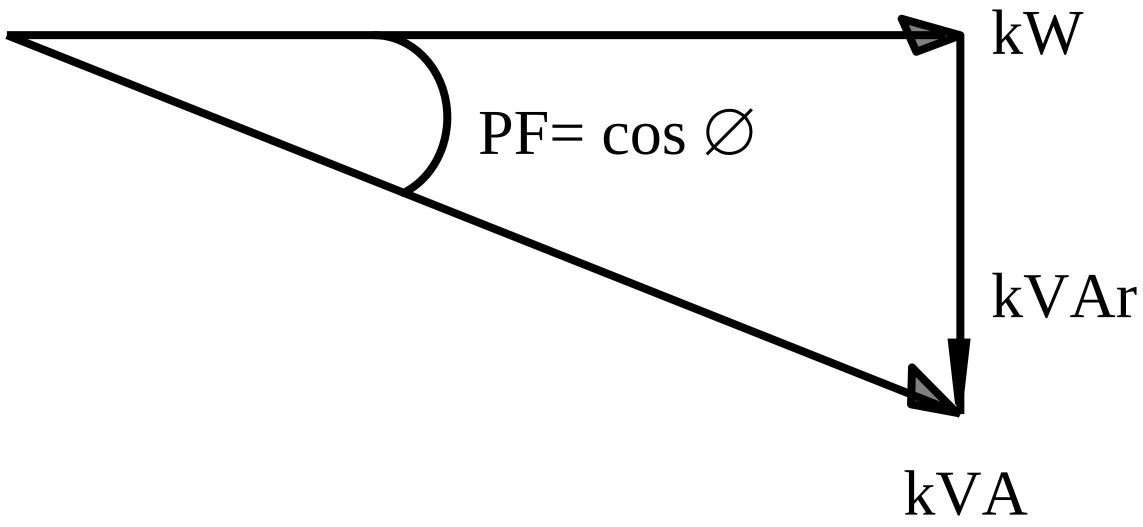
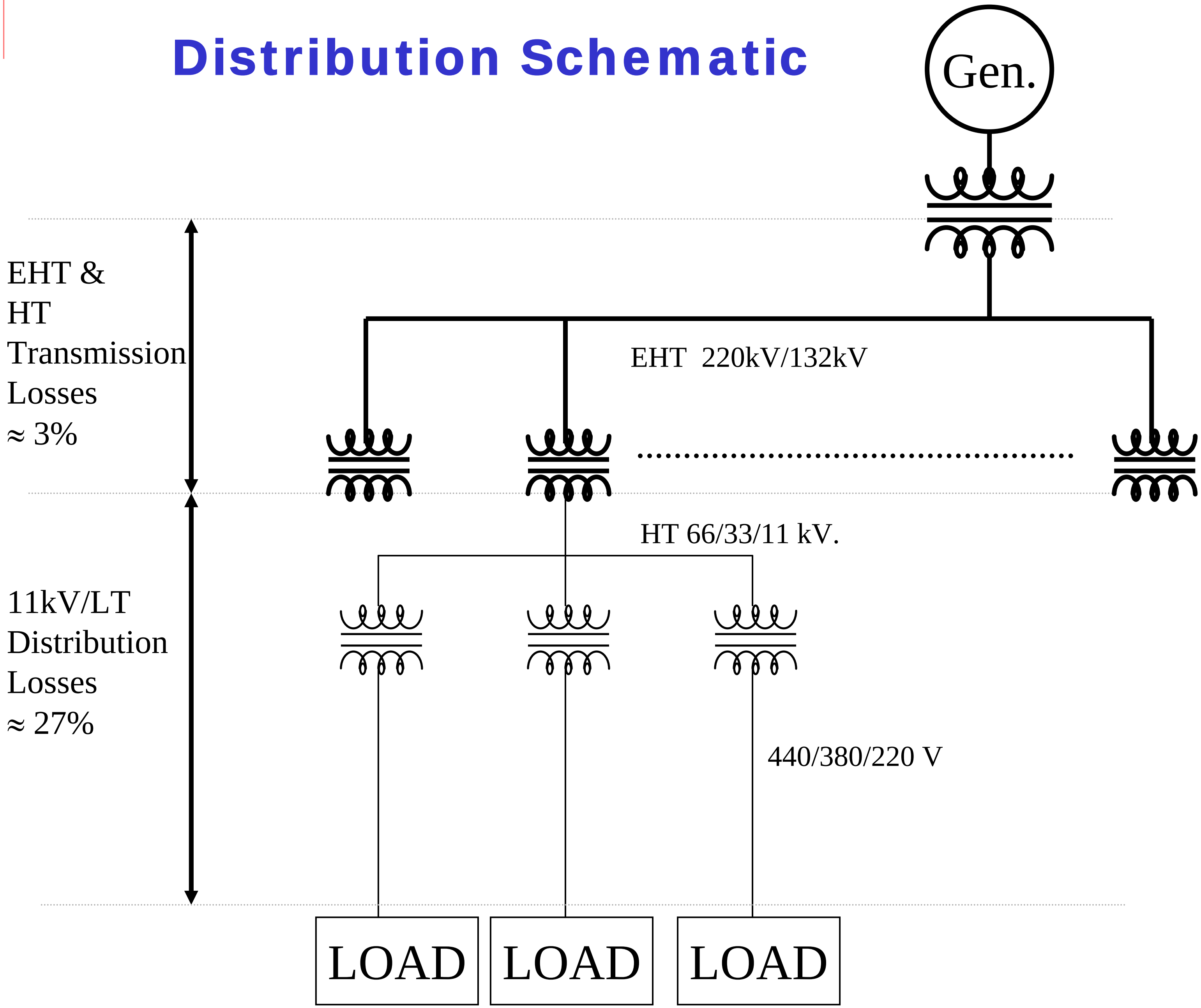
Effect of Power Factor Improvement On Electrical Distribution Systems.



Problems Due to poor Power Factor

- Extra Losses in Transmission and Distribution Networks.
- Overloading the Supply System
- Increase in Maximum Demand.
- Poor Voltage regulation.
- Supply Network instability.

Distribution Schematic



A Lot of Electricity Boards do not generate Electricity But purchases the electricity from Generating Plants.

The basis on which they are charged are:

- **On the basis of kWh**
- **Maximum demand in terms of kVA maximum demand.**
- **kVArh consumption.**

But !!!

- **30% Transmission and Distribution losses.**
- **Increase in kVA maximum demand by approx. 20%.**
- **Increase in kVArh consumption around 40% of kWh.**

Are the things that are certainly not desired by the Electricity Boards.

How to take care of all this?

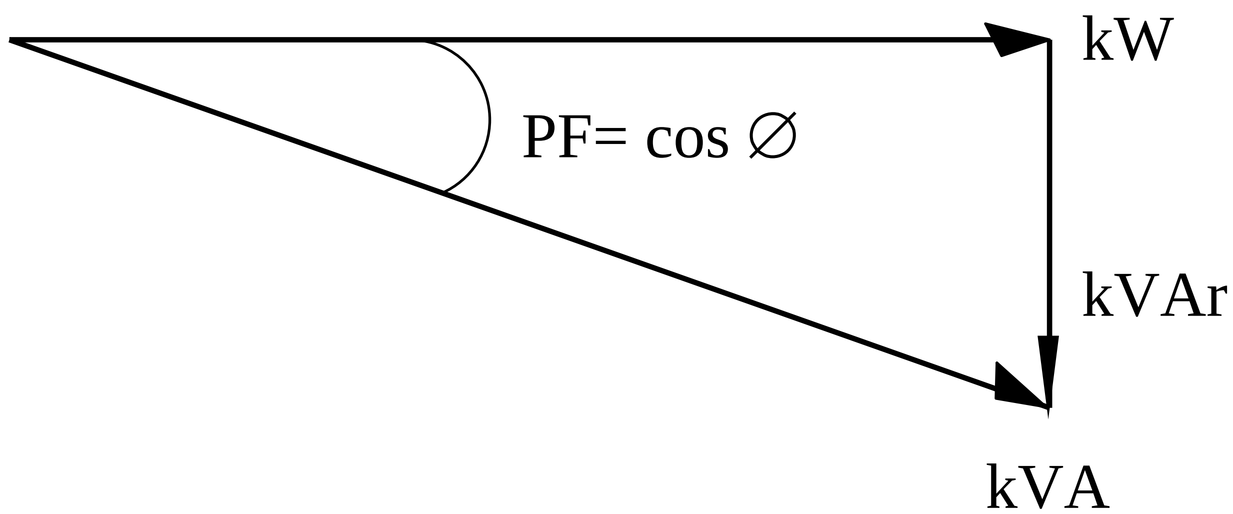
Enhance the Generating as well as T&D capacity.

OR

Improvement in Power Factor at all the levels in Transmission and Distribution.

Ideally speaking, let PF = 1.00 at all the points.

Power Factor Definition



Power Factor is Real (Actual) Power divided by the Apparent Power. i.e. kW/kVA = PF.

PF = 1.00 when kW = kVA i.e. when ∅ = 0.
That's the ideal situation.
And that's what has to be achieved.

The ideal condition is to maintain the PF near 1.00 as close to the load as possible.

This can be achieved by making it mandatory on the electricity consumers to maintain the PF near 1.00

But this may be too much to expect out of the customer, who may not be knowing what money he is spending for and for what equipment. Only bigger Industrial consumers may know the reason.

So the best way to maintain PF=1.00 is by use of Automatic PF correction panel at LT distribution level.

Now if the PF is improved from 0.85 to 0.98, the kVA demand on the supply system is reduced by 13%.

This means that without enhancement in the capacity of the distribution system or without increasing in generating capacity, PF improvement alone is capable to fulfill the requirement.

Now lets compare the costing aspects to achieve the same.

1. By enhancing the capacity of T&D and Generation.
2. By Improvement in Power Factor.

Lets take the case with 500MVA distribution system.
PF = 0.85.

Now to Enhance the capacity of T&D and Generation by 10%, say 50MVA.

By Capacity Enhancement:

Capital Initial investment,
Generation = Rs.175 Cr. (50MVA X Rs.3.5 Cr.per MVA)
Distribution = Rs.75 Cr. (If designed with safety margins can be neglected)
1 year running cost = Rs.280 Cr.
Total cost = Rs.530 Cr.

By PF Improvement to 0.95 :
With 500MVA installed system, 10% VA improvement is by 200MVAr capacitors. i.e. 50MVA extra capacity available by installing 200MVAr switched capacitor system.

Cost of Auto PF correction system for 200MVAr = Rs.25 Cr. (assuming cost of APFC is 1250 Rs./kVAr)

Now Lets even calculate on the basis of just kW criteria.

Average Distribution losses
In the Indian Electricity Boards. = 30 % of Generation.

By reduction in VA by 10%, the total reduction in kW T&D losses is 5% of total distribution losses. i.e. 5% of 30% which is 1.5%.
Thus, by Auto PF correction net saving = 1.5%.

(Av. Cost for 1MW gen.) + (running cost for 1 year) = 3.5Cr. + 5 Cr = Rs. 8.5 Cr.

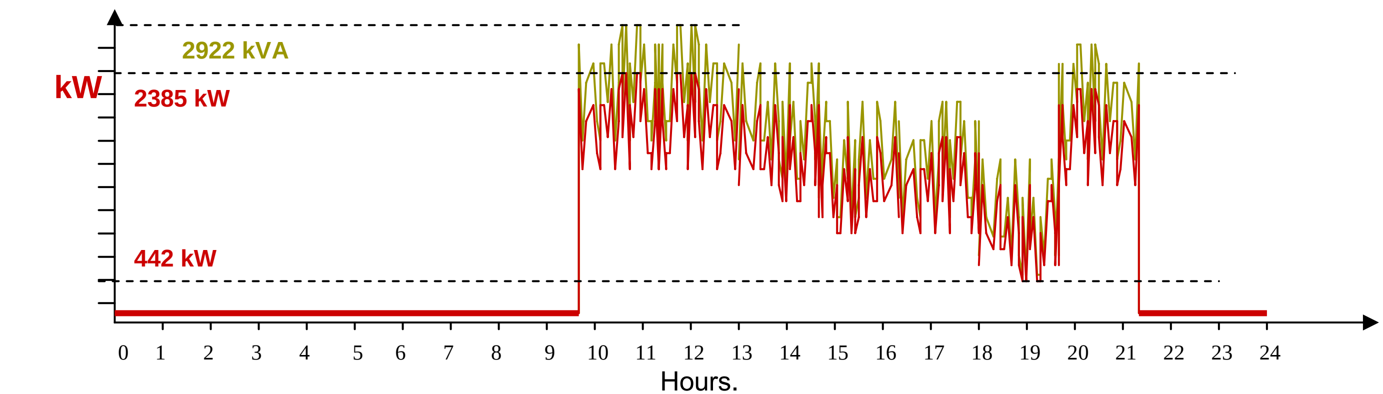
Av. Cost for 1MW saving for 1 year = Rs. 5.5Cr.
With Auto PF correction units(45MVAr).

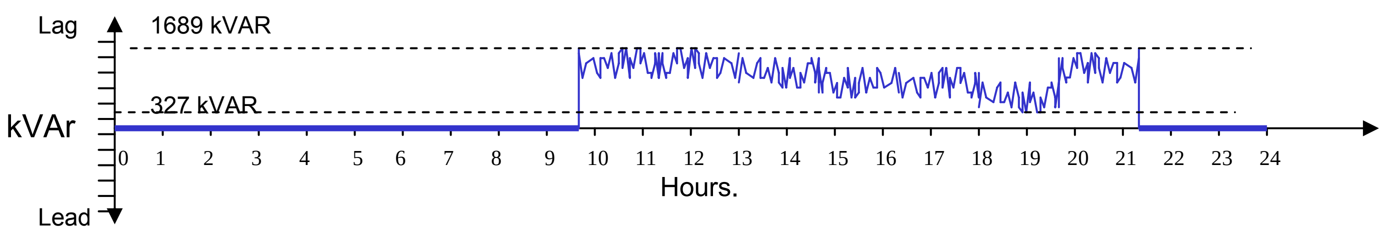
Certainly Makes a Lot of Economic Sense

Compensation – Why Dynamic kVAr?

In present day conditions, the loading on the supply system is quite variable and full of harmonics. The harmonic problems resolving has quite a different approach. But variable loading causes variable kVAr requirements on the supply system.

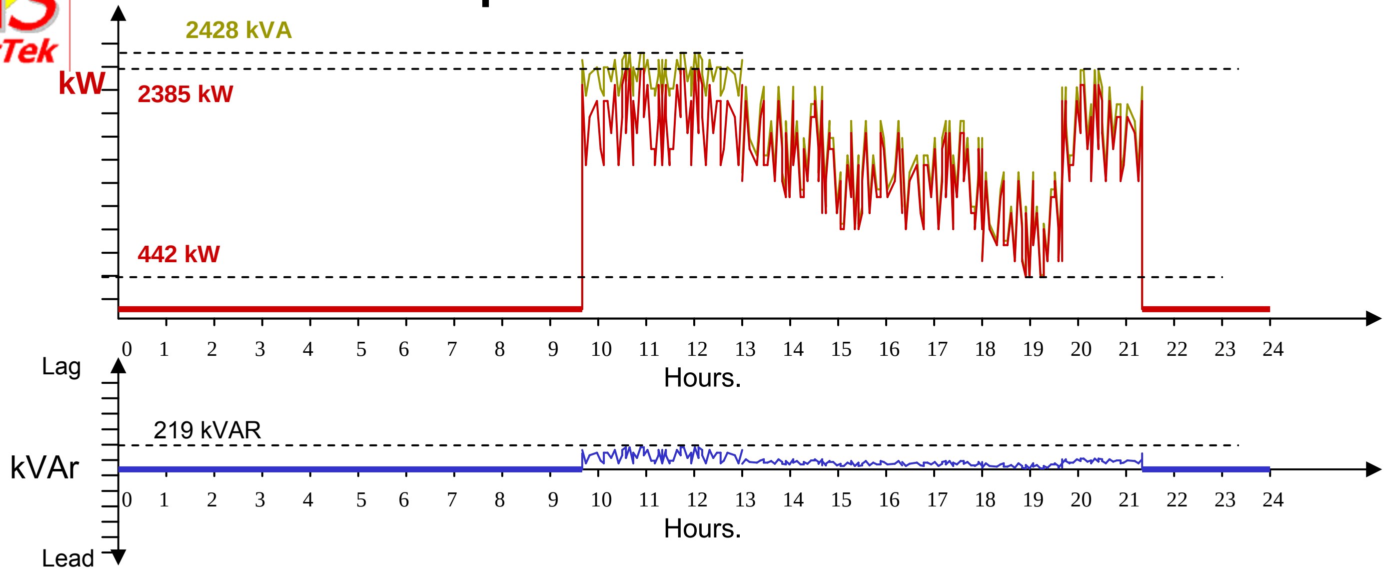
Observe the plot of kW/kVA and kVAr on a typical 11kV feeder. This is over a period of 24 hrs, taken at an interval of every minute.





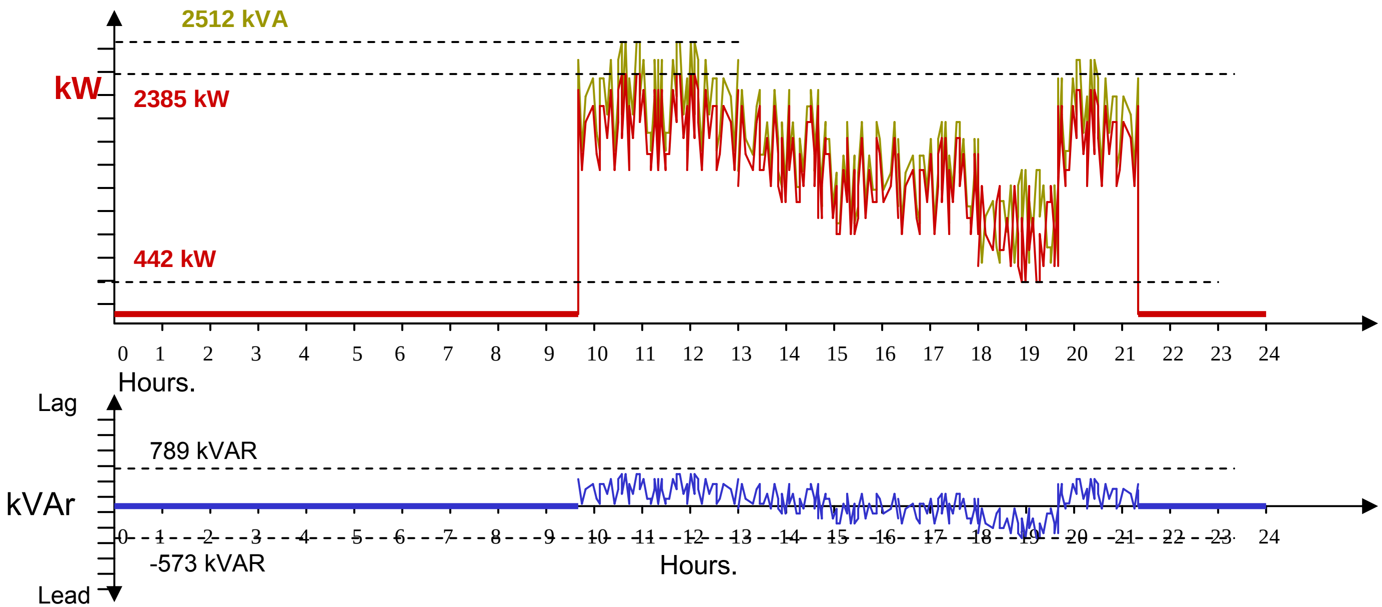
The above plot is on one of the agricultural feeder. In-operation hours are 11:30 Hrs.
The plot is taken when there is no capacitive compensation provided on the feeder.
Total number of APFC systems per feeder provided 45Nos.(various ratings)

With APFC panels installed:



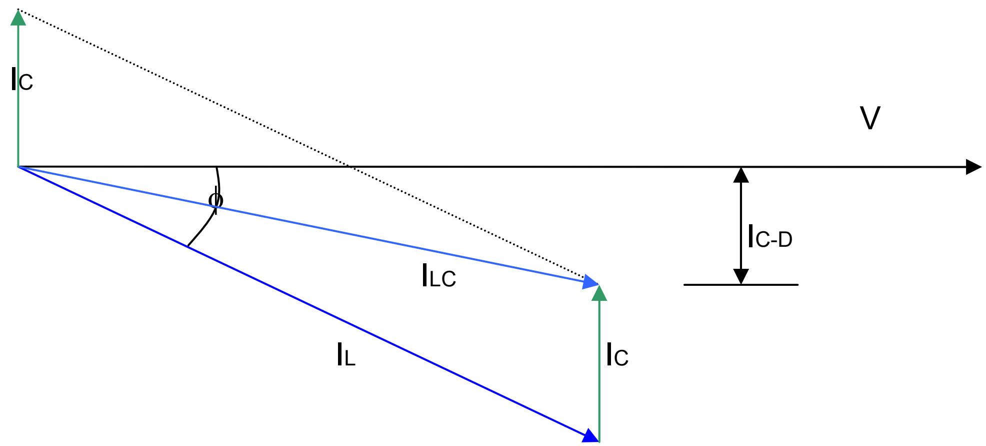
With fixed compensation: Total feeder compensation 900kVAr.

(Achieved by putting APFC panels in manual – fixed compensation)

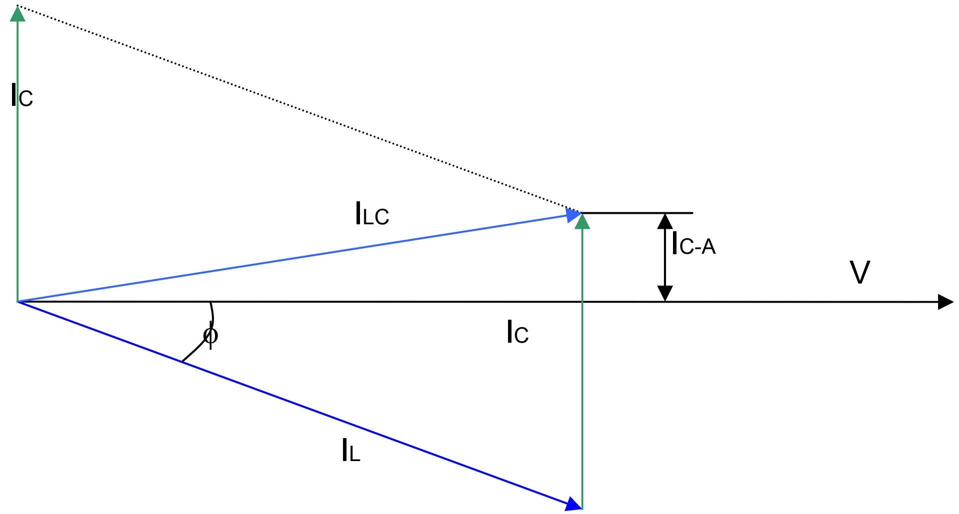


Dynamic kVAr compensation v/s Fixed compensation

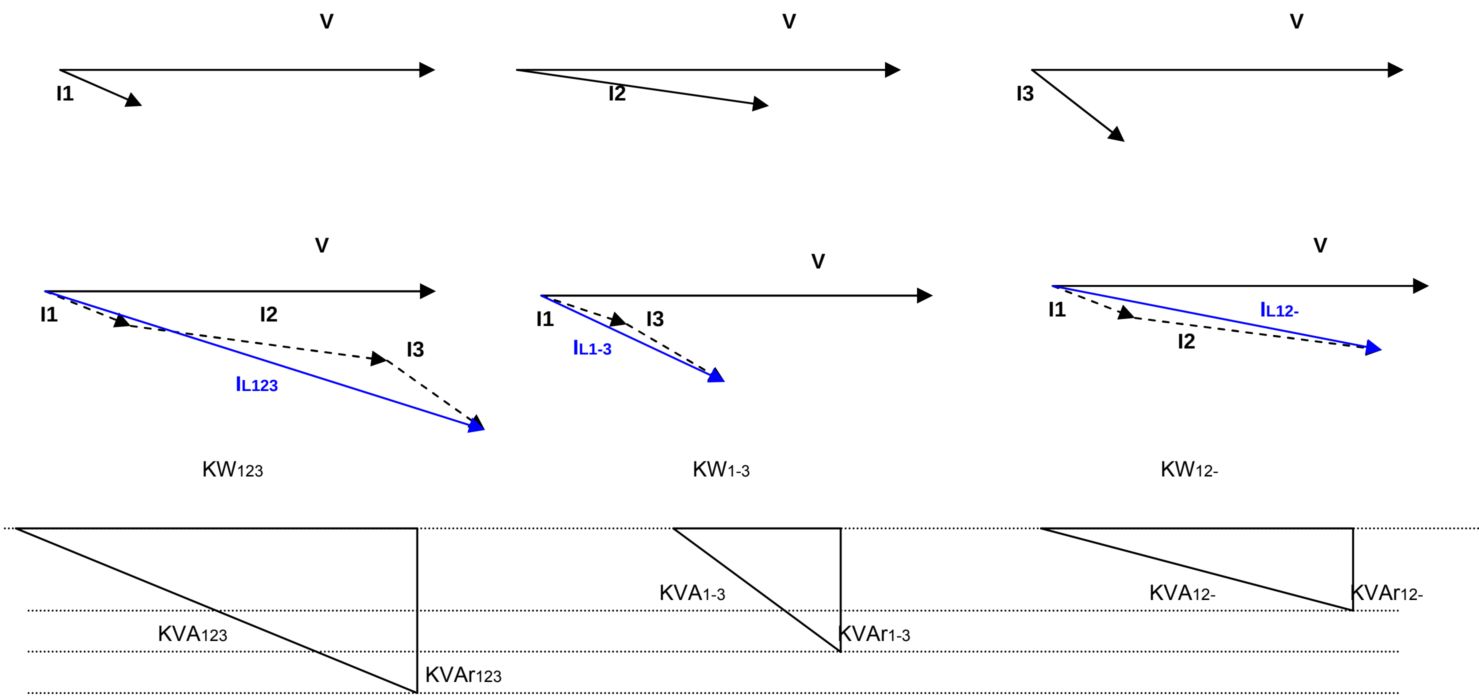
Effect of low kVAr compensation:



Effect of high kVAr compensation:



Effect of Load changing:



The situation above shows that variable kVAr compensation is needed for various loading conditions.

With electricity boards too, as the losses are more on 11kV and lower voltages, the losses that can be compensated by fixed capacitors are only about 60% to 70%. As the compensation provided is on the basis of averaging basis.

With variable compensation, the compensation is 100% with high speed thyristorised kVAr compensation system from TAS.

Cost differential – payback calculation.

In the logged data 11kV feeder example: (number of APFC systems 45Nos fitted)

Reduced kVA due to APFC panels is 84kVA i.e. reduced from 2512kVA
i.e. % reduction in kVA due to APFC = 3.35%.
The losses would be deduced in the square of kVA proportion. $= 1 - (2428 / 2512)^2$.
$= 6.58$ %
If we assume the on the 11kV feeder supplying 3000kVA maximum load has average kVA loading with load factor of 0.65 it is 1950kVA.
The average kW would be (0.81 PF) = 1580kW.

If we consider the total feeder loss factor of 15% of average kW
Total losses = 237kW per feeder.
6.58% of total losses = 15.6kW.

Average working per day assuming 12 hrs. total kWh lost per day = 12 X 15.6
= 187.2 say 187kWh (units)

Per month losses = 30 X 187 = 5610kWh (units)
Assuming cost of electricity to the EB = Rs.3 per unit, total loss per month = 16,830/-
Per year loss for EB = 2,01,960/-

Cost differential between APFC system and fixed system ≈ Rs.15,000/- (averaging basis)
Total cost differential of 45 systems = 45 X 15,000 = 6,75,000/-

i.e. APFC additional cost payback period (by comparison with fixed compensation too)
= 6,75,000 / 2,01,960 = 3.34 years i.e. **3 years – 4 months.**

Other Advantages of APFC over fixed compensation

• Instantaneous Power factor is near unity, not just average. This improves the output voltage stability. Any over-voltages on supply line (even if it is 5%) can cause the motor magnetising losses to be increased and causing motor efficiency to be dropped by about 3 to 5%. Most of the agricultural pumps are induction motor pumps, the increase in the kW consumption.

• APFC provides a complete protection to capacitors against over-voltage, harmonics and supply transients. It even avoids the system resonance phenomenon that can have disastrous effects. Fixed compensation cannot provide such preventive protection. All it can provide is a failed capacitor protection by usage of MCBs in the circuit.

• The APFC system performance is continuously monitored by data logging and/or by GSM communication. This is possible due to the intelligent controller provided. With fixed compensation, the health monitoring of the systems is not possible. Only a manual checks that are extremely laborious in nature can check these fixed capacitors health.

• Regular monitoring available can even provide a complete clue on Assets and Capacity utilization. This can make the EB organisation to operate efficiently by appropriate capital goods capacity utilization.

Thank You.