Table 2. Comparison of Four Precipitator Power Supplies

Comparison of Four Commercially Available Roof-Mounted Precipitator Power Supplies in Different KWs

Power Supply	Low Ripple Output	Frequency	External Control Cabinet	CLR Included in TR Set[1]	Cost Comparison[2]	Footprint on Roof (Sq Ft)	Footprint Comparison[3]	Weight on Roof (Lbs)	Weight Comparison[4]	Cooling on Roof
SMPS(1) 21 KW	Yes	High	No	-	1.49	14.15	0.66	1,050	0.56	Fan
SMPS(2) 20 KW	Yes	High	No	-	1.78	8.37	0.39	528	0.28	Pump & Fan
3 Phase 24 KW	Yes	Low	Yes	Yes	1.16	28.51	1.33	3,527	1.88	Passive
Single Phase 24 KW	No	Low	Yes	Yes	1.00	21.43	1.00	1,874	1.00	Passive
SMPS(1) 35 KW	Yes	High	No	-	1.89	13.81	0.64	1,200	0.64	Fan
SMPS(2) 28 KW	Yes	High	No	-	1.76	8.37	0.39	528	0.28	Pump & Fan
3 Phase 32 KW	Yes	Low	Yes	Yes	1.16	28.51	1.33	3,638	1.94	Passive
Single Phase 32 KW	No	Low	Yes	Yes	1.00	21.43	1.00	1,874	1.00	Passive
SMPS(1) 70 KW	Yes	High	No	-	2.31	15.33	0.65	1,300	0.46	Oil Circulator & Fan
SMPS(2) 60 KW	Yes	High	No	-	1.70	8.37	0.35	528	0.19	Pump & Fan
3 Phase 72 KW	Yes	Low	Yes	Yes	1.17	31.02	1.31	3,968	1.41	Passive
Single Phase 72 KW	No	Low	Yes	Yes	1.00	23.73	1.00	2,822	1.00	Passive
SMPS(1) 120 KW	Yes	High	No	-	2.31	22.23	0.86	2,300	0.65	Oil Circulator & Fan
SMPS(2) 120 KW	Yes	High	No	-	2.22	11.83	0.46	1,100	0.31	Pump & Fan
3 Phase 120 KW	Yes	Low	Yes	Yes	1.12	37.55	1.45	5,071	1.44	Passive
Single Phase 120 KW	No	Low	Yes	Yes	1.00	25.83	1.00	3,527	1.00	Passive

[1] The Current Limiting Reactor (CLR) is applicable only to 3-phase and single phase. Locating the CLR in the TR set increases its footprint and weight. The CLR can be located remotely.

[2] Within each size, the cost of SMPS(1), SMPS(2), and 3-phase is compared to single phase. For Single Phase and 3-Phase, cost includes external control cabinet and CLR in TR set.

[3] Within each size, the footprint of SMPS(1), SMPS(2), and 3-phase is compared to single phase. For Single Phase and 3-Phase, the footprint excludes the external control cabinet.

[4] Within each size, the weight of SMPS(1), SMPS(2), and 3-phase is compared to single phase. For Single Phase and 3-Phase, the weight excludes the external control cabinet.

The high frequency power supply designs shown are integrated units, meaning the entire power supply is contained in one package. This is a necessary configuration since it would be quite difficult to separate the transformer and electronics with high frequency. Having an integrated unit is a very convenient and efficient design with all of the power supply components located in one place. The power supply is packaged as a complete assembly instead of individual components that must be connected together.

The high frequency power supply designs are also physically smaller and lighter. The high frequency power supply designs utilize active cooling which helps achieve the smaller size and weight. This can become very important when trying to fit equipment on a crowded precipitator roof that has a limited ability to carry additional load.

However, there are some disadvantages to this configuration. An integrated unit often means the sensitive electronics are located in a harsh environment. This directly affects the reliability of the power supply, and having personnel service equipment in this environment is less than ideal. In addition, active cooling is another system which must be maintained, with additional energy required to operate these systems. Finally, an integrated unit means there is one source of supply for parts and service which can cause significant service interruptions if there are problems.

The low frequency power supply designs shown in Table 2 are not integrated but have separate control cabinets. This is possible with low frequency designs since standard electrical wiring can be used to connect components. The separate control cabinet allows the high voltage transformer to be located on the roof while the control electronics are located remotely, often in an environmentally controlled room. This configuration has been successfully used for many years with the single-phase power supply. The low frequency power supply designs are physically larger and heavier. They utilize passive cooling for the transformer which eliminates the need to supply and maintain an additional cooling system. Lastly, separating the controls and transformer allows each component to be sourced from multiple suppliers which helps assure a continuous supply.

There are also disadvantages to this configuration. As previously discussed, it is sometimes a challenge to find a suitable location for equipment that is larger and heavier. To solve this problem, the power supply can be located away from the main precipitator structure and then connected by means of high voltage cable. In addition, there is wiring and cabling between components which must be considered.

COST

Cost is also a significant consideration in the selection process of precipitator power supplies. Table 2 shows the comparative cost of four commercially available, roof-mounted precipitator power supplies and again, the differences are significant. The cost shown is the capital cost, or the cost to purchase the entire power supply. For the sake of comparison in Table 2, within each kW size range, the cost of the single-phase power supply was set to 1.00. The cost of the other three power supplies was then compared to the single phase. As can be seen, as the kW size increases, the differences in cost increase as well.

High frequency power supply designs are more expensive. However, since they are integrated, there is less field wiring, and installation cost should therefore, be less than the low frequency power supply designs. On the other hand, due to the combination of environment, high frequency and active cooling, maintenance cost is expected to be more than the low frequency power supply designs.

Low frequency power supply designs are less expensive. However, since they are separate components which must be connected in the field, the wiring and installation cost should be more than the high frequency power supply designs. Since they operate at a lower frequency, have passive cooling, and the electronics are in a protected environment, the maintenance cost should be less than the high frequency power supply designs.

RELIABILITY

The predicted reliability is the most difficult parameter to quantify. It is well known and accepted that the reliability of the single-phase precipitator power supply is excellent. There are many cases of this type of power supply operating continuously for more than 40 years. This is a reliability benchmark that one would like to duplicate with low ripple power supply designs.

Anecdotal evidence has shown that high frequency power supplies have had a poor reliability record, although it has improved in recent years. They suffer from such challenging factors as operating at high frequencies while connected to a device designed for low frequency (precipitator), significant internal heating, active cooling systems, harsh environment, radio frequency interference and harmonics. All of these factors have contributed to reliability issues. Suppliers have made changes over the years in an attempt to address each issue with varying degrees of success. Current experience indicates that additional effort is needed to equal the reliability of a single-phase power supply.

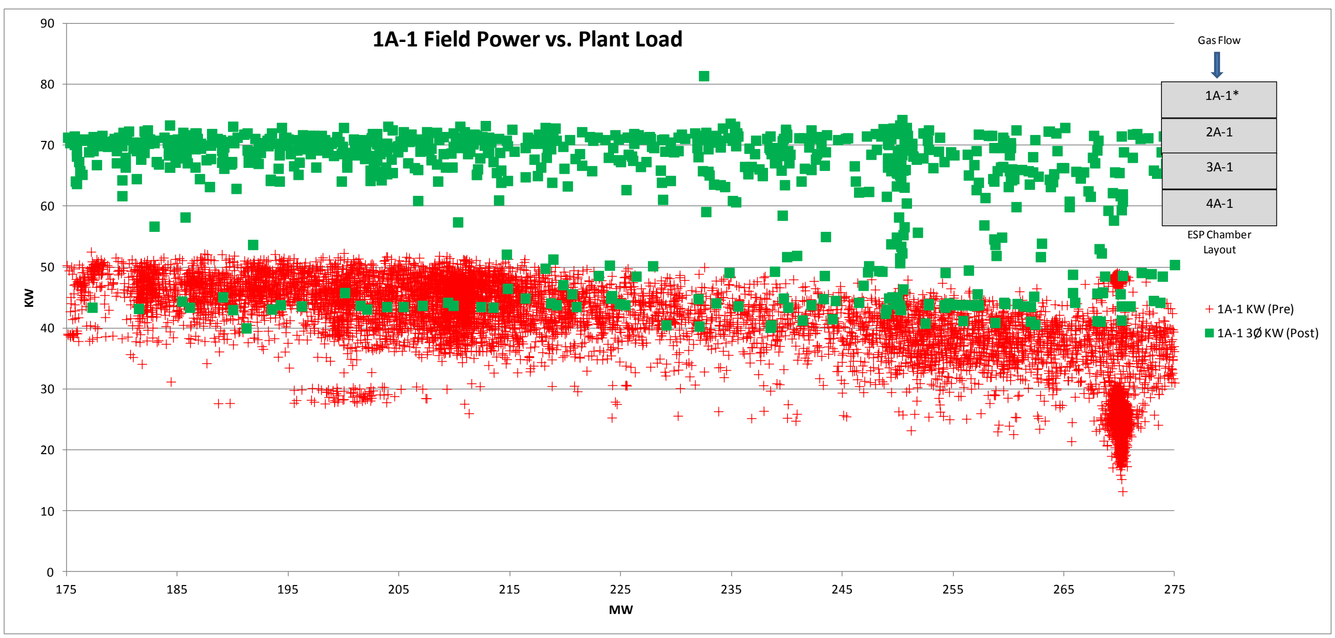
One of the goals of field testing the low frequency 3-phase power supply was to evaluate reliability. The results to date are promising; there have been no failures of the 3-phase power supply during the six-month test run. The results were somewhat expected considering the 3-phase is basically an extension of the single-phase power supply design which has an excellent reliability record, and the modeling and lab testing results support this.

FIELD TESTING OF SINGLE-PHASE AND 3-PHASE POWER SUPPLY AND OPERATING CONDITION OF THE ESP

The ESP used for performing the 3-phase power supply test is on a tangentially-fired boiler. It burns coal with a sulfur content of 1.9 lb/MBtu, has no selective catalytic reduction (SCR) system and no scrubber. The ESP consists of two boxes with rigid discharge electrodes and 16 in. wide gas passages. There are 4 fields (each 12 ft x 50 ft), and there are 8 TR sets per box (2 x 4 matrixes). Fields 1 and 2 have 70 kV, 750 mA conventional TR sets; fields 3 and 4 have 70 kV, 1000 mA sets. All TR sets are controlled by B&W PGG SQ-300® automatic voltage controls. On the "A" box, the inlet field 1A-1 TR set was replaced with a 480 V, 109 A, 90 kV, 900 mA, 3-phase TR set for the purpose of testing.

The results obtained when comparing the operating power levels of the test 3-phase power supply and the conventional power supply are shown in Figure 3.

Figure 3. MW vs. kW (Pre and Post 3-Phase Install)



As shown in Figure 3, the 3-phase power supply typically produced ESP kW values 1.5 times that of the conventional power supply (as determined by the average 3-phase power/average single-phase power). This field test confirmed the results of the laboratory testing which indicated that low ripple power supplies are expected to provide more precipitator field power. A significant impact on opacity was not anticipated because the test only involved 1/16th of the ESP.

Conditions at the field test site and the operation of the low frequency 3-phase power supply that has been installed continue to be monitored. More tests will be run at varied precipitator loads.

SUMMARY

A systematic study was performed using electrical modeling, laboratory tests, and field tests to determine the advantages and disadvantages of the many types of ESP power supplies. The results show that:

- A 3-phase low frequency precipitator power supply was developed and field tested as a result of this study to overcome many of the deficiencies discovered in the analysis of precipitator power supplies.
- The increase in corona power from a low ripple power supply can be achieved with several different technologies (SMPS, 3-phase low frequency, mid-frequency).
- Modeling data showed that the energy delivered by the precipitator power supply to the spark was insignificant compared to the total energy dissipated by the spark.
- Harmonics are unwanted and have been shown to be a concern on both the input and output of the precipitator power supply. Low frequency designs (including the 3-phase) produce fewer harmonics.
- Integrating all components into one package has the advantage of the most compact configuration. This can have the disadvantage of placing the power supply in a harsh environment which affects service life and maintenance and restricts the user to a single source of supply.
- Providing a separate transformer and control cabinet has the advantage of placing the electronic controls in a controlled environment and allows for duplicate sources of supply. This has the disadvantage of the need for a remote control cabinet and larger size and weight.
- Low frequency power supply designs (including the 3-phase) use passive cooling while high frequency power supply designs require active cooling. The increase in components and complexity for active cooling increase cost and maintenance.
- High frequency precipitator power supply designs provide low ripple at higher cost, lower reliability, but in a smaller, lighter integrated package.
- Low frequency precipitator power supply designs (including the 3-phase) provide low ripple at lower cost, higher reliability, but in a larger, heavier package with a separate control cabinet.
- The 3-phase and high frequency switch mode precipitator power supplies provide the lowest ripple voltage on an ESP load.
- The field test showed the 3-phase precipitator power supply produced an average 50% higher power in the ESP compared to the single-phase precipitator power supply. This suggests that like other low ripple power supplies, the 3-phase power supply can produce higher ESP collection efficiencies.

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