APPLICATION REPORT for MEETING NEW EMISSION REG’S in CEMENT PLANTS

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Cement Plant Precipitator Enhancements to Meet New Emission Regulations, using ModuPower™

All Industrial facilities commonly utilise Electrostatic Precipitators (ESP) for collection of filterable particulate matter, from process gas streams (clinker, cement mill, power flue gas, etc). Historically, the vast majority of precipitators have been powered by conventional power systems operating on 50 / 60 Hz. Conventional power systems have an inherent flaw limiting the amount of power they can transmit to the ESP before a spark occurs.

This in turn limits the collection efficiency of each ESP section well below its maximum capability. This paper will demonstrate how ModuPower technology can be retrofitted to an existing ESP, to increase performance in terms of reduction in emissions.

The ModuPower MPX improves the particulate matter (PM) collection efficiency of any electrostatic precipitator, by increasing the average power into the process, regardless of application. Implementation of ModuPower MPX is a standard part of many environmental projects involving:

- Reducing baseline particulate matter (PM) emissions to meet the new emission regulations
- Regulatory compliance for emission standards mitigating additional inlet dust loading from DSI (Dry Sorbent Injection) and ACI (Activated Carbon Injection)
- Mitigating effects of fuel switching or blending while meeting the emission results
- Reducing PM emission during transient operating periods (startup, shutdown, boiler load ramp)
- Reducing opacity spikes from soot blowing and rapping

Introduction to Conventional Power Supply Systems for ESP’s

In principle, ESP operation is very straightforward. Particles to be removed from the gas stream are charged through contact, with negatively charged ions (corona discharge) generated inside the ESP. At the same time, a high voltage potential is applied to the gas stream, providing the driving force for moving charged particles to the collecting plates.

The ESP removal efficiency is highly dependent on the voltage differential between the discharge electrode (Eo) and the collection plate (Ep). The typical ESP operates at a voltage in the range of 30kV and 100kV. Specialised power systems are required to convert common supply voltages to the high voltage DC, which is required to power the ESP.

Conventional power supply systems have been used to energise ESP’s, in most applications. Each conventional power system consists of the transformer-rectifier (TR) set current-limiting reactor (CLR) and silicone-controlled rectifier (SCR) that produce the high voltage power source for the discharge electrodes.

The TR set is a high voltage transformer and rectifier that together, convert low voltage single phase AC power to high voltage DC power. The CLR limits the peak current draw during transient overload (sparking) conditions. The SCR regulates the voltage into the TR set, to adjust the output voltage and current to the ESP.

Though very reliable, conventional power systems have several drawbacks that result in excessive auxiliary power usage and limit ESP operating efficiency.

Although T/R units are reliable and guarantee a long operating life, they have a very poor power factor and unfavorable waveform of electric currents and voltages. The thyristor commutation creates harmonic distortion, while the presence of relatively high series reactance, along with phase delays due to thyristor firing angle, creates substantial reactive power.

In addition, electrode voltage has a large pulsating component at the fundamental frequency of 100 Hz, which causes a decrease in the average voltage. Namely, the peak voltage must not be higher than breakdown voltage. For that reason, the average voltage must be significantly lower.

The short summary of T/R supplied, ESP is summarised below:

- Due to a large voltage ripple, the average voltage and the corona current density are lowered
- It is necessary to have a larger surface of the plates and spend a larger quantity of steel
- The reactive power, distortion power and losses are relatively high
- T/R unit represents a single-phase load
- Spark energy amounts 130 J – 200 J due to a slow thyristor reaction
- High spark energy causes a rapid erosion of collecting plates
- The eroded collecting plates are more difficult to de-dust, so the inner ash layers are permanently retained and fused
- Very long de-ionization intervals (from 40 ms to 100 ms) are necessary due to higher spark energy

Due to the low operating frequency (50/60 Hz), the majority of the losses are observed in the large windings and core materials for the CLR & TR set.

Maximum power conversion efficiencies for conventional power supplies range from 60%-65%.

The lost power is converted to heat, which is expelled, mostly from the SCR, CLR, and TR Set and to some lesser extent by remaining components within the system.

The calculated power losses from each component in a system rated for 30 kW output, are highlighted in table 1 below.

Table 1: Comparison of Losses in Conventional Power Systems and HFPS

Conventional Power System			ModuPower High Frequency Power System		
Rated System Output	30000	Watts	Rated system Output	30000	Watts
SCR Losses	161	Watts	Rectifier & IGBT Losses	1560	Watts
CLR Losses	4284	Watts	DC DC Coil Losses	240	Watts
TR Set Losses	12840	Watts	HV Unit Loss	1200	Watts
Total Losses	17285	Watts	Total Losses	3000	Watts
Efficiency	63.40%		Efficiency	91%	
ModuPower High Frequency system reduces losses by 75% vs Conventional Power system					

Solution: ModuPower High Frequency Power System

Often a quicker, less intrusive and more cost-effective solution to improve ESP performance, is replacing the conventional power supply system with a high frequency power system that converts 50/60 Hz power to a low ripple DC, with output waveform ripple below 3%.

The reduced ripple in the output voltage allows the HFPS to produce a higher average output voltage (Eo), which in turn produces higher collection efficiency. The typical voltage output from the HFPS, usually determined by the ESP plate spacing, discharge electrode type, and the particle resistivity; ranges from 50 kV to 120 kV with improved spark handling. The HFPS also has a faster spark and arc response time—microseconds instead of milliseconds—that reduces power dissipated in sparks and arcs and reduces wear on power feed components and ESP internals.

The HFPS upgrade option has two principal benefits that are dependent on how the unit is operated.

1. The first benefit is to improve ESP collection efficiency, when less particulate emissions are desired. The SMPS puts more power (increased Eo) into the ESP, resulting in higher collection efficiency
2. The second benefit for plant owners is for a unit where less ESP auxiliary power use is desired, in order to either improve unit heat rate or increase sellable power to the grid

With this option, the HFPS replaces the inefficient conventional power systems used on an ESP - operating with acceptable collection efficiency, by limiting the power output to that of the TR and CLR it replaces. The HFPS operates at >90% power efficiency compared to the TR, which generally operates at <60%. For the same power input into the ESP (and the same ESP collection efficiency), HFPS can reduce auxiliary power use by 30%. ModuPower™ HFPS systems have also been used in a variety of unique applications, as the following three case studies will illustrate. The physical differences and changes to circuit topology are shown below in Figure 1

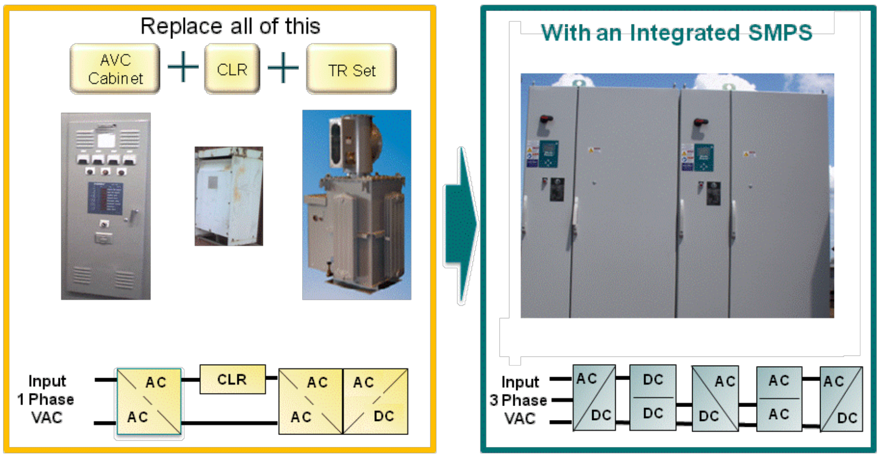


Fig-1: Conventional Power Supply System vs. ModuPower High Frequency Power System

The topology initially requires higher power losses in the rectifier and IGBT switching components to achieve the higher operation frequency of 35 kHz. The high frequency generated by the system yield significantly lowers the power loss in the HV Unit vs. the conventional TR set.

This reduces the overall size and energy storage capacity of the power system. The decrease in energy storage potential and circuit topology allow for a significant reduction in size and therefore losses of the DC coil, when compared to the conventional power system CLR. Strategic component selection and optimized IGBT operation accounts for additional major efficiency improvements.

Table 1 further above, highlights the differences in power losses between a conventional power system and a ModuPower High Frequency Power system, for the same 30 kW output rating. The significantly lower losses with ModuPower HFPS for the same power input to the ESP will result in 75% less wasted energy. **HFPS provides:**

- Low ripple DC with output waveform ripple below 3% when conventional TRSET is 30%
- Reduced ripple allows the ModuPower HIFPS to produce a higher average output voltage, which in turn produces higher collection efficiency
- Faster spark and arc response time — microseconds instead of milliseconds
- Switching frequency – 35KHz
- Power factor 0.94
- Easier to service – replaceable modular parts – crane, etc. no required to lift TR set

Examples of Success

Case Study: 1

Schenck Process supplied ModuPower™ HFPS power supplies for a clinker cooler ESP at a 5,500 TPD capacity cement plant, located in Andhra Pradesh for Sree Jayjyothi Cements Limited (My Home Industries Limited).

To control PM (Particulate Matter) emissions, the clinker cooler was originally equipped with a 4 field Thermax Electrostatic Precipitator (ESP) energised by conventional power supplies (TRSET).

The ESP was originally designed for a gas flow rate of 519,400 Am3/hr, maximum inlet dust concentration of 22,000 mg/Nm3 and outlet emission of 50 mg/Nm3. The original design collection efficiency is 99.77%. While the plant was able to meet 48.9 mg/Nm3, additional changes to the ESP were required to meet new the government PM emission limit regulation of 30mg/Nm3.

My Home Industries (MHIPL) initially tried to meet the emission regulations by replacing conventional TRSETs with 3 phase TRSETs in all 4 fields. However, after installation of the 3 phase TRSETs, the PM emissions remained at 43.89 mg/Nm3, well above the level expected by MHIPL.

The 3 phase TRSETs also created sparking issues in each field causing poor performance and excessive damage inside the ESP. MHIPL then reinstalled the conventional TRSETs while searching for alternate solutions.

MHIPL contacted Schenck Process in January 2016 to discuss potential solutions to meet the government emission regulations.

Fig- 2: 2 x 60 kW ModuPower™ TM MPX cabinets mounted remotely in control room. 100kV rated HV cable used to connect MPX to ESP

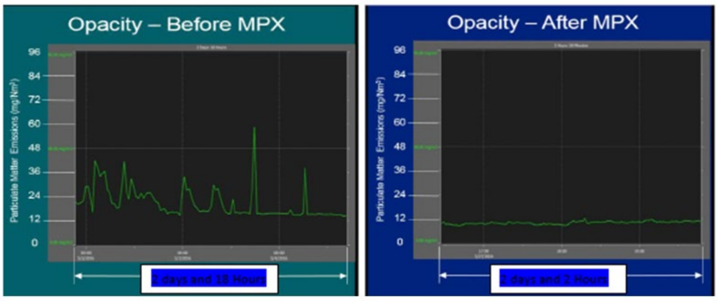
Schenck Process utilised their process expertise to provide the customer with performance estimates for a variety of scenarios. The confidence generated by this analysis prompted the customer to quickly exercise the proposed solution to lower the PM emission rate.

MHIPL decided to perform a trial run by replacing conventional TRSETs with MPX in only the first 2 fields, out of 4 fields to get confidence about the MPX product and evaluate performance at steady state operation. For this scenario, Schenck Process calculated and guaranteed an emission reduction from 48.9 mg/Nm3 to <30 mg/Nm3.

The complete scope of the project consisted of replacing (2) of (4) conventional TRSETs with (2) 60 kW MPX, replacing existing ESP ground switches and equipment to remotely install the MPX cabinets 50 meters from the ESP using a HV cable. Comprehensive field service support was provided by SPG throughout the duration of the project, which included a pre-commissioning site evaluation, installation supervision and commissioning as well as additional support for process tuning and emission measurement verification.

After MPX commissioning, plant startup and tuning of the MPX and rapper controls, the PM emissions were confirmed to be well below target at 27.4 mg/Nm3 using (2) MPX and (2) conventional TRSETs. No other changes or repairs were made to the precipitator during the installation. The resulting performance improvement was better than expected and allowed the plant to resume full production while maintaining emission compliance.

The MPX is able to achieve these results by supplying a more constant voltage to the ESP versus the original conventional TRSETs or 3 Phase TRSETs. This eliminated unwanted peaks in the output voltage waveform that caused excess sparking and poor performance.



Before Condition: 4 X Conventional TRSET					After Condition: 2 X MPX & 2 X Conventional TRSET				
Description	Type	SV(KV)	SI (mA)		Description	Type	SV(KV)	SI (mA)	
Field-1	TRSET	38	240		Field-1	MPX	43	600	
Field-2	TRSET	33	250		Field-2	MPX	40	446	
Field-3	TRSET	35	450		Field-3	TRSET	38	520	
Field-4	TRSET	34	470		Field-4	TRSET	40	501	

Fig- 3: Opacity comparison before and after installing ModuPower™

Following the above (fig-3) performance tests, additional testing was performed by taking the outlet field TRSET out of service and operating the ESP with only (2) MPX and (1) TRSET.

The emission levels remained below the 30 mg/Nm3 target. Further automation of power optimisation will be performed to ensure the facility continues to operate below the emission limit while using the least amount of auxiliary power.

Case Study: 2

Figure 4: 1 x 60 kW ModuPower™ MPX cabinets mounted in ESP rooftop. 100kV rated HV cable used to connect MPX to ESP

Schenck Process provided ModuPower™

MPX to Shree Cements Limited, RAS includes ESP fitness check, Gas distribution test (GD Test), ModuPower™ MPX supply and commissioning. The process tuning of rapper and ModuPower™ has been done through online support.

The existing 3 field clinker cooler ESP with gas volume of 128.94 am3/sec has a design outlet emission of 50mg/Nm3.

The operating conditions are limited with ESP emission of 82mg/Nm3 when all fields are in operation. After MPX -60kw/67KV/900mA installation, the outlet emission achieved 47mg/Nm3. The emission limits are well within the guaranteed parameters.

The performance improvement totaled 47.2% with (1) ModuPower™ MPX. This success allowed subsequent orders for other units of Shree Cements and Captive Power Plant (CPP) of Shree Cements.

Before HFTR														
Location	Date	Sampling Time	Value Observed (mg/Nm3)	Kill feed (TPH)	AQC Status	Recirculation Damper	Stack Damper	TR1		TR2		TR3		Remarks
								kV	mA	kV	mA	kV	mA	
Unit VIII Cooler ESP	02.04.2017	11.52AM-12:28AM	82	241	In-Circuit	0%	100%	29	137	30	237	28	300	With Old System (Single Phase Conventional TRSET)
	02.04.2017	12:43PM-01.21PM	77	241	In-Circuit	0%	100%	41	136	40	236	36	300	
Average Sampling(mg/Nm3)			80											
After HFTR														
Location	Date	Sampling Time	Value Observed (mg/Nm3)	Kill feed (TPH)	AQC Status	Recirculation Damper	Stack Damper	HFTR-1		TR2		TR3		Remarks
								kV	mA	kV	mA	kV	mA	
Unit VIII Cooler ESP	25.05.2017	01:26PM-01:59PM	47	230	In-Circuit	0%	100%	51	518	46	458	41	464	With New System HFTR in (1st) first field only
	19.07.2017	04:34PM-05:09PM	49	239	In-Circuit	0%	100%	51	571	46	528	42	537	
	24.07.2017	12:45PM-01:18PM	35	239	In-Circuit	0%	100%	51	542	47	528	44	539	
	28.07.2017	11:42PM-12:15PM	37	252	In-Circuit	0%	100%	52	571	48	529	44	537	
Average Sampling(mg/Nm3)			42											
Percentage of Reduction in dust emission (%)			47.2	Reduction by Installation of High Frequency TRSET in 1st field only										

Table: 2 Emission measurements & Operating parameters before and after HFTR

Based on the below chart in figure 5&6, the HFTR increased the secondary voltage (kV) and secondary current (mA) drastically, in the first field. The elimination of un-wanted peaks in the output voltage waveform which caused excess sparking and poor performance, provided much needed current into the ESP for better charging and collection efficiency, which in turn lowered the PM emissions.

As shown, the HFTR performance also impacts the 2nd and 3rd field, as there is higher improvement in the kV & mA, compared with the existing single phase 50Hz conventional TR Set. This leads overall higher collection efficiency to reduce the emissions. The overall performance of the HFTR 1st field is 47.2%. The emission has been reduced from an average of 80mg/Nm3 to an average of 42 mg/Nm3 only, with 1 HFTR is the first of Unit-VIII cooler ESP. Figures 5 & 6 graph the KV & mA before and after the HFTR was installed.

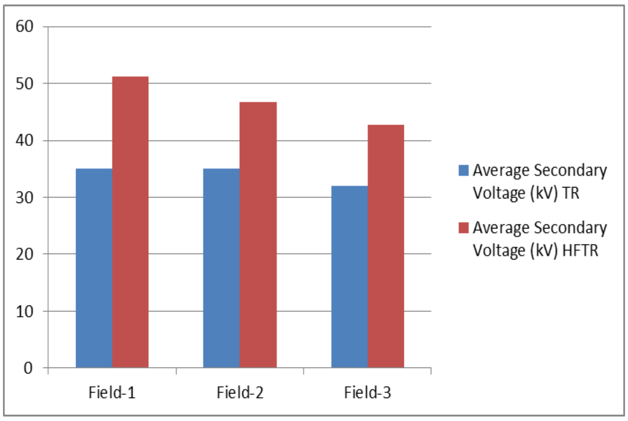


Figure 5: kV comparison between TR vs HFTR

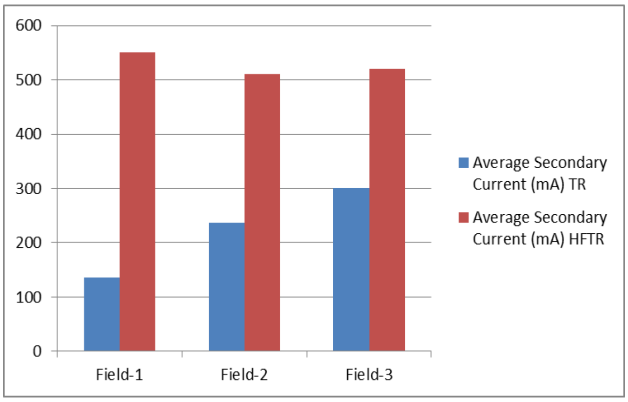


Figure 6: mA comparison between TR vs HFTR

Case Study: 3

Schenck Process supplied ModuPower™ MPX power supplies for a clinker cooler ESP at a 5,500 TPD capacity cement plant located in Yerraguntla, Andhra Pradesh for Zuari Cements (Heidelberg Cements group). To control PM (Particulate Matter) emissions, the clinker cooler was originally equipped with a 2 field FLSmidth Electrostatic Precipitator (ESP) energised by conventional power supplies (TRSET).

The ESP was originally designed for a gas flow rate of 640,000 Am3/hr, maximum inlet dust concentration of 30,000 mg/Nm3 and outlet emission of 50 mg/Nm3. The original design collection efficiency is 99.77%. While the plant was able to meet 90-100 mg/Nm3, additional changes to the ESP were required to meet new the government PM emission limit regulation of 30mg/Nm3.Schenck Process took this project as a turnkey project, with the scope inclusive of ESP retrofitting and revival.

Comprehensive field service support was provided by Schenck Process throughout the duration of the project, which included an EPS inspection, GD test, ESP repair, Rapper tuning, pre-commissioning site evaluation, installation supervision, commissioning as well as additional support for process tuning and emission measurement verification.

After MPX in both fields with the rating of 90KW/75KV/1200mA & 120KW/75KV/1600mA, the outlet emission achieved <30mg/Nm3 and the emission limits are well within the guaranteed parameters.

Before Condition: 2 X Conv TRSET			
Description	Type	SV (KV)	SI (mA)
Field-1	TRSET	35	250
Field-2	TRSET	35	250
After Condition: 2 X MPX			
Field-1	MPX	46	650
Field-2	MPX	49	800

Table: 3 ESP TRSET readings before and after ModuPower™

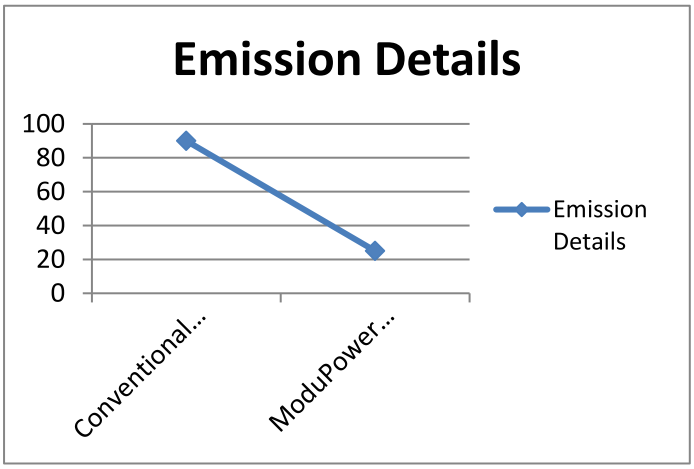
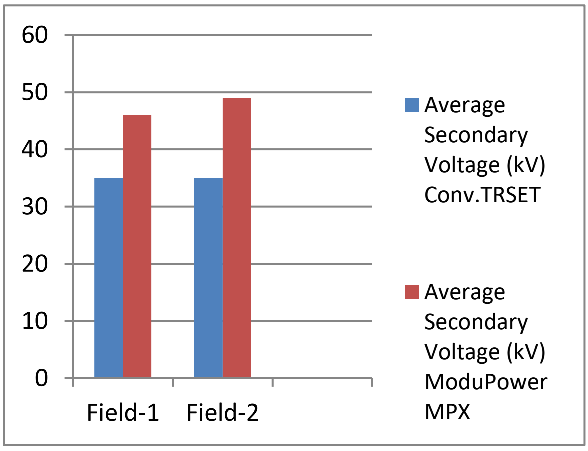


Fig: 9 Emission comparison chart

Based on the Fig (9) the emission has been reduced drastically from 95mg/Nm3 to 25mg/Nm3.

Precipitator retrofit benefits using HFPS:

- Replaced existing conventional TRSET with High Frequency power system and provided the repair of existing precipitator internals, to achieve the higher DC voltage which reduces emissions and increases the performance of the ESP
- No major shutdown (downtime) required. The only downtime was within 24 hours of stoppage, enough to make the changes in the existing ESP for final arrangement of HV connection
- There was no additional space and no civil work involved in this setup
- Erection & commissioning time was 3-6 days based on the qty of the HFPS, which reduced the installation cost
- Existing ID fan can be utilised, with low power consumption, lower maintenance and no extra space required at the existing control room



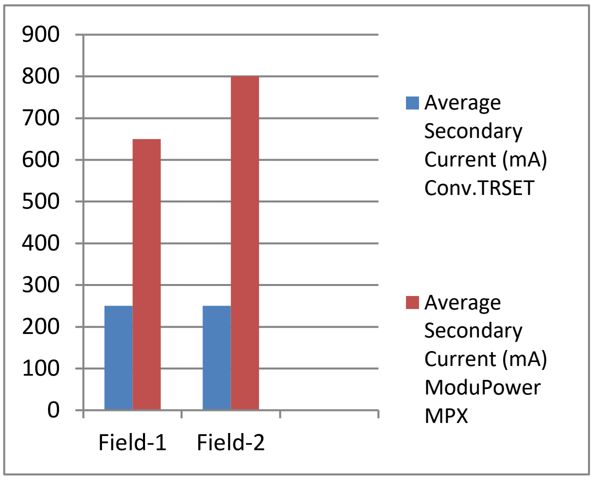


Fig: 7 kV comparison between TR vs HFTR
Fig: 8 mA comparison between TR vs HFTR

Summary

ModuPower High Frequency Power system provides significant power conversion efficiency improvements, versus conventional power supply systems.

Combining this with other High Frequency Power system features, such as advanced control methods and low output ripple voltage, the system provided multiple options for taking advantage of the superior efficiency.

Full implementation of High frequency Power systems across the entire ESP will offer the biggest advantages in power conversion efficiency and collection efficiency. In addition to full implementation of a high frequency power system across the entire ESP, partial or staged installation plans can be utilised to yield the necessary improvements, while optimising project costs.

The optimal project plan should be developed in collaboration with power supply system experts. A summary of the advantages from using ModuPower in a retrofit project:

- Reduces up to 60% PM (Particulate Matter) emissions compared to conventional technologies
- Suitable for ESPs in Cement (Clinker cooler ESP, Cement Mill & other related process ESP's)
- Over 97% electrical efficiency
- Suitable for installation on new or existing ESPs
- ModuPower™ operates at 35KHZ fixed frequency
- The HFPS system allows the above collection improvements to be obtained without upgrading the existing ESP Feeder system. At the same time, the power plant now has the opportunity to generate additional revenue through the kVA that has been made available to loads connected to the grid
- Avoids cost-intensive retrofit
- Avoids major shutdown of the plant operation

Biography of Author:

Elavarasu Jayakumar is an Application Engineer for the Environmental Controls product line at Schenck Process UK Ltd. With over 11 years of experience in pollution control equipment, Elavarasu is responsible for end-to-end process of Environmental Control Products for various industrial segments such as power, cement & Steel industries in UK & Europe. Apart from this, Elavarasu has authored articles for the World Pollution control Association (WPCA) newsletters about the case studies of High frequency power systems and he presented papers at 15th NCB International Seminar at New Delhi India. Elavarasu holds a Bachelor of Engineering degree in Electronics and Communication from Anna University, India.

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End of report

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