AUTOMATE YOUR DG POWER FACTOR TO UTILIZE ITS OPTIMUM CAPACITY

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The Diesel Generator's DG Sankey Energy flow diagram indicates that the generation efficiency is around 30 % only. But practically measured values indicate that, for the given 1 liter of Diesel at 9800 Kcal input, the DG gives output of around UPL of 2.5 to 3 units of Electricity @ 860 Kcal. Since the industry is already losing the DG generation efficiency now due to poor loading level of around 50 to 60 % only, this case study paper suggests how the same DG KVA can be effectively utilized further by matching the function of APFC to the DG set so as utilize its output by 25 % more and getting better UPL as well since DG is utilized optimally, efficiently to its deliverable capacity.

The industry is using the DG, only to drive few critical loads due to its Throttled Output capacity as safely recommended by the DG OEM. Even if you the industry want to run few more loads within the DG rated capacity, you are curbed by the DG OEM safety based recommendations not to overstep the PF Power Factor of 0.80, as well not to load above 80 % capacity as this is the safe value to operate DG's Alternator. We are discussing the ways how to optimize your DG set rated capacity's full utilization without compromising its safety and ensure an efficient loading to give better UPL.

EXISTING SAFETY BASED INHIBITIONS FOLLOWED BY INDUSTRY:-

1. Let us take case study of 160 KVA DG set. During the commissioning, the DG OEM recommends you to operate DG safely in all aspects by loading at 80% and especially, he strictly recommends you to maintain PF of 0.80

2. So you are directed to run safely to the maximum loading & safe running of around 80 % that is 128 KVA. Now you are instructed not to exceed the PF of 0.80 and hence 102 KW only as the safe deliverable load by DG. So having bought 160 KVA DG, now you are throttled to deliver at 102 KW only as the overall allowed KW. And your Electrical dept becomes very much safety conscious, especially in this DG running and reduce its capacity to half now.

3. When you are running a batch of full machines within the EB supply service limits in KVA and KW, so in the standby DG mode, you have to safe throttle your DG output, truncate your batch operations, and this affects your productivity chain.

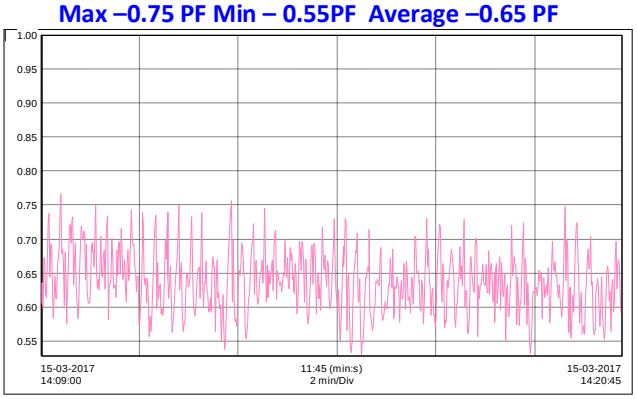
4. Even in the available 102 KW delivered by your DG, You are not allowed to start heavy motors frequently. These are the handicaps, you are facing with your correctly rated DG suiting to your EB service.

5. Diesel saving point is that you could achieve 25 % more Units per Liter of Diesel because of this reduced DG running now.

6. Take the case study of your 500 KVA DG set, the same conditions are religiously applied by OEM and your team and your DG deliverable output will be around 300 to 320 KW only on your 500 KVA set, 25 % losses in Diesel as the delivered KVA could not be utilized due to this Alternator Safety Throttle PF @.0.80

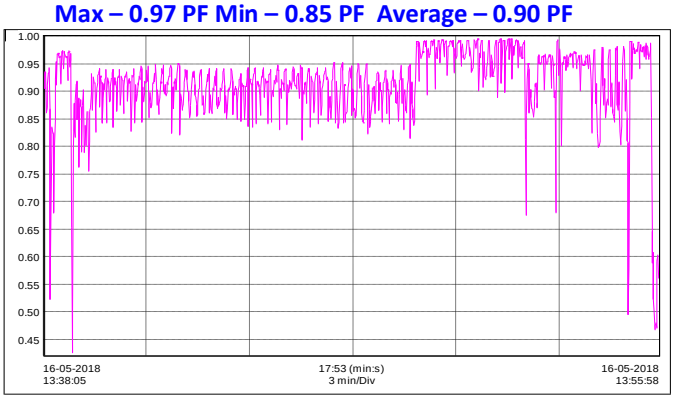
PF readings without APFC panel

Max –0.75 PF Min – 0.55PF Average –0.65 PF



PF readings with APFC panel

Max – 0.97 PF Min – 0.85 PF Average – 0.90 PF



Case Study done in 2017- 18 by Sttar Engineering Services at SP Industry ,Chennai for 160 KVA DG Set working with and without 100 KVAR APFC Panel

The average PF is raised from Lagging 0.65 PF to Lagging 0.90 PF and DG set running is allowed to enhance by 25 % within the rated capacity. The graphs show that in spite of heavy fluctuating zig-zag load PF variation, the DG set APFC was able to maintain a steady PF catering to the loads and never crossed the safety limits. This is pinpointed in this DG running PF chart.

7. As a DG OEM, he is safe because he wants to ensure that the DG and its Alternator is not put to overload by your loads that demand extra KVA from the DG, even though your loads added are rated less than DG rating.

8. As an analogy to say, DG is like a POND whereas EB network is like a SEA. The power generated by DG is definitely clipped when overloading is demanded by you. And the DG could deliver lower output as well it needs to strain more to deliver to fullest optimum rated KVA output.

9. So far this is as the linear loads are concerned. Now your DG is put to more strain by the non-linear loads, some industries complain that their age-old Alternator failed now since, it could not withstand harmonics from non-linear loads now.

10. You will come across in your industry, the portion of non-linear loads increased due to production flexibility requirements and the same achieved by the machine VFD. But here, you did not House Arrest the Harmonics within the VFD incoming circuit at the machine panel itself, and you allowed the Harmonics from your VFD to hit back the EB grid and as well scatter out to the horizontal Electrical and Electronic networks surrounding the machine. This Harmonics generated at the VFD are silently magnified by your capacitor banks at the VFD's Incoming DB and SSB level and at the Power House.

11. Since your decade-old DG is left un-protected from VFD harmonic hazards now, from the field, this strained your DG Alternator first and over-loaded the Alternator when fluctuating Harmonics was pumped in. This resulted in un-steady PF, and heavy fluctuations going upto Leading PF region, where the DG voltage output fluctuates at Unstable Voltage Region.

12. At any instant of your DG running, what your Alternator needs Safe Steady PF band of 0.80 to 0.90 only, as Acceptable Steady State Operating Region for the DG Alternator to smooth run the DG, from the Electrical safety point of view.

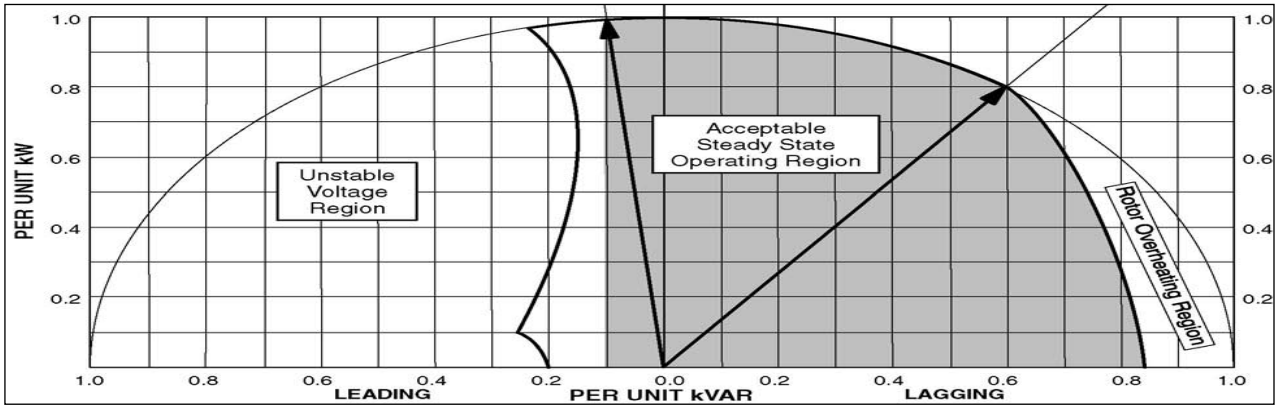
HOW TO FOCUS & ACHIEVE STEADY PF BAND FOR DG SET & EB GRID?

1. The rule is that all your Linear loads involving motors of 5 HP and above, must have Load End Compensation Capacitor always. So majority of your motors need to be slightly PF compensated at motor terminal or panel end and this was not done practically for all lower HP motors now. Since this is not readymade solution but has to tailor-made for each motor.

2. The capacitor is sized so that it is equal to 90 % of rated No-Load KVAR of the given motor. Hence the capacitor rating is selected that PF at motor end, retrofitted to achieve lagging PF 0.85 around on the safer side, no overshooting PF strictly.

3. Motors, when loaded around say 50 %, will have around PF 0.7 only. The IE 2, IE 3 latest version of Energy efficient motor OEMs has improved their motor's efficiency only at the cost of PF. The idea is that their motor PF can be improved / compensated at the field by the user industry, whereas their Motor's Efficiency is already fixed at their Factory. Now, you have to improve the PF basically at all your motor Incoming circuits for above 5 HP motors & above, at machine end.

4. When you observe your DG power parameters before this Load-End Compensation exercise, the output PF demanded by the half-loaded machines will around PF 0.60 only. And any machine start-stop will give jerk to the DG running, as steep step input from the load is demanded from your DG Alternator.



Courtesy: CUMMINS PF chart. When the Acceptable Steady State Operating Region as per the above graph is between Lagging 0.80 PF to Unity, we can safely operate the DG set at the mid region of lagging 0.90 PF strictly. By pinpointing the PF at around 0.90 PF here, DG set can avoid the Unstable voltage region on leading PF side. On the Lagging PF side, Rotor overheating region can also avoided by selecting by Automatic Power Factor control to match to the DG running.

5. Now after this Load-End Compensation Exercise to your Heavy motors first, you will find the DG output PF has improved now to PF 0.80 PF Band. Since the base-load compensation is given, this will not give jerk to your DG during the switching on & off of machines.

6. **So the Hybrid compensation first partly at the load end compensation to around 0.80 to 0.85 range PF and the next the finely tuned to 3 CT sensing APFC to match to the DG running function. This two ends of compensation is needed now.**

DG AUTOMATION TO Improve the Deliverable LINEAR KVA:-

1. Now you have given a coarse improvement in your electrical network PF band and this improved PF band will reduce the Line losses from your machines DB to the Power House. Also this will reduce your overall KVA demand as well.

2. **Now let us introduce the Retrofit 3 CT sensing DUAL SET POINT APFC, the Automatic Power Factor Correction Panel suiting to the DG operated loads at common point of coupling of DG and EB in the MV panel at the Power house.**

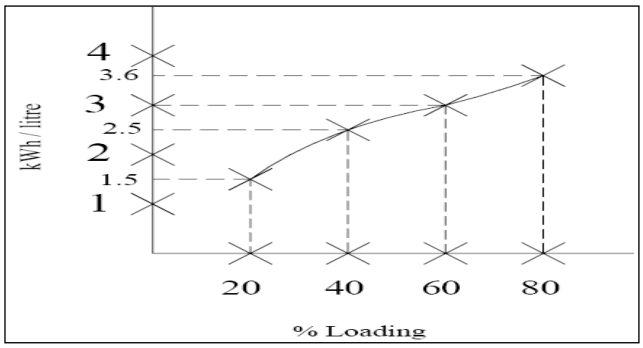
3. This APFC will ensure the PF band around PF 0.90 at the DG output that will have FINER control of PF to achieve the DG Acceptable Steady Operating Region PF in that segment. And during EB operation it will maintain around 0.98 PF.

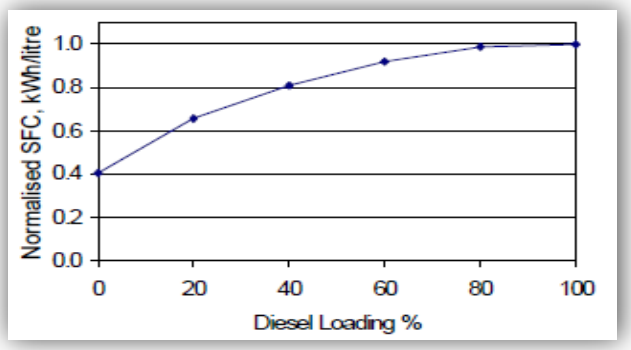
4. This will reduce the KVA burden from the load end and release the 25 % KVA to the load, so as to add more loads to say 125 KW from 100 KW in your 160 KVA rated DG. If yours is 500 KVA DG, then you can add 60 KW more loads from your 300 KW @ PF band of 0.55 to the 360 KW @ PF band of 0.85

5. It means that for 10 hour, 500 KVA DG running, this industry consumes 1000 liters per day. For the same consumption of 1000 liters for steady loads, this DG delivered 3000 units per day. After implementing this above APFC, the DG was able to accept to the loading demand to 3600 units per day for the same 1000 liters consumption, ie 600 units More per day. 20 % extra output still within the rated DG capacity is achievable now.

6. It means that for 10 hour per day, this 160 KVA DG delivered around 800 units per day and consumed 400 liters. After implementing this APFC retrofit, the DG consumed the same 400 liters and the output was able to able to match the extra load demands by 200 units, totaling 1000 units per day. 20 % more output in un-steady but intermittent loading condition.

7. **Thanks to the Intelligent Interface in the APFC control, this steady band at say PF band around 0.90 will stay constant PF. Same APFC controller can be put at Dual Set Point to operate for DG at 0.90 PF and EB at 0.99 PF as two set points.**





The curves explain the Units per Liter versus the DG set loading in KVA.

DG load at 40 – 80 % raises the UPL by 50 % . Maintain Healthy steady P.F. from 0.80 to 0.90 for more Units / Liter.
When we operate our DG set, we can get 50 % more units for same liter of diesel when we load DG from 40 to 80 %
Or, We can reduce diesel consumption by One Third 33 %, provided we load at 80 % of rated KVA instead of 40 %

FINE TUNE AUTOMATION to Deliver Non-Linear KVA:-

1. The above retrofit APFC with capacitors is for linear loads only which the DG, needs to handle in case of power cuts.

2. If you have Non-linear loads as a fraction of main loads, then you can plan for Passive type Harmonic Filter cum APFC, which will reduce the Harmonics and as well improve the PF and reduce the KVA demand burden in DG.

3. If you have majority of loads as Non-Linear, then you can plan for Reactor coupled capacitors in your APFC to suit to the nature of loads and thus improve the PF and as well reduce the KVA demand burden to the DG set.

4. First of all, Retrofit Line Reactance Choke to all your VFD now to partly arrest Harmonics generating from Source point.

5. The DG set is rated by KVA only and hence how much KVA, deliverable from DG set is the focus point now.

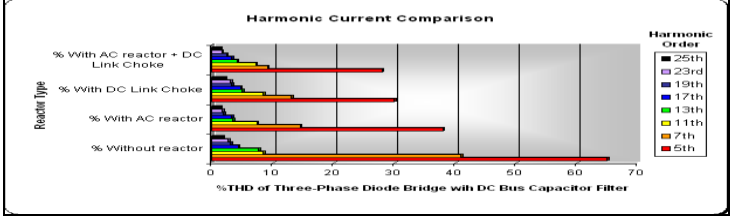
6. The power factor improvement capacitors on linear loads only and not to be located at the incoming of VFD loads etc.

7. The healthy symptom of a good VFD is that the VFD maintains PF 0.90 Lagging at the input at the minimum & maximum level of motor loading. Still the Line Reactance choke to be fitted at VFD input, though the VFD may have DC link choke.

Now we understand, why Load End Compensation is required for our 3-Phase motors rated above 5 HP?

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

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. Thisonsume more KW power compared to loadend, passive filters inhybrid mode



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 + for non-linear loads.
PF improvement IN STAGES & THD Current H5 & H7 reduction IN STAGES to implement NOW.

DG SET POWER PARAMETERS' MONITORING:-

1. **Hence to have control over the DG output in terms of KVA, KW, and the PF, automation of DG set energy parameters is one of the ways to get the best out of DG set comfortably. So the Maximum Demand Controller MDC & APFC will be operating at PF 0.9 instead of 0.6 now.**

2. These are retrofitted to the existing DG set then, it will cap the max demand from the load to the DG set as well DG set is put to max optimum rating. Its audio visual alarm & multiple alarm settings can be used to pro-rate the production.

3. The user can think of replacing ordinary KWH meter in his DG set with this MDC which gives per phase KVAH, KWH, and average PF and this not only acts to monitor but also control the max KVA demanded by the load automatically.

4. It should be ensured the single phase loads are distributed evenly across the three phases so that the unbalance between 3 phases is not more than 10 % of the total DG set capacity. More the unbalance, this will lead to less UPL.

CONCLUSION:-

At the present day crisis of increasing Diesel fuel prices, it is suggested to the industry to optimize the units per liter from your DG set. Either you plan to have basic minimum essential loads and reduce your DG size or optimize the DG loading to achieve Diesel saving. Or, if you are forced to run your DG during standby, then fully utilize your DG to its optimum running capacity compared to its rating. Here it is prudent to achieve higher units for the same Diesel consumption otherwise. **DG set loading decides the UPL and its efficiency, this point can be well-taken by the industry now and implement the same to judiciously use the DG set to suit to your rational, optimum and essential requirements deliverable efficiently now.**

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