CASE STUDY

LV STATCOM IN MANUFACTURING SECTOR

1. PROBLEM DEFINITION

Voestalpine VAE SA (Pty) Ltd is a leading partner for complete turnout systems, including drive and safety technology, as well as for diagnostic and hazard notification systems for all railway applications – ranging from high speed to heavy haul, urban traffic and mining.

The manufacturing processes at the heavy-engineering VAE Plant in Isando, Gauteng, creates an electrical demand from the local supply authority that is very dynamic in nature, with processes switching on and off throughout the day. VAE is purchasing the electricity from the supplier against a two-part electricity tariff, which is basically a kWh real energy consumption part and a kVA Maximum Demand part.

In a drive to reduce the annual electrical energy purchases from the local supply authority, the VAE plant in Isando, Gauteng, has installed a 314kW Rooftop Solar PV Plant in 2014. This plant was commissioned in August 2014, and since then there was a reduction in kWh real energy purchases from the supply authority.

To reduce the monthly kVA Maximum Demand cost on the electricity bill, Power Factor Correction (PFC) is the most general solution to realise this. However, the low voltage (LV) PFC system of the switched-capacitor type was not functional at this plant due to failed components. These failed components could be attributed to higher than normal switching frequency of the capacitor steps as a result of the high dynamic nature of the plant's electrical load, and due to resonant over-voltages in the capacitors caused by harmonic currents and voltages present on the LV network.

The connection of the Solar PV Grid-tie Inverters on the plant's LV electrical network in August 2014 introduced another dynamic to the electrical load of the plant as seen from the supply utility's side. The Grid-tie inverters were configured to generate power directly into the AC grid at unity Power Factor (PF), meaning that only real power (kW) is injected into the grid from the Solar Plant. The result of this is that during daytime when the sun shines, the Solar PV Plant will reduce the instantaneous kW real power demand from the supply utility, while the instantaneous kVAr reactive power demand will remain unchanged at that instant, and will only be determined by the electrical load of the manufacturing plant itself.

While the kW demand from the supply utility drops when the sun shines, the kVAr demand stays the same – the result is that the PF of the plant as a whole as seen by the supply utility decreases.

So VAE SA required a new PFC solution to control the PF of the plant continuously at a target level better than 0.96 (lagging) under dynamic load conditions and dynamic power generation conditions from the Solar PV plant.

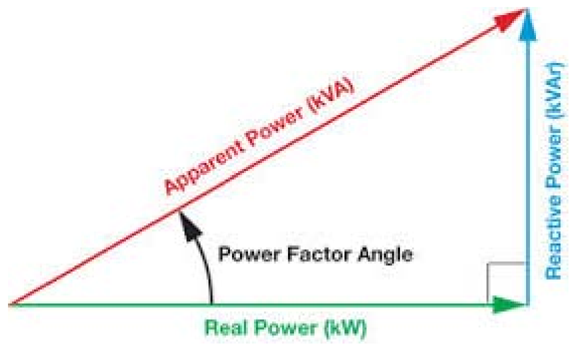
2. APPLICATION DESCRIPTION

The improvement of electrical energy distribution efficiency has long been realized using passive power factor compensators containing shunt capacitors. Shunt capacitors are relatively inexpensive to install and maintain. However, shunt capacitors have the problem of poor dynamics, poor voltage regulation and may suffer from resonances with distributed inductances of the power grid.

A typical industry solution for this problem is the application of tuned filter reactors in series with each compensation capacitor bank. This solution, however, significantly increases the required capacitance and rated voltage of the capacitors, as well as the cost of the whole compensator. This justifies application of more advanced techniques like SCR based dynamic power factor compensators (SVC) or STATCOM (Static Synchronous Compensator) converters, which can cope with all the problems mentioned above.

STATCOMs are part of the flexible alternating current transmission systems (FACTS) device family. Their primary purpose is to supply a fast-acting, precise, and adjustable amount of reactive power to the ac power system to which they are connected.

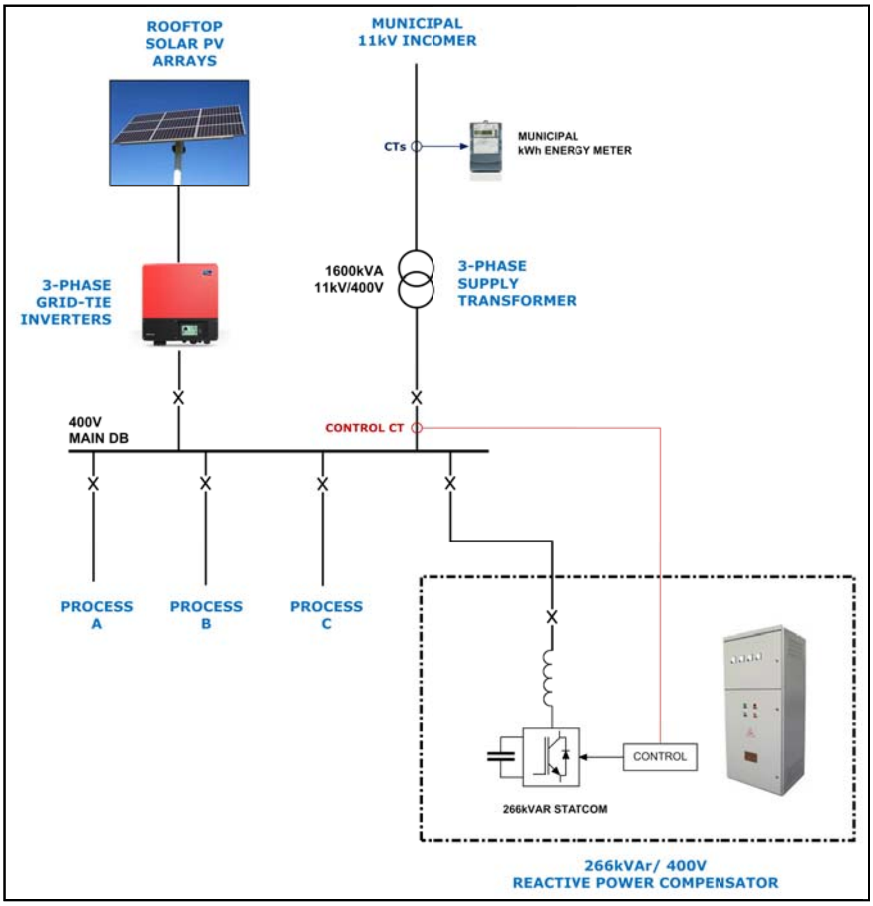
STATCOMs are also commonly used for dynamic power factor correction (i.e., dynamic reactive power compensation) in industrial plants operating with large, time-varying peaks of reactive power demand. STATCOMs increase the PF of the plant, minimize the voltage fluctuations at the plant input (which prevents damage to the equipment), and reduce the plant's operating costs.



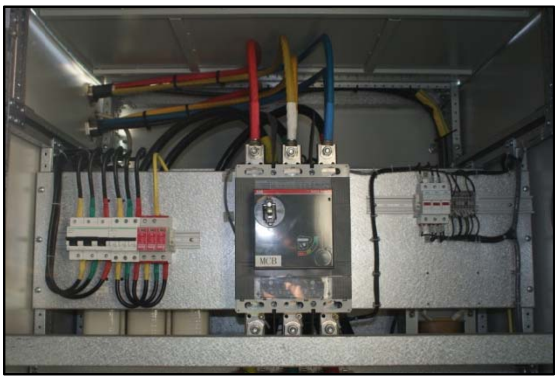
A LV STATCOM solution was designed and implemented at the VAE SA plant in Isando in April 2015. The rating of this STATCOM is 266kVAr @ 400V.

The single line below shows the Solar PV Plant feeding into the LV (400V) plant network, while the STATCOM is also connected on the same 400V Bus. The STATCOM uses measured current of the Main LV Incomer to calculate the correct amount of instantaneous reactive power to be injected into the network. This amount of reactive power required is determined by the plant's instantaneous electrical load and by the instantaneous real power generated by the Solar PV Plant.

The STATCOM dynamically varies the amount of reactive power that it injects into the 400V Bus in order to keep the instantaneous PF on the Main LV Incomer better than 0.96. The transient response time of the STATCOM is 0.1ms, meaning that it will follow very fast step changes in the electrical load of the plant. In this application the PF on the LV Incomer is controlled on 0.98 (lagging), while the PF on the 11kV Input of the Transformer follows that on a constant 0.97 (lagging).



The pictures below show the 266kVAr LV STATCOM installed at the VAE SA plant in Isando, Gauteng.

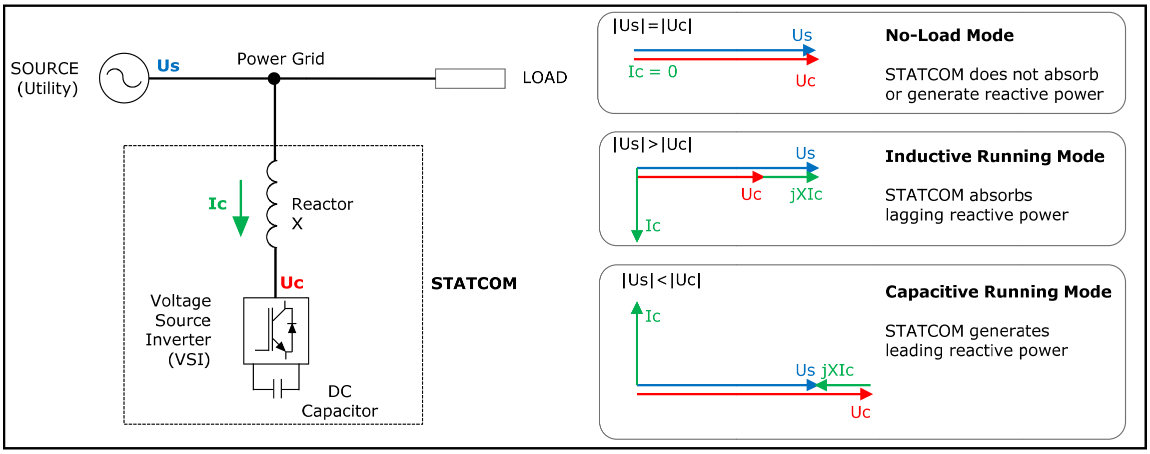


3. STATCOM WORKING PRINCIPLE

The term Static Synchronous Compensator is derived from its capabilities and operating principle, which are similar to those of rotating synchronous compensators (i.e. generators), but with relatively faster operation.

By definition, STATCOM is a static converter that uses force-commutated power electronics (i.e. GTO, IGBT) to control power flow and improve transient stability on electrical power networks. STATCOM is a shunt device that operates as a parallel connected static reactive power compensator, which capacitive or inductive output current can be controlled independent of the ac system voltage. In addition to system voltage control, which typically is the main task of the STATCOM, it may also be employed for additional tasks such as damping of power system oscillations, which results in improvement of the transmission capability.

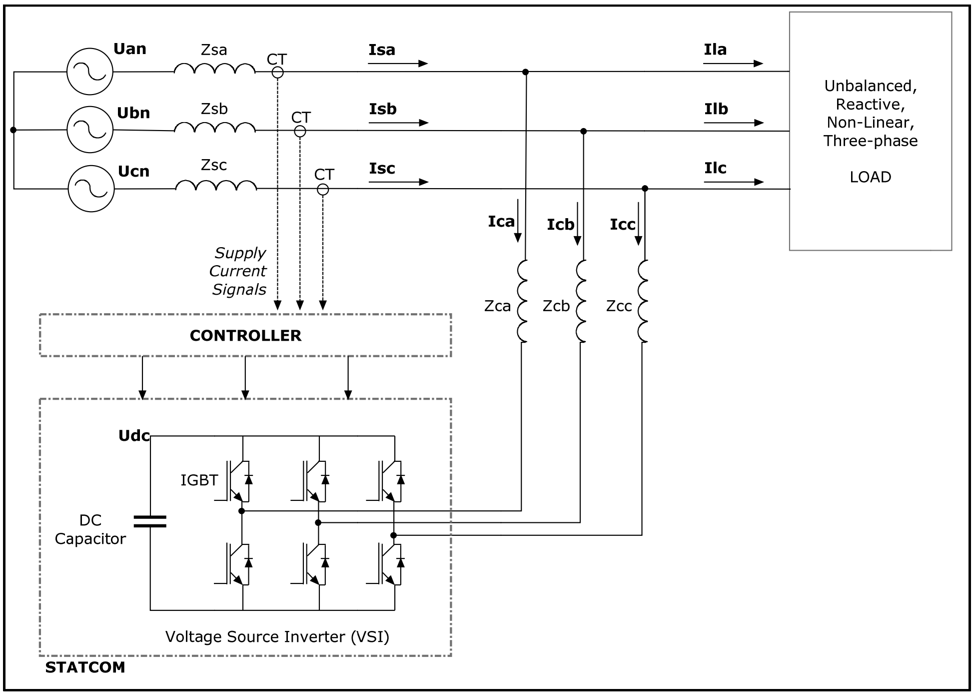
STATCOMs achieve this by adjusting the magnitude and polarity (phase) of the reactive component of the current flowing through their ac side. This enables STATCOMs to almost instantaneously control the amount and direction of flow of the reactive power exchanged with the ac power system. The picture below indicates that a STATCOM can absorb lagging reactive power (Inductive mode) or generate leading reactive power (Capacitive mode). It can change between these modes almost instantaneously.



Structurally a STATCOM is a voltage-source inverter (VSI) based device, which converts a DC input voltage into an AC output voltage in order to compensate the reactive power and improve power factor in the system. In case the system voltage drops sufficiently to force the STATCOM output to its ceiling, its reactive power output is still not affected by the grid voltage magnitude.

Therefore, it exhibits constant current characteristics when the voltage is low. STATCOM can provide instantaneous and continuously variable reactive power in response to grid voltage transients, enhancing the grid voltage stability. The STATCOM operates according to voltage source principles, which together with unique PWM (Pulsed Width Modulation) switching of power switches gives it unequalled performance in terms of effective rating and response speed. This performance can be dedicated to active harmonic filtering and voltage flicker mitigation, but it also allows providing displacement power factor compensation of the load, thus improving the PF.

An electrical diagram of a typical application of a STATCOM and its control CTs (current transformers) in a LV power network is shown below.



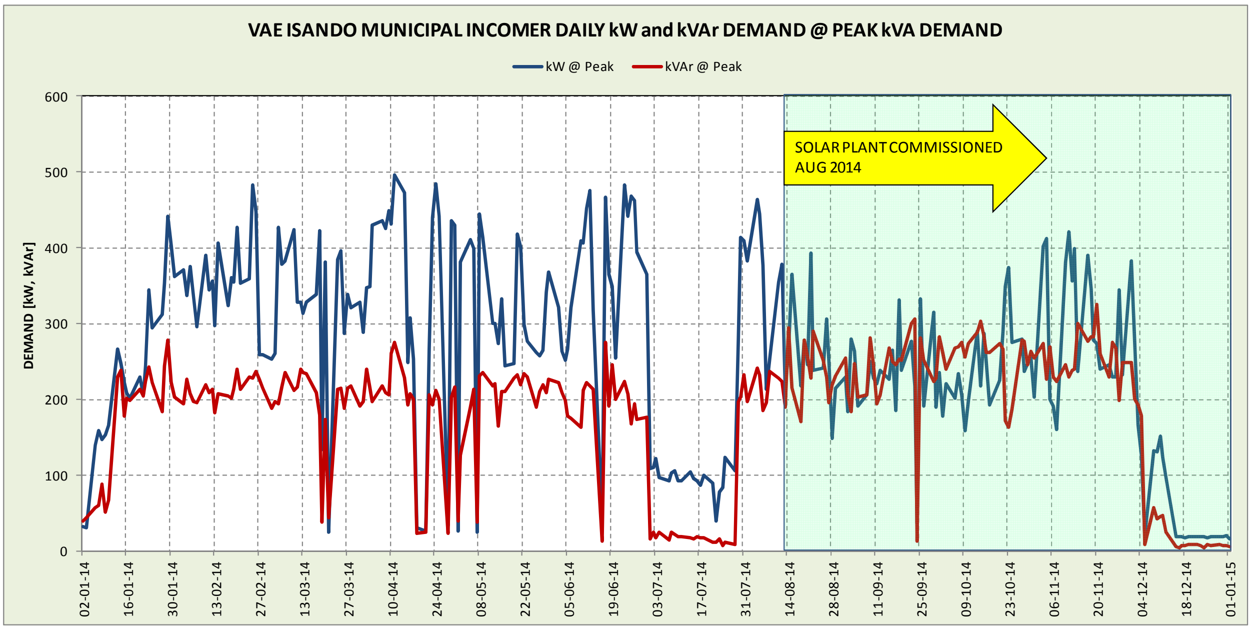
4. STATCOM ADVANTAGES

A STATCOM is used where traditional solutions won't work:

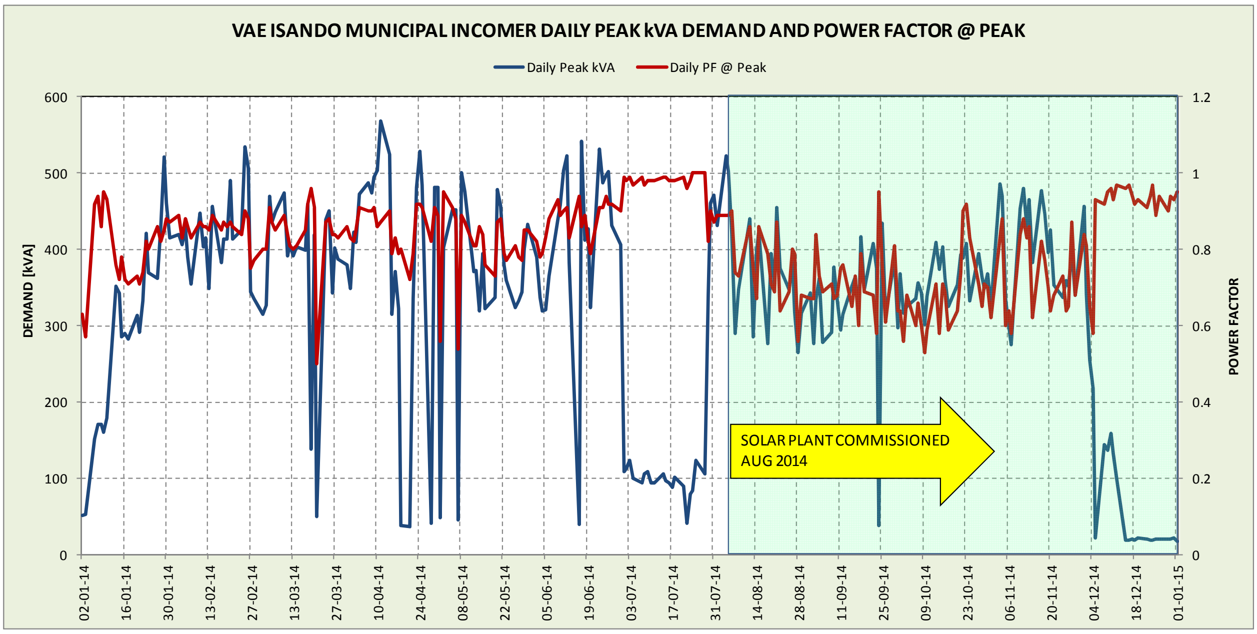
- It is able to autonomously control the voltage resulting in a much faster power factor correction.
- It can generate a continuously variable output without steps, no harmonics, no transients.
- It can generate and absorb reactive power, linear to system voltage.
- For all practical purposes it reacts instantaneously. Reaction starts ≤ 5ms after event, full power results in 20-50ms. It can change from rated capacitive reactive power output to rated inductive reactive power output in a response time ≤ 10ms.
- It has the ability to restrain voltage flicker.
- It has a diversified compensation function – it can not only compensate system reactive power, but can also compensate load harmonic current, negative-sequence current and other power quality problems.
- Its covering area is small - the footprint of a STATCOM is typically 50% of an SVC with the same capacity.
- It has low power losses <2%.
- It is immune against harmonics that are present on a power network.

5. RESULTS

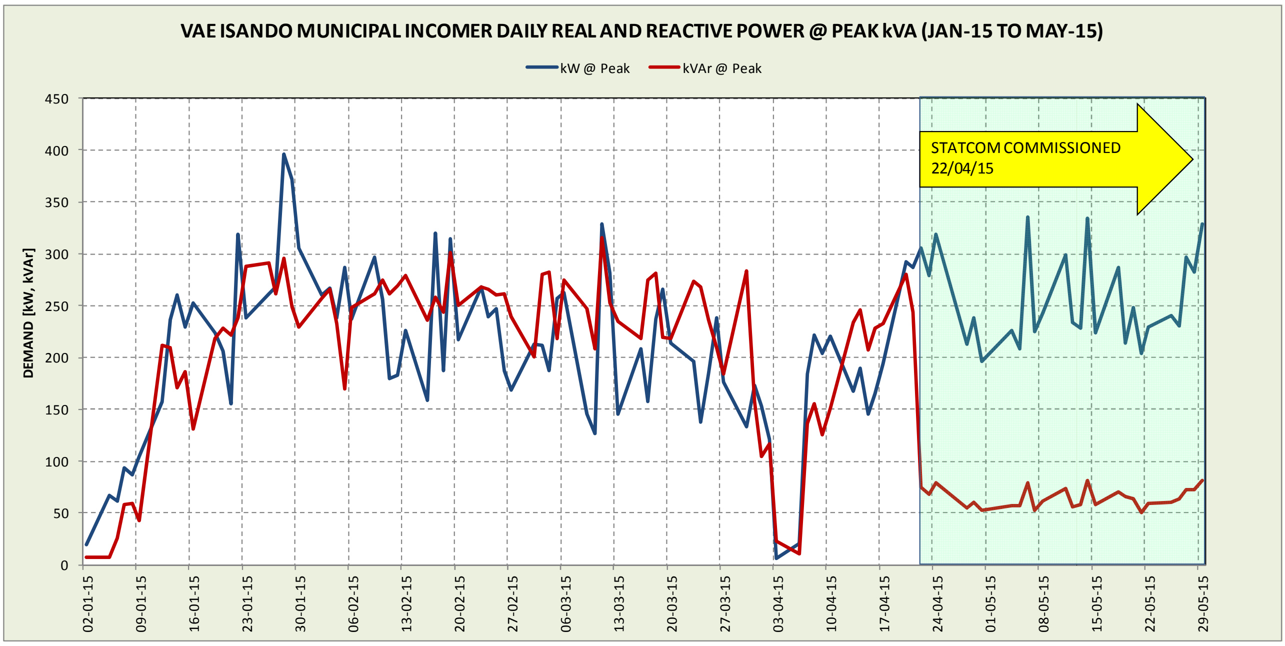
Just to give some background, the effect of the Solar PV Plant at VAE SA in Isando that was commissioned in August 2014 is shown below. The first graph below shows the weekday daily kW real power and kVAr reactive power profiles taken at daily kVA peak demand, as measured on the 11kV Municipal Incomer, for 2014. The reduction in kW real power demand (blue line) is evident since the commissioning of the Solar PV Plant. The peak kW values dropped from about 500kW to about 400kW.



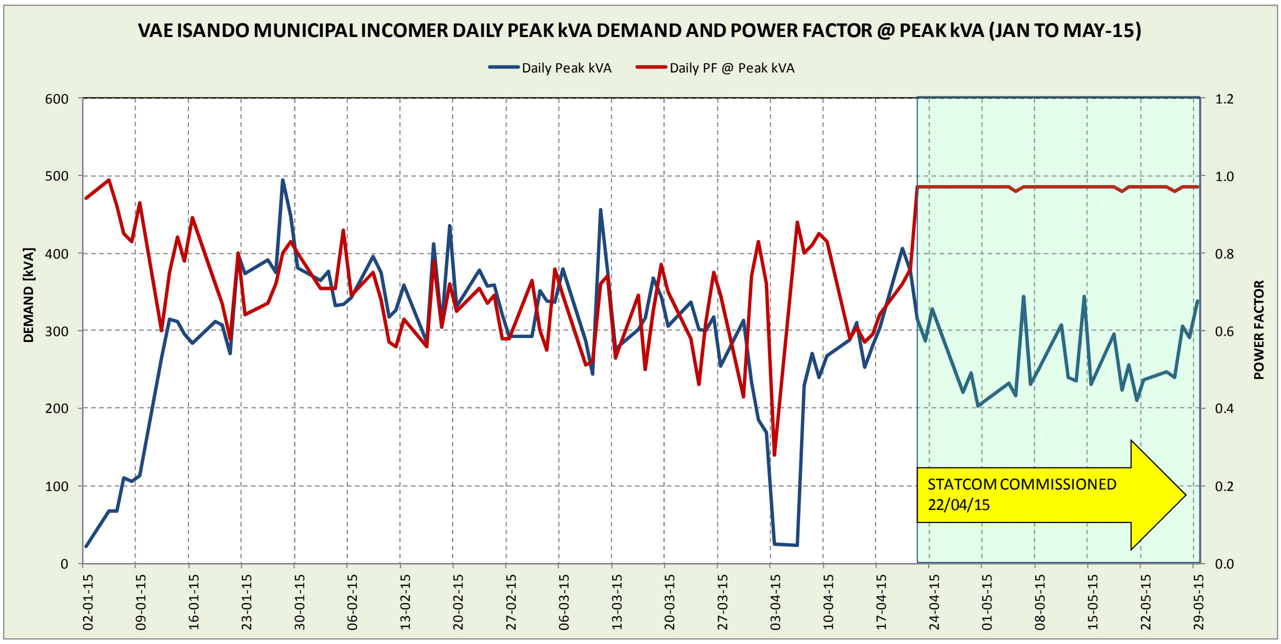
The graph below shows the weekday daily Peak kVA demand and the Power Factor @ Peak. The reduction in daily kVA Peak kVA demand as well as the reduction in Power Factor @ Peak is evident since the commissioning of the Solar PV Plant.



The effect of the STATCOM is shown in the graphs below. The first graph shows the weekday daily kW real power and kVAr reactive power profiles taken at daily kVA peak demand, as measured on the 11kV Municipal Incomer, for 2015 until the end of May 2015. The reduction in the kVAr demand is evident since the commissioning of the STATCOM in April 2015.



The graph below shows the weekday daily Peak kVA demand and the Power Factor @ Peak for 2015 until the end of May 2015. The reduction in daily kVA Peak demand as well as the **increase** in Power Factor @ Peak is evident since the commissioning of the STATCOM in April 2015. The Power Factor @ Peak as measured on the Municipal Incomer is constant on 0.97 since commissioning of the STATCOM.



6. CONCLUSION

The LV STATCOM that was implemented at the VAE SA manufacturing plant in Isando proves to be a very efficient and successful solution to control the Power Factor of the plant, as measured on the Municipal Incomer, on an excellent 0.97 (lagging) under dynamic plant and solar conditions.

Since commissioning of the STATCOM, the monthly kVA Maximum Demand is reduced by about 50kVA, which will result in monthly cost savings on VAE SA's electricity bill. The simple payback period of this solution is estimated to be within 6 years.

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