Abatement of particulate emission with only changes in ESP Energization with case studies across the globe

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The installations of SMPS (Switch Mode Power Supplies) in the inlet fields of an electrostatic precipitator (ESP) tend to provide and produce a combined effect greater than the sum of their separate effects when placed further back in the ESP.

The degree in improvement of achievable collecting efficiency, as always, depends heavily on the process conditions.

The better the mechanical state of the ESP, the more energy electrical can be delivered in search of optimum collection results.

With the stricter environmental norms better performance is required from both in service as well as ESPs still on the drawing board.

Conventionally, design improvements and rebuilds to increase SCA (specific collecting area) are always one of the preferred methods of performance improvement.

This process while in general preferred is often not practicable for a number of different reasons.

Some of these might include:

- finance considerations,
- space and mechanical structure considerations,
- shortage of time to meet regulations,
- immediate productivity improvements.

Under these circumstances, other methods are sought to improve performance without the need to address the above mentioned points in their entirety.

A change in the Energization strategy has long been one of the methods employed.

The advancement from:

- analog controls to microprocessor based system, while still not complete on many precipitators has been a major factor;
- the implementation of I.E or Intermittent energization as it is known has been employed to minimize the effects of back corona on ESP where high fly ash resistivity is found;
- the implementation of micro second pulsing to enhance the process mentioned above;
- the upgrade of the power pack to deliver an essential pure DC signal with little or no ripple by delivering power to the ESP at frequencies in the kHz range;
- certainly not a new concept, but rather a reinvented method of upgrading the front end from a standard conventional 50/60 Hz power supply to a switch mode front ending allowing the engineer the opportunity to deliver power to

the ESP across a multitude of frequencies with either the existing standard TR sets or the additional of a proposed design higher frequency TR.

It is this last method that we discuss in this paper and cite some of the experiences that we have had as we experiment and subsequentially install these the power sources.

The development of an SMPS that allows for flexibility in its implementation is a milestone for improved ESP efficiency for many types of ESP applications.

Advantages have become apparent for a number of reasons, not only that of emission reductions.

As is the norm benefits are not realized with 100% success. There are far too many factors involved with the electrostatic process for this to be a "FIX ALL" solution.

It is becoming clear though, that there are certain precipitators that almost always benefit while on others, testing and research before jumping to conclusions is a worthwhile exercise.

It is generally considered that SMPS power supplies deliver performance improvements as a result of certain well known concepts:

- a reduction in the peak to peak voltage applied to the precipitator yielding a higher average power;
- the ability to operate the ESP at more moderate flashover levels to mitigate sparking and thus improve long term power delivery;
- the opportunity to detect sparks and arcs, and instead of waiting for them to extinguish while the power reduces of its own accord, remove the power to the ESP instantaneously;
- managing the spark response to this higher degree mitigates hot spots, ash erosion and reentrainment.

The particular type of SMPS used in the process of creating the results for this paper, takes advantage of other concepts to benefit its inclusion in the wide world of ESP power supplies.

- A more robust, solid and reliable IGBT (Insulated gate bipolar transistor) front end while using a transformer, rectifier and other components that have been available to the transformer industry for well over 3 decades.
- The opportunity to use it as a controls/front end retrofit package.

- The opportunity to include it with a multitude of different manufacturers controls and TR sets.
- And the most valuable of them all is the use the system as part of a hybrid ESP where all the controls need not be SMPS units, but rather a mix of technologies where it is recognized that SMPS technology provides no "significant" benefit over the controls and TR (transformer rectifier) sets already installed and operating reliably on the plant in question.

Numerous plants have afforded us the opportunity to test and to quantify this type of equipment in situ along with opportunities to demonstrate performance benefits and prepare for other issues to do with power supplies such as the ever concerning issue of obsolescence and the fact that this aging industry requires an injection of new younger engineers who are not familiar with earlier techniques.

As with any technology put into service in an industry such as ours, it is necessary to gather as much information by covering as many fule type precipitator types as possible.

These stretch across a multitude of industries since the use of ESPs is so wide spread. One needs to cover processes that reduce pollutants, recover product and of course to most important, keep us safe from harmful airborne gasses and particulates.

South Africa has long had issues with its local coals and has such boasts some of the largest ESPs in the world. Notwithstanding this, particulate management in an environment where funding and investment are hard to come by, is a significant problem.

The tests described below were done on one of ESKOMs (the South African electricity utility) plants.

With such a large ESP having multiple gas passes and multiple electrical sections, only recording opacity on a stack mount monitor, the task of assessing performance improvement is difficult, but power improvements of the field under test and also of fields directly behind the field under test are generally considered to be an indication of enhanced performance.

An SMPS front end operating on a conventional TR was fitted in place of one of the existing 50 Hz front ends.

Measurements were taken with the SMPS and then the 50 Hz unit was returned to service in order to take the comparative data.

With reasonably stable generator, at 591 MW, the SMPS delivered 6 kV more than the 50 Hz unit. This improvement in voltage allowed the Precip to draw an additional 231 mA.

This additional power in the inlet field cleaned up enough particulate such that the 2^{nd} fields showed improved performance with an additional 2 kVdelivering an additional 140 mA. The 3^{rd} field appears to climbed in voltage and yet remains somewhat current supressed.

Table 1.

GENERATOR	DUST EMISSIONS	DUST EMISSIONS	LHI 1	LHI1	LHI 2	LHI 2	LHI 3	LHI 3	DCI Lin Comico	Total VW	Dates
LOAD	CORRELATED	EXTRAPOLATED	Current	Voltage	Current	Voltage	Current	Voltage	P SU III Service	TULdi KW	2012
591	127	223	456	36	418	37	943	37	REDKOH Average	62	Jul 9-11
501	127	216	225	30	278	35	9/6	34	50Hz	40	W 11.14

The data is averaged over a number of days and so we cannot truly explain why the current has not risen as a result of the greater kV.

One possible explanation is that with less ash being presented to the field and the original rapping times still being implemented, the dust layer on the plates is not shearing well and is being re-entrained and adhering to the Discharge electrodes rendering them less effective.

Without multiple data points to create continual VI curves, the graph below simply shows a relationship for the volts and the amp and makes an assumption as to the initial corona onset voltage.



Figure 1.

The VI curve steepens considerably faster under the SMPS energization in the first field.

1. Faster spark control at higher operating frequency

This site experiment was done to check the effect of spark in kV and mA waveforms at verious operating frequncy.



Figure 2. Maximum spark rate set at 100/min and 50 Hz TR operating at 100 Hz



Figure 3. Maximum spark rate set at 100/min and 50 Hz TR operating at 200 Hz



Figure 4. Maximum spark rate set at 100/min and 50 Hz TR operating at 300 Hz



Figure 5. Maximum spark rate set at 100/min and 50Hz TR operating at 400 Hz

It was observed that there was faster control in spark even when a conventional 50 Hz transformer was operating at 100, 200, 300, 400 Hz.

2. Higher collection efficiency

Various site experiments were carried at various process to check the effect of SMPS in terms of improved collection efficiency.

The experiment was carried with SMPS installed at inlet field and resulting approximatly 20% emision reduction from earlier running opacity without any mechnical modifications at verious process.

- Cooler ESP of Cement plant.
- Cement mill ESP of Cement plant.
- Thermal Power plant.
- Steel industry.

• Recovery boiler of paper plant.

Imidiade effect of emmission reduction is observed after changeover visible on trend of opacity.

• 700 MW coal fired thermal power plant in India where opacity drop after SMPS was installed in inlet field.



• PF boiler precipitator with GEECOM electrodes,South Africa.



Figure 7. Before – Inlet Field Reading 50 Hz conventional supply 50 spm



Figure 8. After – Inlet Field Reading on Redkoh Switch Mode supply 20 spm

• Cooler ESP of cement plant



Figure 9. Before – Inlet Field Reading 50 Hz conventional supply 24 spm



Figure 10. After – Inlet Field Reading on Redkoh Switch Mode supply 17 spm

Some more results of cooler ESP in India where the SMPS was placed in inlet field and resuls in opacity drop was monitored.

These are various site results in india on cement plant cooler ESP where the emission was lowered to the desired range just by adding SMPS panels at inlet of ESP.

- The effect of SMPS is checked in terms of opacity for low resitive dust also and high resitivity dust also.
- The effect of SMPS is checked in terms of opacity in Small ESP also and big Coal Fired ESP also.
- The effect of SMPS is checked in terms of opacity by replacing all single phase major controllers of world.
- The effect of SMPS is checked in terms of opacity at many variable process.
- 210 MW (4×6 field) Coal fired ESP in India

The test was carried for 3 months with inlet field of each pass added with SMPS.Customer was benifited by following reasons by installing SMPS in there ESP.

- 1. With SMPS in first field the emission was same as it was with ammonia dosing.so there is no need for ammonia dosing if we use SMPS in field 1 of each pass.
- 2. With SMPS in first field at earlier condition with ammonia dosing also there was a reduction of 20% emission.
- 3. The TR sets at 25 year old still there was no problem to TR sets.

4. Customer was able to run the plant at full load without any shoot in Opacity.

f HFPS Installed s field	Earlier emission	Emission effect	
		arter HFF5	
FIRST	39	32	
ALL THREE FIELDS	1083	75	
FIRST	COMPOUND MODE:- 41-64 DIRECT MODE:- 83-98	COMPOUND MODE:- 29-52 DIRECT MODE:- 23-46	
SECOND FIELD AS FIRST FIELD WAS MECHANICALLY DOWN	133	93	
FIRST	45	37	
FIRST	15	13	
FIRST	35	25	
	FIRST ALL THREE FIELDS FIRST SECOND FIELD AS FIRST FIELD WAS MECHANICALLY DOWN FIRST FIRST FIRST FIRST FIRST FIRST	FIRST39ALL THREE FIELDS1083ALL THREE FIELDS1083FIRSTCOMPOUND MODE:- 41-64 DIRECT MODE:- 83-98SECOND FIELD AS FIRST FIELD WAS MECHANICALLY DOWN133SECOND FIELD AS FIRST FIELD WAS MECHANICALLY DOWN133FIRST45FIRST15FIRST35	

The readings monitored was recorded at same ESP and boiler condition and now customer was able to run the plan at stable load and coal since the opacity has no effect on type of Coal fed .The resistivity of dust at this site 10^{13} .

The ESP was was giving better results even at worst coal.

Table 3.					
Type of ESP	No of fields	HFPS installed field	Emission before HFPS	Emission with HFPS (Various readings recorded at same ESP/Boiler conditions)	
COAL FIRED 210MW BOILER	6X4 = 24	FIRST FIELD OF ALL PASS	68.67	49.7	
COAL FIRED 210MW BOILER	6X4 = 24	FIRST FIELD OF ALL PASS	58	45.03	
COAL FIRED 210MW BOILER	6X4 = 24	FIRST FIELD OF ALL PASS	58.87	49.43	
COAL FIRED 210MW BOILER	6X4 = 24	FIRST FIELD OF ALL PASS	57.11	41.69	

• Pulp and Paper

Pulp and Paper Plant USA

Salt cake recovery boiler precipitator – by Clyde Bergemann EEC.

Here at same process parameter after installation of SMPS there was a fall in opacity by 19%.

Table 4

	D 1	D 2	
Parameter	Run I Redkoh	Kun 2 Conventional	
	Reukoli	Conventional	
Date of Run	8/29/2012	8/29/2012	
Time of Run	14:18-15:26	17:00-18:07	
Inlet			
Particulate Mass Rate, LB/HR			
Dry Catch Particulate	13953	13547	
Particulate Concentration, GR/DSCF			
Dry Catch Particulate	7.6263	7.5163	
Outlet			
Particulate Mass Rate, LB/HR			
Dry Catch Particulate	9.76	12.05	
Particulate Concentration, GR/DSCF			
Dry Catch Particulate	0.0053	0.0066	
Source Gas Velocity, Feet Per Second	80.58	80.65	
Isokinetic Variation, %	99.6	100.5	

The same type of test carried out at Pulp and paper industry in India.

Pulp and Paper Plant INDIA

We have added only one SMPS panel in field 1 of ESP 1 this resulted in a common chimney emission reduction drastically:

- 23 % emission reduction AT 450 RPM,
- 33 % emission reduction at 550 RPM.
- Reliablility of 50-60 Hz trasformer at elevated frequency

At one of the coal fired Thermal Power plant in India the SMPS panels were connected to 25 year old ESP and 25 year old Transformer.There the TR sets were running smooth for 3 months long trial without any heating effect and trip of trasformer.The healthiness of transformer was confirmed again by charging the trasformer with conventional SCR based panel and all the readings were same as it was before trail.



Figure 11. 25 year old BHEL make transformer which was designed at input voltage 373 VAC was running for 3 months with SMPS panels at 200 Hz and there

was no issues with the transformer. The heat dissipation was also measured near traformer all the times and there was no heating effect in transformer

This site is a 210 MW (4×6 field) Coal fired ESP in India and the SMPS panels are installed in first field of all 4 pass

5. User friendly as compared to > 15 kHz system with nearly all features of > 15 kHz

14010 5.							
Technology	3.2 kHz	> 15 kHz					
Requires a 3 Phase Power Source	Yes	Yes					
Technology uses Isolated Gate Bipolar Transistor (IGBT) "H" bridge for power switching	Yes	Yes					
Resonant mode used	No	Yes					
Transformer Rectifier requires forced cooling	No	Yes					
Must be mounted in cool clean environment	No	Yes					
Switching electronics can be mounted remotely from the transformer rectifier	Yes	No					
3 Phase power for Switch Mode Power Supply (SMPS) must be available at the TR location	No	Yes					
3 Phase cables must be run to the ESP Roof	No	Yes					
Allows more power to be drawn by the precipitator	Yes	Yes					
Power factor better than 0.9	Yes	Yes					
IGBT Switching Losses	Low	High					
Re-use of existing Transformer rectifier set	Possible	No					

Table 5.

- 6. Upper hand with conventional 3 phase SCR based system
- 8-10% more power to the ESP field using 15 to 20% less electricity.
- Higher Power Factor of 0.9 at rated output of the transformer & .88 at 50% of rated output compared to 10.84 at rated kV and 0.43 at 50% of rated kV for the 3 phase power supplies.
- Higher average voltage throughout the operating range.
- Faster and more responsive intermittent energisation.

a T/R set rarely runs at full rated output. In-let fields tend to operate at high kVDC with suppressed mADC levels. As the exhaust gas moves to the ESP outlet, the kVDC levels tend to drop and fields tend to run at mADC current limit levels.

• The disparity between IGBT and 3 phase T/R power factors becomes even more pronounced at less than full rated output. For example, at 67% kVDC and 100% mADC, the T/R delivers 37.2 kW and IGBT 44.0 kW. The T/R input kVA is 90; the IGBT is 50.7. This is a kVA reduction of almost 44%.

- No Mechanical changes required at ESP top.
- Exisitng TR can easily be used.
- No extra cable from control panel to TR set is required.

Closing arguments (No Project, Just solution)

Redkoh make SMPS system has successfully achieved emission reduction with no major electrical or mechanical shutdown at smooth running process and has given a result of better performance than designed parameter of ESP and with following goals we achieved the optimum result of ESP.

- Increased average voltage to the ESP.
- Increased current flow to the ESP.
- Fast response times to events occurring in both the ESP and Power system.
- Possess all the benefits of the tried and trusted transformer rectifier design.
- Significantly high power capabilities.
- Reuse of existing cabling, control rooms and Mechanical TR footprints.
- Provides a solution rather than a one fits all product?