so we have to add a capacitor in parallel to our example circuit as the additional load. The effect of these two-opposing reactance in parallel is to bring the circuit's total impedance equal to its total resistance (to make the impedance phase angle equal, or at least closer, to zero).

Power factor measures how efficiently the current is being converted intoreal work with a low power factor, more electrical current is required to provide the same amount of real power. All current causes dissipation in a distribution

System. These losses can be modeled as (loss – i2*r), where r is the resistance. A power factor of 1 will result in the most efficient loading of the supply' a load with a power factor of 0.5 will result in higher losses in the distribution system.

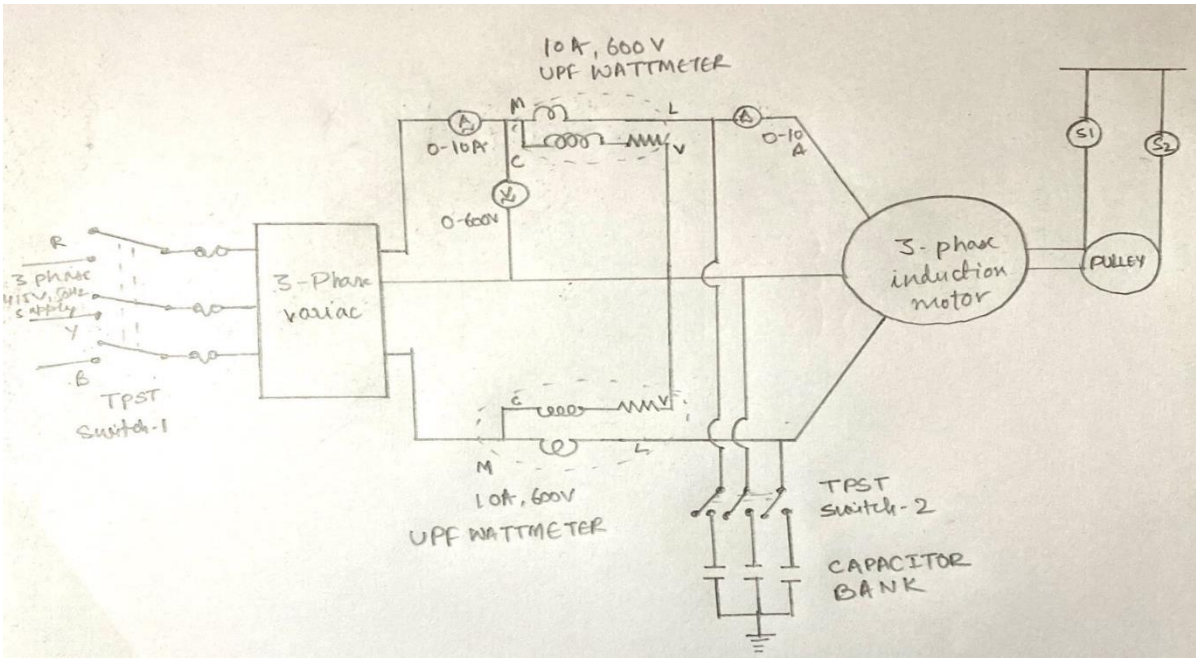


[Phasor Diagram for Power factor improvement by Capacitor Bank]



[Power Triangle]

Circuit Diagram:



PRECAUTIONS:

- CONNECTION SHOULD BE RIGHT AND TIGHT.
- CHECK THE CIRCUIT CONNECTION THOROUGHLY BEFORE SWITCHING ON THE SUPPLY.
- INSTRUMENTS SHOULD BE CONNECTED IN PROPER POLARITY AND RANGE.
- DO NOT TOUCH ANY NON-INSULATED PART OF ANY INSTRUMENT OR EQUIPMENT.
- BE ENSURED THE ZERO SETTING OF INSTRUMENT IS ON RIGHT POSITION. AVOID PARALLAX ERROR.
- BEFORE SWITCHING ON THE SUPPLY SET THE 3-① VARIAC AT ITS MINIMUM POSITION.

PROCEDURE:

- MAKE THE CONNECTION AS PER THE CIRCUIT DIAGRAM.
- KEEP T.P.S.T.-2 OPEN AND T.P.S.T.-1 CLOSE TO CONDUCT FULL-LOAD TEST WITHOUT CAPACITOR BANK.
- KEEP BOTH T.P.S.T.-2 AND T.P.S.T.-1 CLOSE TO CONDUCT FULL-LOAD TEST WITH CAPACITOR BANK.

- INCREASE THE LOAD UP TO RATED CURRENT WITH RATED VOLTAGE FOR BOTH CASES.
- TAKE THE READINGS OF THE WATTMETER'S IN WATT (W1 AND W2) AMMETER IN AMPERE (I) AND VOLTMETER IN VOLT (VL).

OBSERVATION:

FOR TESTING WITHOUT CAPACITOR BANK

SL.NO	V_L	I_1	I_2	W_1	W_2	$P_L = W_1 + W_2$	$\cos cos \varnothing_2$
1 (NO LOAD)	415	3.9	3.9	116*8 = 928	-65*8 = -520	408	0.16057
2(WITH LOAD)	415	5.2	5.2	250*8 = 2000	80*8 = 640	2640	0.7461

FOR TESTING WITH CAPACITOR BANK

SL.NO	V_L	I_1	I_2	W_1	W_2	$P_L = W_1 + W_2$	$\cos cos \varnothing_1$
1 (NO LOAD)	415	2.6	3.9	92*8 = 736	-41*8 = -328	408	0.21615
2 (WITH LOAD)	415	4.3	5.2	220*8 = 1760	100*8 = 800	2560	0.8386

CALCULATIONS:

For no load test

without capacitor: without capacitor

$W_1 = 928\ W$, $W_1 = -520W$

$$\tan\phi_0 = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$$

$$= \sqrt{3}\ \frac{(928+520)}{408} = 6.14$$

$$\phi_0 = 80.75^\circ$$

$$\cos\phi_0 = 0.16057$$

with capacitor

$W_1 = 736\ W$, $W_2 = -328\ W$

$$\tan\phi = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right) = \sqrt{3}\left(\frac{736+328}{736-328}\right)$$

$$\phi = \cancel{47} \ 47.5^\circ$$

$$\cos\phi = 0.21615$$

For with-load Test

Without capacitor bank

$W_1 = 2000\ W$, $W_2 = 640W$

$$\tan\phi = \sqrt{3}\left(\frac{2000-640}{2000+640}\right)$$

$$\phi = 41.74^\circ$$

$$\cos\phi = 0.7461$$

With capacitor bank

$W_1 = 1760W$, $W_2 = 800W$

$$\tan\phi = \sqrt{3}\left(\frac{1760-800}{1760+800}\right)$$

$$\phi = 33.004^\circ$$

$$\boxed{\cos\phi = 0.8386}$$

CONCLUSION

Connections were made properly and carefully. Readings of different voltameters, ammeters, and wattmeters were taken carefully without any parallax error. The power factors in both cases i.e., with and without capacitor banks were calculated. Page | 6 we there after found that the power factor has been increased after connecting the power bank. Thereby, we also accomplished our aim to study the power factor improvement of a 3- phase load by capacitor bank successfully.

DISCUSSION

1. **IS THERE ANY ALTERNATIVE METHOD TO IMPROVE POWER FACTOR? DISCUSS ABOUT ITS ADVANTAGES AND DISADVANTAGES AS COMPAREDTO CAPACITOR METHOD?**

Another way to improve the power factor is to use a 3 phase synchronous motor which is over excited and runs on no load. This setup is known as the synchronous condenser. The interesting part is that the synchronous motor can operate under leading, lagging or unity power factor.
When a Synchronous motor operates at No-Load and is over-excited then it's called a synchronous Condenser. Whenever a Synchronous motor is over-excited then it provides leading current and works like a capacitor. When a synchronous condenser is connected across supply voltage (in parallel) then it draws leading current and partially eliminates the re-active component and this way, power factor is improved. Generally, synchronous condensers are used to improve the power factor in large industries.

Advantages:
¬ Long life (almost 25 years)
¬ High Reliability
¬ Stepless adjustment of power factor.
¬ No generation of harmonics of maintenance
¬ The faults can be removed easily ¬ It's not affected by harmonics.
¬ Require Low maintenance (only periodic bearing greasing is necessary)

Disadvantages:

¬ It is expensive (maintenance cost is also high) and therefore mostly used by large power users.

¬ An auxiliary device has to be used for this operation because synchronous motor has no self-starting torque

¬ It produces noise

2. WHAT ARE THE DISADVANTAGES OF LOW POWER FACTOR?

- Higher current is required by the equipment, due to which the economic cost of the equipment is increased.
- At low power factor, the current is high which gives rise to high copper losses in the system.
- Main disadvantages of low power factor in our electrical system.
- Large kva rating and size of electrical equipment
- Greater conductor size and cost of transmission line
- High transmission loss hence poor efficiency
- Poor voltage regulation
- Penalty from power supply company

3. HOW TO IMPROVE POWER FACTOR IN CASE IT LEADS?

Minimize operation of idling or lightly loaded motors. Avoid operation of equipment above its rated voltage. Replace standard motors as they burn out with energy-efficient motors. Even with energy-efficient motors, however, the power factor is significantly affected by variations in load.