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WHEN DOES PF IMPROVEMENT REDUCE ENERGY CONSUMPTION / COST.

1. A very brief overview on what is Reactive Power & Power factor :

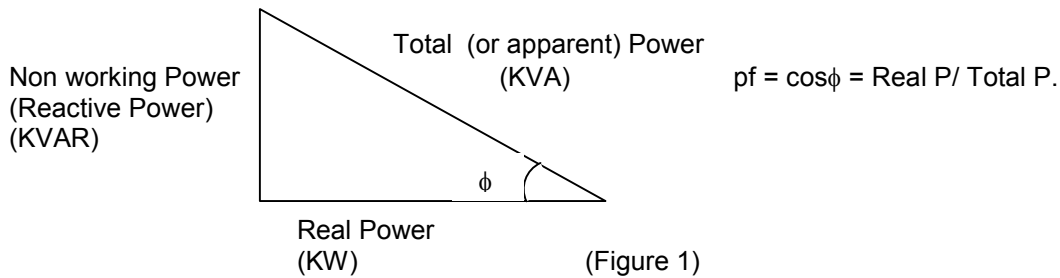
Unlike resistive loads in which the current is used to create heat for the work output, inductive loads like motors in a factory use require the current to create a magnetic field, and the magnetic field produces the desired work.

This total (or apparent) power required by an inductive device comprises the following:

- Real power (measured in kilowatts, kW)
- Reactive power, the nonworking power caused by the magnetizing current, required to operate & sustain the magnetism in the device (measured in kilovars, KVAR)

Reactive power required by inductive loads increases the amount of apparent power (measured in kVA) in the distribution system. The increase in reactive and apparent power causes the power factor to decrease.

Power factor is defined as the ratio of the real power to the apparent power. As seen from the simplest diagram below representing the same,



2. Understanding the concepts & benefits through a case study :

2.1 Equipment details & procedure:

Let us consider the impact & benefits of Power factor corrections through an illustration This can be replicated at any site & with the help of portable energy analyzers.

The equipment considered for data is a fan motor that is installed in our factory.

The name plate motor rating is as follows:

NGEF make, 22KW,415V,40A,1465 rpm.

The fan motor was run on same normal load in 2 conditions -

1. Without any power factor improvement, at the nominal actual motor pf of 0.84.
2. With Power factor improvement at the motor starter feeder by connecting a 3 phase 5 KVAR capacitor, which improved the power factor from 0.84 to 0.94.

In both the conditions above, the fan motor was run for half an hour each & the parameters recorded.

2.2 Data Results :

1. Without improvement in pf in feeder, at the end of 30 minutes, the data was as follows : (Fig 2)

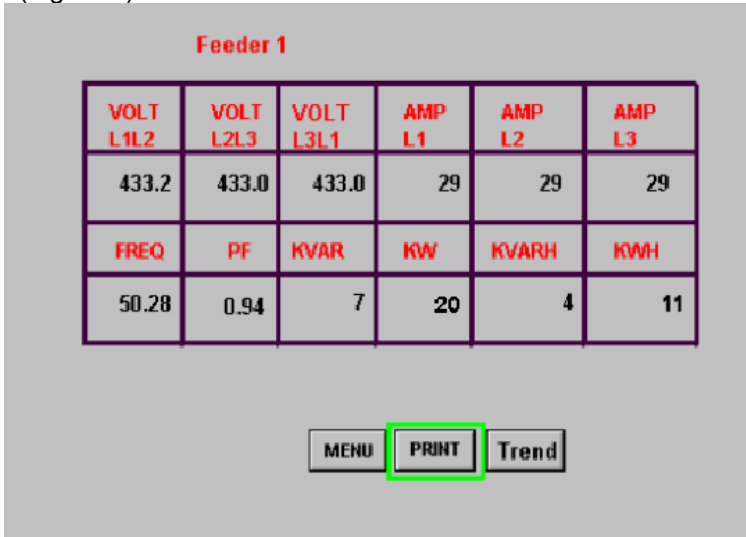
Feeder 1

VOLT L1L2	VOLT L2L3	VOLT L3L1	AMP L1	AMP L2	AMP L3
433.0	433.0	433.0	33	33	33
FREQ	PF	KVAR	KW	KVARH	KWH
50.39	0.84	13	20	7	11

(The above Fig 2 is a snapshot from the energy analyzer just a fraction of a second before motor shut off).

2. After connecting a 5KVAR capacitor to the feeder of the motor, the drive was run for another half an hour & the parameters monitored again.

(Figure 3)



As seen from the parameters (Fig 2 & Fig 3), what has been done is a pf correction from 0.84 to 0.94 using the most common method of a capacitor.

The summation of results is as follows:

	1 st Trial	2 nd Trial
Mode	Normal	With Capacitor to improve pf
Pf	0.84	0.94
Trial time in mins.	30	30
Amps taken by motor	33	29
KVAR	13	7
KW	20	20
KVARH	7	4
KWH	11	11
KVA (calculated)	23	21

The data when viewed directly shows that although there is a reduction in current by 4 Amps, there is no appreciable change in KW & hence the KWH.
(Statement 1).

2.3 Interpretation of results

2.3.1 Reduction in Electricity Cost:

For many connected motors in a system, as in any industry, on pf improvement, the following direct benefit will accrue to the consumer as Electricity cost:

1. In case the tariff structure is one that considers the KVA / KVAH drawn as a component for billing, the above situation shows that the consumer would stand to benefit.
2. Moreover, in some cases there is a direct sop offered, usually as a % of the units consumed, for e.g. 0.5% of the energy cost for every 0.01 pf improvement over & above 0.9 which is normally a substantial amount. (Normally there is a reverse penalty also in case pf falls below the benchmark)

This is a case that would result in direct cost benefit to the Consumer.

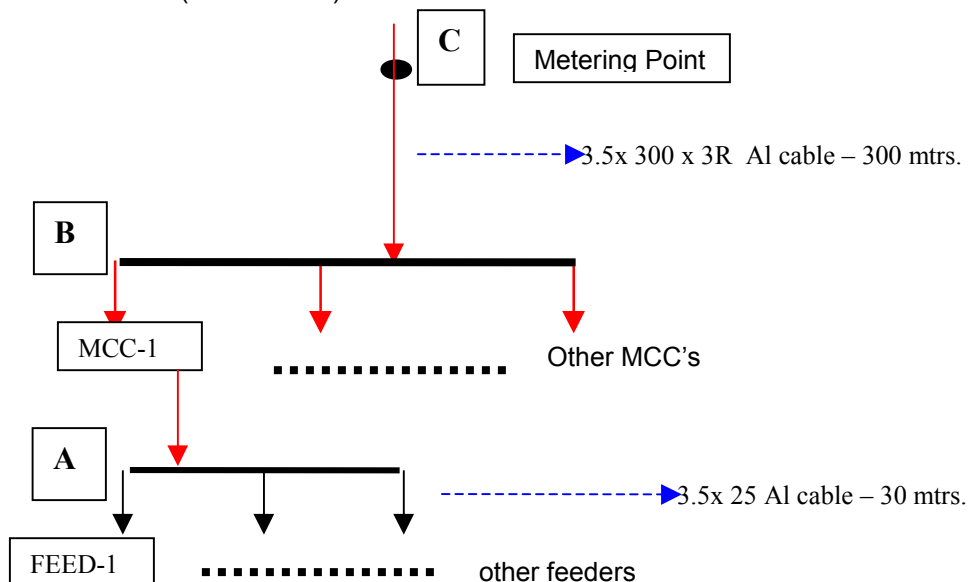
2.3.2 Reduction in Electricity Consumption:

What the consumer sees or infers as Statement 1 from the example above, is one reason why people argue that the process of pf improvement would not benefit unless the tariff offers benefit for the same. But, this is not the case.

To explain this, Let us proceed further on the same data collected above:

1. We have reduced the non working Power of the motor from 7KVAR to 4KVARH during the 30 mins operation period. This has to translate in the improved efficiency. One place it reflects in is the KVA rating. So, if there is an improvement of 2 KVA for 1 drive on pf improvement by 0.1, in case there are approx 100 drives, it would result in huge reduction in KVA thereby actually indirectly enhancing operating & transmission capacities since Generator / Transformer are all rated for their KVA.
2. Lower Current through the cable (By 4 Amps from the table) actually means lower heat loss & hence lower power loss through the supply cable. In the example above, energy monitoring has been done at the feeder level (at Point A in Fig 4 below), where the Power factor correction has been made.

Let us consider a very simple SLD (Figure 4). Here starter feeders are located locally near the motor ("Feed 1" etc).



Actual plant models could include PCC/Transformer & HT supply source but the principle would remain the same.

Suppose the above motor is connected to Feeder – 1 on MCC-1 with cable details & connections as shown for 1 motor connected on Feeder # 1.

The difference in I²R loss component from A to C , the point where the Grid bills the Consumer, or when the I²R component is considered even further upto the point of Grid distribution there would definitely be a reduction in KWH component.

2.3.3 Calculation on KWH saved through I²R loss :

We can calculate the cable loss by using the formula $I_{(diff)}^2 \times r$, where “r” is the cable resistance & $I_{(diff)}$ is the difference in current drawn with & without using pf improvement.

1. From Feeder to MCC

The cable resistance for a single core of 25 sqmm is approx 1.4 Ω / km. Hence for a 3 ph conductor of 30 mtrs length, cable resistance is
 $= 1.4 \times 3 \times 30 / 1000 = 0.09 \Omega$

Power loss on cable = $r = 0.126 \Omega$

Calculating the saving in Power loss , on this cable, it will be

$= (4)^2 \times 0.126 = 2.016 \text{ Watt.}$ (At MCC-1 in the diagram, although low to reflect on a meter).

Even In case there are 100 such motors on the MCC's in the diagram, the Power saving would be

$= 100 \times 2.016 = 201.6 \text{ W.}$ (when monitored from MCC level).

2. From MCC to Metering point (Supply source)

By Kirchoff's law, the sum of all ($I_{(diff)}$) of all motors on the MCC would be the differential current on the cable from the MCC to the metering point (Point B to C)

Say, for 300 meters of average length of all MCC's from the metering point
This differential current would be $= 4 \times 100 = 400 \text{ Amps.}$

In case this cable is of 3Run x 3.5x 300 sqmm (with resistance of 0.1 Ω / km), current carried by individual run is $400/3 = 133.3 \text{ Amps}$

Reduction in Power loss on the cable from MCC to metering point
 $= \frac{(133.3)^2 \times (0.1 \times 3 \times 300)}{(1000)} \text{ W}$

$= 1.6 \text{ KW}$

∴ Total saving = 1.6 + 0.2016 = 1.802 KW.

This translates to approx 43 units per day. (At point C).

The above calculation is a very simplified version on small motor models with 0.1 pf improvement only. When this model is replicated to actual plant motors that run on considerably low pf's & the cumulative effects of these losses & the reactive losses the cables themselves have, the saving in KW will be much higher.

2.4 Concept of Economic Power factor:

At the same time, this again does not mean that a 1.0 pf is always the most "economic Power factor" for the consumer. In case the pf at the consumer end is not very low or the total KW consumption is on a much lower scale & confined to a very small area, connected to a Grid that does not charge based on KVA/offer discounts, the consumer is dependent entirely on the component of KWH saving as calculated by the above working for reducing his electricity costs. In this case, when the cost of installing the Capacitors & their panel etc is considered, it may work out that a pf that is maybe lower than 1.0 is the most "economic Power factor". This can be calculated in a simple way as shown in the example, along with pf improvement tables.

2.5 Inference:

Undoubtedly, there is a direct cost benefit the Consumer may get on KVA tariff / pf rebate. Even otherwise, The same example above which made us believe that there is no change in KWH initially, shows that there is actually a reduction in energy consumption when it is viewed at a macro level. Similarly, every consumer is connected to the Grid & if those distribution lengths are also to be considered, there is obviously a reduction in energy that would be measurable & considerable at an upstream point. The immediate monitoring within the consumer premise may/may not reflect it substantially, but where there is a reduction in current drawn with improvement in pf, the KVARH component will decrease. This is a Non working component as described above. This saving has to necessarily reflect in reduced energy consumption directly in 2 major components

1. As a KVA improvement for generating stations/ distributing stations &
2. As reduction in $I^2 R$ loss component.

& this would be apart from the direct cost benefit to the consumer as incentive.

