

INDUSTRY NEEDS TO REVERT BACK TO LOAD END PF COMPENSATION NOW.

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High time the industry realized the merits and benefits of Load End Power Factor Improvements and it is time to act now. As part of Electrical Distribution, the load end Power Factor compensation is always, neglected area by the industry since decades as they think it was trivial to be tried. Every Energy Auditor gives proposal to this neglected practice after his energy auditing done in the industry. But the industry overlooked this exercise right from project commissioning many years back, because they had been recommended to install only at Power House & SSB, fixed capacitor banks & APFC, Automatic power factor correction panel, during commissioning. **Why they need to change now and what is the need to partly revert back to this Load End compensation TODAY?**

DRAWBACKS IN THE EXISTING ELECTRICAL DISTRIBUTION:-

So for our sanctioned demand KVA today, we are feeding to the mixture of Linear & Non-linear loads in the industry. The decade-old thumb-rule of capacitors sizing to the today's industry mix of linear & non-linear loads, and wrong location of majority of the cap banks at Power house have increased the demand KVA, leading KVARH, excess PF, voltage fluctuations, Total Demand Distortion, failures of sensitive electronic devices due to scattering of Harmonic Distortion, Increase in Line Losses from Load end to Power House due to increased current values, Voltage drops more than rated values from Power House to Load end, and ultimately, machines are strained to run due to lower voltages because of line losses and hence KW loss happening at the machine ends.



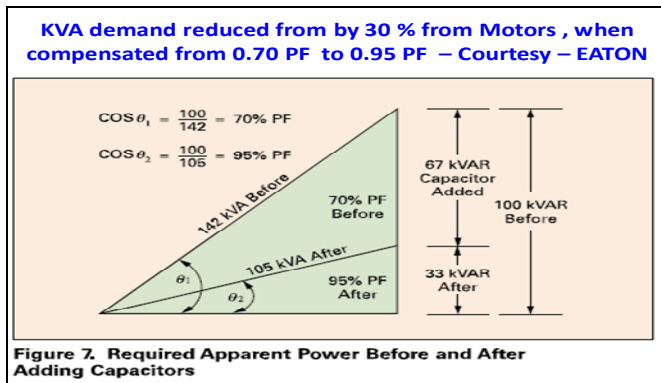
Load end capacitor bank sizing and patterns

Table 2. Summary of Advantages/Disadvantages of Individual, Fixed Banks, Automatic Banks, Combination

Method	Advantages	Disadvantages
Individual capacitors	Most technically efficient, most flexible	Higher installation and maintenance cost
Fixed bank	Most economical, fewer installations	Less flexible, requires switches and/or circuit breakers
Automatic bank	Best for variable loads, prevents overvoltages, low installation cost	Higher equipment cost
Combination	Most practical for larger numbers of motors	Least flexible

Wrong Practice - When the loads are added in the field, capacitor banks are added in the Powerhouse MV panel only. Right Practice – capacitor added to the 55 KW textile ring frame motor end, and not at motor panel 40 meters away. Courtesy:- Eaton / Advantages of Load End PF correction overweighs other options and must be FIRST to start with.

When the industry was commissioned many years back, the industry did not have many VFD and other Non-linear loads within their premises. Even if they had, they had installed for few of their critical production machines. So, during the stage of project commissioning from the Electrical aspects, the industry decided to install around 40 % KVAR of the sanctioned demand, as capacitor banks in fixed format and APFC formats, mostly in Power House and few in some SSB at the field.



Uncorrected PF at load ends at 0.70 PF. This needs to be addressed first . Till date we maintained unity PF by fitting more cap banks at Power House. Courtesy – EATON.

Table 1. Typical Low Power Factor Industries

Industry	Uncorrected Power Factor
Saw mills	45%–60%
Plastic (especially extruders)	55%–70%
Machine tools, stamping	60%–70%
Plating, textiles, chemicals, breweries	65%–75%
Hospitals, granaries, foundries	70%–80%

KVA Demand Reduction by Load End Compensation / Average Uncorrected PF in all industry segments is around 70 %.

Say, the industry case study shows for every 1000 KVA Sanctioned Demand, the industry planned to install total 400 KVAR, as 200 KVAR in fixed banks (25 or 50 KVAR sizes) + 200 KVAR in APFC panel in the power house, on case to case basis. **Right from the project stage, the industry went with the thumb rule of installing 40 % of rated capacitor in banks, for their KVA sanctioned demand.**

In that sanctioned 1000 KVA demand, the same industry later, retrofitted VFD to the machines in production & in utility for 400 KVA load, so as to meet to the daily product variations as per the market demanded conditions for their product. The branded VFD vendor says that his VFD will maintain PF of around 0.90 for any loading of the motor say from 30 % to 90 %. So out of 1000 KVA demand, 400 KVA size of VFD load demand maintains the PF around 0.90 and the balance 600 KVA linear load demand only needs PF compensation. So the linear of 600 KVA needs approx 200 KVAR only as PF compensation. **But the same industry in this updated condition, runs with 200 KVAR APFC + already existing 200 KVAR. So the existing 200 KVAR is excess capacitors ON in Power house.**

In that industry, now the VFD vendor has retrofitted to some machines and this improved PF at their feed end of machines. **But that VFD pumped THD Harmonics back to Incoming header, and still the industry is still keeping its excess capacitors ON at the Power House.** These Power house capacitor banks in turn, amplify the Harmonic Distortion, and cause all the Harmonic related hazards, breakdowns and failures inside the premises and inviting the Harmonic Penalty from the Incoming EB supply.

BARRIERS TO LOAD END COMPENSATION:-

1. Industry was recommended before, that 100 % APFC for loads to be put in Power House and not to take capacitors to load ends.
2. When some many VFD drives are working near the motors, why cant' they retrofit the sized capacitors to linear motor ends?
3. This involves extra work in the field to put in existing panel or box up capacitor along with MCB to locate near motor ends.
4. Every industry wants to fit as extra or add-on at the Power house only, without retro-fitting into the existing field motor panels.
5. Industry since project stage is aware of this, but the same retrofit capacitor to motor is neglected and left to user to fine-tune.
6. **7 out of 10 industries have not implemented this, assuming this does not give that much ROI for the field work involved.**
7. The simple payback period is just FOUR months only and it gives host of benefits to the user, directly and indirectly.
8. The above facts are known to all Industry Electrical Maintenance, but they could not put the capacitor in the machine panels.

HOW THIS LOAD END CORRECTION CAN BE IMPLEMENTED NOW?

Now we understand, why Load End Compensation is required for our 3-Phase motors rated above 3 HP? Our motors are always around 50 to 75 % loading only except our overloaded compressor motor.

Output		Power factor			
kW	hp	¼L	½L	¾L	FL
3.7	5	0.44	0.55	0.62	0.7
7.5	10	0.58	0.64	0.72	0.76
15	20	0.6	0.62	0.7	0.75
18.5	25	0.62	0.64	0.72	0.77
45	60	0.68	0.75	0.77	0.79
75	100	0.72	0.8	0.85	0.87

KVA IMPROVEMENT IN THE Electrical Load End PF Compensation

Improved Power Factor Correction on typical 50HP Motor gives significant results.

50 HP motor Without Cap	50 HP motor (with Cap)	% Change in parameters
37.3 KW	36.2 KW	3% Decrease
28 KVAR	15.1KVAR	46% Decrease
46.6 KVA	38.4 KVA	17% Decrease
0.8 PF	0.92 PF	15% improvement

From the above, we understand the individual capacitor to the motor above 3 HP needs to be compensated at the motor end. Many of old motors have PF of around 0.70 only for their average loading around 70 % of rated capacity. **Benefits of PF improvement resulted in KVA demand reduction in loads, and KW reduction due to less Line Losses.**

TEXTILE MILLS LOSING upto 1 KW in RING FRAMES, say UPTO Rs.50,000/- Annually per Frame:-

Textile mill ring frame needs a sized KVAR for the given ring frame motor rated 55 KW, here say 15 KVAR fixed capacitor + MCB needs to be located near main motor end. This can save UPTO 1 KW per ring frame say 1 to 2 % energy saving, depending on the motor brand, motor loading related uncorrected PF. **So the load end PF compensation can save around Rs.30,000 to Rs.50,000 annually per frame to mill, as motors run continuously for 24 hour x 360 days annually.**

But the mill puts 50 KVAR at the incoming of SSB (located 50 meters away from motor) that feeds to 6 ring frames. Some mills record voltage drop from the main motor to motor panel across 40 meters long ring frame as high as 6 volts between panel to motor end, can reduce this voltage drop by half by retrofitting capacitor. This improves the motor running and reduces motor losses.

So compared to individual frame wise compensation, the mill planned to economize the retrofit and put 50 KVAR cap bank at the SSB, to compensate for 6 ring frames of 55 KW non-VFD main motors. Now most of the mill installed VFD control to their pneumafil 5.5 KW motors at their motor panel. So this existing 50 KVAR capacitor at SSB magnifies the Harmonics mitigated from each frame's pneumafil VFD. **This is adding to the energy losses in KW and in KVA due to THD now. Apart from load end PF correction, the mill has to put Reactor coupled capacitor bank at SSB, to improve the PF further and reduce the THD at the SSB stage.**

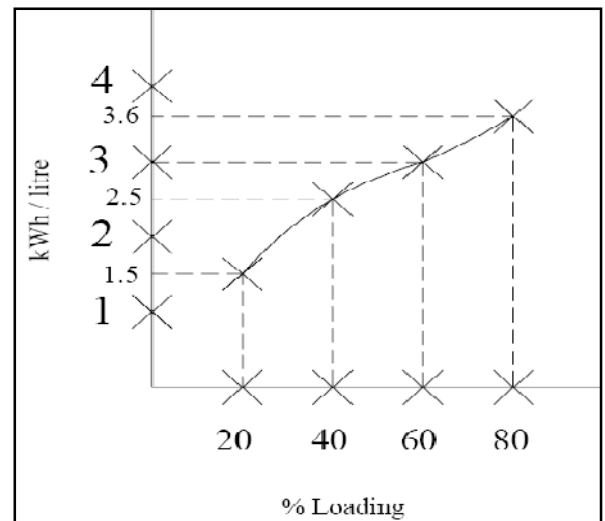
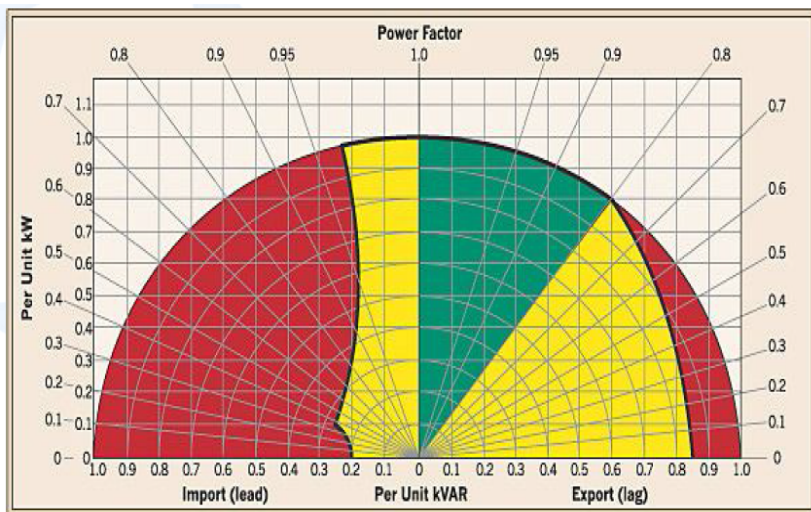
Take the case of 12000 spindle textile spinning mill, this mill runs with 10 ring frames of 55 KW main motor capacity. Each frame runs at an average 40 units per hour, consumes 10,000 units out of mill consumption of 22000 units per day. **Many mills have not implemented this Load end correction. Hence implementation of this exercise here, will conservatively yield Rs.3 Lakhs annually.**

This is not only happening in the textile mill, it is happening in all the industry segments, on the material handling motors to be specific as High Torque-Start & Low Torque-Run type. These motors are there in each industry and we have to identify first and measure the PF in the run-mode of motors and many motors have recorded PF of around 0.50 to 0.60 PF. Whatever may be the size of this motor, it is better to fix Load end PF capacitor so as to improve the PF at the feed end.

The capacitor will be sized to match the no load KVAR or no-load magnetizing current of the motor. Let us say the motor is belt driven, this capacitor need not be sized to open shaft of motor. Just De-couple the motor and machine by removing the belts. Whatever is the no load KVAR or the no load Magnetizing current, (even when the motor pulley is there fixed on the motor shaft, still it is okay), this can be measured with clamp-on power meter, or better measured accurately with the Load Analyzer and then the capacitor is sized. **This can be done by the mill during energy study routinely and can be done during Energy Audits as well.**

INDIRECT BENEFITS OF LOAD END COMPENSATION:- FULL UTILIZATION OF DG CAPACITY:-

The industry is having 160 KVA DG set and how the industry had been running their DG set since commissioning say 10 years back. Industry was restricted by the DG OEM, not to exceed 80 % of the rated capacity in KVA, means 128 KVA. Also for the safe running DG set Alternator, the industry was recommended not to exceed 0.80 PF as feeding PF of genset, **Hence the industry was forced to run 160 KVA DG upto only 103 KW load only as maximum, and not more than due to genset safety priority.**



CUMMINS DG PF spectrum shows the optimum of PF band in green band 0.90 to 0.95 PF & UPL Improvements.

Since the industry had not load end compensated PF loads, the average PF is around 0.70 only. Hence the same 160 KVA genset feeding to the uncorrected PF loads at average of 0.70 only, hence the industry could not load their 160 KVA DG more than 90 KW loading. **Here, first stage is to plan for load end compensation upto 0.90 PF and this enhances the genset running KVA capacity by 25 % more, say from 90 KW to 115 KW available from the 160 KVA rated DG to feed to the loads.**

The next stage is to plan to retrofit or procure Dual PF set point APFC, 3 C.T. sensing Automatic Power Factor Controller and install the current CT at the common point of coupling between Genset and the EB. **This APFC during DG run, will take set point as 0.95 PF and manipulate KVAR in the APFC. When EB current is there, the same APFC will take set point as 0.99 PF and improve the PF accordingly. So the APFC will work as Dual set point PF as 0.90 or 0.95 during DG / EB running.** This will ensure the DG is put to say 25 % more capacity to feed to the loads. Also this improves the DG's UPL, the Units per Liter of Diesel consumption of your DG.

LOAD END HARMONIC MITIGATION

The industry installed the VFD later to their machines to achieve the flexibility of their operations and to suit to variable product outputs delivery. Here the industry focused on the productive output variation deliverable by VFD, but did not demand for Harmonic compliance from the VFD OEM. Here the VFD was procured on L1 basis, on lowest cost. The VFDs available in the market delivered varying PF due to their poor compensation inside, at the VFD input and threw back Harmonic distortion more, back to the input side.

The branded VFDs maintained PF of around 0.90 for any loading, and restricted the THD-current back-rush to Incoming grid, to say, around 25 % from their VFD machines. Few years back, in the utility especially the VFD operated compressor, generated more than 50 % THD-current to even 90 % THD. This increases the overall THD % at that industry Incoming side. Also that VFD OEM provided only DC Link choke, and not the AC Line Reactance choke to reduce the THD-current, thrown back to Input.

Electrical Load Pattern	Harmonic level less than IEEE519	Harmonic level above IEEE 519/ IEC 1000-2-4.		
		THD >10% & <20%	THD >20% & major odd Harmonics	THD >20% & major 3 rd Harmonics
THD levels %	IEC 1000-2-4			
Steady Load	Power Capacitors up to 90 % of No-Load Magnetising current / KVAR	Fixed De-Tuned Harmonic Suppression Filter & P.F Correction	Fixed Tuned Harmonic Filter & P.F Correction	Fixed Triplen Harmonic Filter & P.F Correction
Varying Loads	APFC System up to 100% of the Reactive Power.	Variable De-Tuned Harmonic Suppression Filter & APFC	Variable Tuned Harmonic Filter & APFC	Variable Triplen Harmonic Filters & APFC

Harmonic currents if not partially arrested at the VFD by Line Reactor chokes, same dumped to MV panel to grid ! and Passive & Active Harmonic filter needs to oversized. H 5 Amps is reduced from 65 % to 28 % using Reactors. Please don't' oversize Active filter. This consume more KW power compared to load end, passive filters in hybrid mode

Reactor Type	5th	7th	11th	13th	17th	19th	23rd	25th
% Without reactor	65	35	25	15	10	8	6	5
% With AC reactor	28	15	10	8	6	5	4	3
% With DC Link Choke	35	20	15	10	8	6	5	4
% With AC reactor + DC Link Choke	25	12	8	6	5	4	3	2

Load end Capacitor + Field Fixed bank at SSB + Automatic PF controller at Power house for linear loads = Line Choke at VFD + Reactance coupled Cap at SSB + if reqd, Active Harmonic Filter at Power house for non linear loads. PF improvement IN STAGES done before & now Harmonic distortion reduction IN STAGES needed to done.

This hybrid working will be economical now for the initial costing, reduced running KWH cost of harmonic suppression & filtering, reduced Line losses since fraction of harmonics is arrested at the VFD load end.

Now the industry is very much aware of THD norms, and so when they buy any equipment, the Electrical maintenance insists on the harmonic compliance with the Equipment OEMs. Also the user must insist with the OEM to add the AC line choke of 3 % or 5 % rating to suit to the motor loading and the running KW average, to reduce the Harmonics at the VFD incoming.

Some OEM give Spike Suppression Filter Line choke of 1 % rating and this gives only the protection to VFD and this does not reduce THD. First, the user must get to know, THD generated from their machine VFD at their machine's loading of ¼, ½, ¾ and Full loading conditions now. Also how much this Harmonic Reduction Filter choke reduce at above quarterly stages of machine-loading.

CONCLUSION:-

The irony is that when the industry is procuring and buying excess capacitors to mount in the Powerhouse MV panel to maintain to unity power factor, the same industry motor load ends are very much lagging in their PF for their existing loading. Large Scale Industry groups have realized this Un-noticed Low Hanging Fruit now in Electrical Distribution and have reverted back to this, looking for direct power KWH saving benefits and indirect benefit of DG running at higher capacity than now. Here, BEE must mandate this option of buying a KWH meter and sized capacitor to the motor, as a System Efficiency Improver cum Monitor NOW.

When the industry is having of mixture of Linear and Non-Linear loads feeding from their Power House, it is always prudent to deal the linear loads separately (& non linear loads separately) at each Load end point by improving PF at motor which only pulls down the PF. This improves the safety of electrical distribution and reduces their KWh consumption and KVA demand reduction.

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