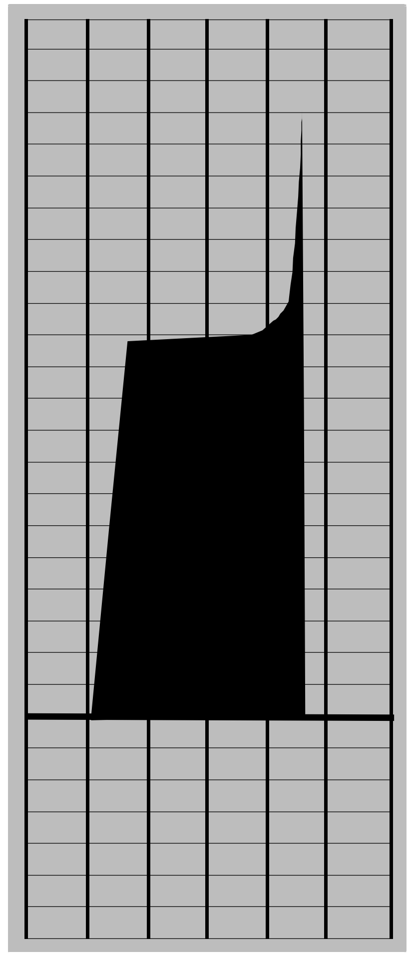
PRECIPITATOR VOLTAGE CONTROL EVALUATION FOR IMPROVED PERFORMANCE AND ENERGY SAVINGS



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By
Karl Artz
Michael Neundorfer
Neundorfer, Inc.
4590 Hamann Parkway
Willoughby, Ohio 44094

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ABSTRACT

Electrostatic precipitator voltage control technology has progressed rapidly in recent years. New automatic voltage controls (AVCs) can provide dramatically improved electrostatic precipitator performance as well as energy savings. However, the amount of potential improvement in performance and energy savings is site specific and dependent on process and other precipitator subsystem conditions. There are over 15 suppliers of microprocessor type electrostatic precipitator voltage controls. The broad possibilities for equipment selection combined with site specific results often creates confusion when selecting the best equipment and features for an application.

In order to make an informed decision, it is common for a precipitator user to temporarily install a number of competitive voltage controls for comparative evaluation.

Comparative evaluations of voltage controls are difficult due to changing process conditions, variation in bus section performance caused by conditions unrelated to the voltage controls, calibration, and many other factors. This paper provides direction for the design and implementation of on-site voltage control performance comparisons.

Selection of test bus sections is an important part of voltage control trial evaluations. It is important to know the gas flow, temperature, dust loading, and resistivity differences through the precipitator, and the internal condition of the selected bus sections. This paper provides guidance in selecting test bus sections.

Examples are presented to reinforce methods which can assure that the results from on-site voltage control evaluations are meaningful and useful.

CREATE PRIORITIZED LIST OF OBJECTIVES

The initial step in the evaluation process begins when the precipitator owner decides to replace the existing controls. The owner must first define and prioritize the objectives for the replacement controls. Usually these objectives will fall into one or more of the following categories:

- Improved particulate collection
- Reduced energy consumption / energy management
- Increased reliability of controls
- Automatic data logging

VENDOR PRE-QUALIFICATION

During the process of creating the prioritized list of objectives, the owner can begin the vendor pre-qualification process by requesting precipitator control information from reputable control suppliers. It would be wise, from the standpoint of future service, to limit the prospective vendors to those companies who actually design and manufacture their own controls.

Since the owner may eventually want to connect both the AVCs and rapper controls to a host computer, it would be wise to look at the vendors complete line of precipitator control systems. Each control manufacturer has developed their own interface hardware and communications protocol, and there is little chance that company X s rapper controls will talk to company Y s voltage controls or company Z s computer system. At this early point, make it clear to prospective vendors that, if awarded the contract, they will be required to provide full documentation on their interface hardware and communications protocol as well as a site license giving you freedom to have another vendor develop an interface to your AVCs.

Once the prioritized list of objectives is complete and you have received sufficient information to pre-qualify a number of vendors, arrange to have sales presentations at your facility. Before the presentations you should communicate your prioritized list of objectives to the vendors. This will assure that your specific needs are addressed during the sales presentations.

For example, you may have a process creating rapidly changing precipitator loading, burst sparking, and opacity problems. The controls may be mounted on the precipitator roof where internal cabinet temperatures reach 140°F in the summer. In that case, all you may be interested in is a high reliability stand alone control that can manage your T/R sets for minimum opacity under all conditions.

A vendor who does not understand your needs may present his high tech bells and whistles computer system without adequately demonstrating the capabilities of his stand alone, extended temperature-rated controls to meet your needs.

On the other hand, you may have a precipitator that is oversized and in need of an energy management system that will minimize energy consumption at the lowest achievable opacity. The vendor may, through a misunderstanding of your needs, stress increased power input with his stand alone controls while failing to present an outstanding energy management system.

Discussing your objectives with the vendors can be a valuable learning process that may very well result in a modified list of objectives. For example you may wish to implement intermittent energization to control back corona and reduce energy consumption. Some T/R sets, however, are known to be unsuitable for IE. The vendor may suggest modification of the T/R sets or the use of back corona control software combined with operating level turn down for energy management.

Your original intention may be to replace saturable core reactors with current limiting reactors (CLRs), also known as linear reactors, and silicone controlled rectifiers (SCRs). Several vendors supply a power supply to bias the saturable core reactor to a constant impedance using it as a CLR. While this approach does not provide the ideal characteristics of a CLR, in many cases the performance results are satisfactory at a considerable cost savings over CLRs.

REDUCE POTENTIAL VENDORS TO A SHORT LIST

Evaluation of the information now gathered will enable the owner to reduce the potential vendors to a short list of preferably no more than four manufacturers. Attempting to perform in-plant evaluations of more than about four controls will result in a tremendous amount of data and plant disruption spread over a considerable time frame. It is likely that the end result will be confusion and a selection process based less on facts and more on a dart board approach.

DETERMINE TRIAL EQUIPMENT TO BE INSTALLED

The equipment to be installed for evaluation can range from a simple retrofit AVC to one or more complete AVCs with current limiting reactors and a data logging system. The required equipment will be site specific. Proper selection can improve the accuracy of test results and ease the evaluation process.

If controls are being upgraded from saturable core reactors to current limiting reactors and SCRs, proper evaluation will only be possible if a linear reactor properly sized to your T/R sets is utilized for the trial. On the other hand if you are planning to bias saturable core reactors and use them in place of CLRs, then the trial results would be invalid using a CLR.

If the scope of the upgrade calls for a data logging system, it may be educational and beneficial to install the data logging system as part of the trial. The computer can then automatically record the trial unit s performance. The hands-on experience with the computer system will enable you to evaluate it with the same thoroughness as the AVCs.

Discuss special needs with the vendor. Most vendors do not want to customize the AVC software, but are usually willing to customize the data logging and energy management computer software.

SELECT TRIAL BUS SECTION

- Choose a bus section with average or typical conditions
- Select a bus section in good mechanical condition
- Select a bus section in good electrical condition
- Choose a sparking bus section
- Avoid outlet fields
- Avoid sides of precipitator

Gas flow, temperature, and resistivity often vary throughout the precipitator. Ideally these variables should be known for each bus section. If this data is available, choose a bus section that is typical for the precipitator.

Select a bus section in good mechanical and electrical condition. Realize that no automatic voltage control can make a deficient bus section perform like one in good condition. We once made the mistake of installing a demo control on a bus section preselected by the customer. We had not actually seen the bus section in operation. After the control was started we found to our astonishment that the bus section was shorted. The customer remarked that he wanted to see if our control could fix that problem.

Choose a sparking bus section running at 50% to 75% of T/R set nameplate current. Testing controls on a bus section that is running at low power levels will make it difficult to discern control differences, while a bus section operating near current limit may go into current limit for all demo controls again making differentiation impossible.

Observation of the demo control s effect on the following field is often a good indicator of changes in collection efficiency in the test bus section. It is, therefore, good to avoid the outlet field as a test site. Also, outlet fields provide the most stable gas flow and load to the T/R set making them the least challenging for an AVC.

For precipitators with three or more T/Rs per field, try to select a site in a field with adjacent T/Rs in the same field consistently operating the same as, or at a constant ratio to, the T/R at the selected test position.

Figure 1 depicts a typical small precipitator. In this case choices are limited. If T/Rs B1 and B2 are operating consistently relative to each other and are at reasonable (50%-75%) power levels, then choose one of these locations. If not, then pick A1 or A2 if at reasonable power levels, or choose C1 or C2 if they are not above 75% of rated current.

Figure 1. Small Precipitator

OUTLET

C1	C2
B1	B2
A1	A2

INLET

Figure 2 illustrates a typical large precipitator box. This provides many prospective test sites. The best choices will be in the B, C, or D fields in rows 2 through 5. Pick from these 12 bus sections the one or ones that best satisfy the criteria set fourth above. For a large precipitator with several adjacent T/Rs in the same field operating similarly, it may be possible to install several demo controls at the same time for direct comparison.

Figure 2. Large Precipitator

OUTLET

E1	E2	E3	E4	E5	E6
D1	D2	D3	D4	D5	D6
C1	C2	C3 TRIAL AVC	C4	C5	C6
B1	B2	B3	B4	B5	B6
A1	A2	A3	A4	A5	A6

INLET

OBTAIN BASELINE OPERATING DATA

In order to draw valid conclusions from the trial AVC installation, it will be necessary to obtain precipitator and various bus section operating data under the same operating conditions that will occur during the trial period. The frequency and time period over which data must be taken to meet this requirement is site specific. Ideally, for a power plant or other relatively stable process, data should be taken at least every four hours for a week prior to the test installation and hourly for 24 hours before the test. For batch processes it may be necessary to take data every few minutes during the process. The following data will need to be logged:

- Boiler load or process rate
- Opacity
- Fuel analysis and conditioning rates
- Gas conditioning rates
- Precipitator gas temperature
- Ambient temperature
- Operation of soot blowers, mills & hopper evacuation system
- Spark rate and control readings for test bus section using portable true RMS meter for primary current and primary voltage and averaging meter for secondary current and secondary kilovolts
- Above control readings for bus sections immediately to the left and right of the selected test site
- Above control readings for bus section that is one electrical section closer to the outlet in the same gas passages as the test section
- V-I curves for the above identified four bus sections
- Control readings taken at least once per shift for the entire precipitator

INSTALLATION OF TRIAL CONTROL

The installation of the trial AVC is usually the responsibility of the control manufacturer. Part of the owner s evaluation of the AVC is related to the ease of installation and quality of materials supplied. This part of the evaluation can best be ccomplished by having the owner s electricians assist the supplier with the installation of the AVC. The owner s evaluating engineer should also be present during the installation of the trial unit. Take notes of likes and dislikes during the installation process. Some vendors may be eliminated at this time due to impressions of quality of equipment, service, or ease of installation. Treat the installation process as a learning experience that will aid your ability to install the controls should you select that vendor.

Take advantage of the opportunity to ask questions of the vendor s service engineer. On the spot corroboration between the vendor and owner can often lead to minor customization of the AVC that will make installation of production units easier with little or no additional cost.

Realize that demo controls are often configured somewhat differently than production units. Be sure to ascertain the differences between the trial unit and production units that would be supplied to your plant.

If you have more than one manufacturer s demo control installed at the same time, honor your responsibility to prevent vendors access to competitors proprietary information.

As part of the trial installation, the vendor will calibrate the demo AVC. If possible, this calibration should be done with the same instrumentation used by the owner to log pre-trial installation precipitator operating data. Since, in most cases, the vendor will want to use his instrumentation, take the opportunity to check calibration between the vendor s instruments and yours. Any discrepancies must be used to adjust control panel readings on the trial unit.

When the newly installed AVC is started up, the vendor will optimize the control settings for the bus section and often point out the immediate improvement in the control readings over the control that has just been removed. Be cautious in your enthusiasm. The bus section has been off for some time. During that time, rapping has continued resulting in control start up with a cleaner than normal bus section. Allow the control (and precipitator) to stabilize for several hours before attempting to draw any conclusions from operating data.

Figure 3 shows typical operating data for a trial AVC on bus section C3 of the large precipitator model in *figure 2* and for the AVC on bus section D3 immediately down stream from the trial unit. Patterns of electrical changes and rapping effects on these changes are site and process specific. Time zero represents the trial unit s data after initial turn on and ramp up, and corresponds to the following unit s readings just before the trial unit is turned on. Notice that the trial unit shows initial impressive power levels, but then begins to decline after about 30 to 40 minutes as the bus section becomes slightly fouled. Operation stabilizes after about 80 minutes.

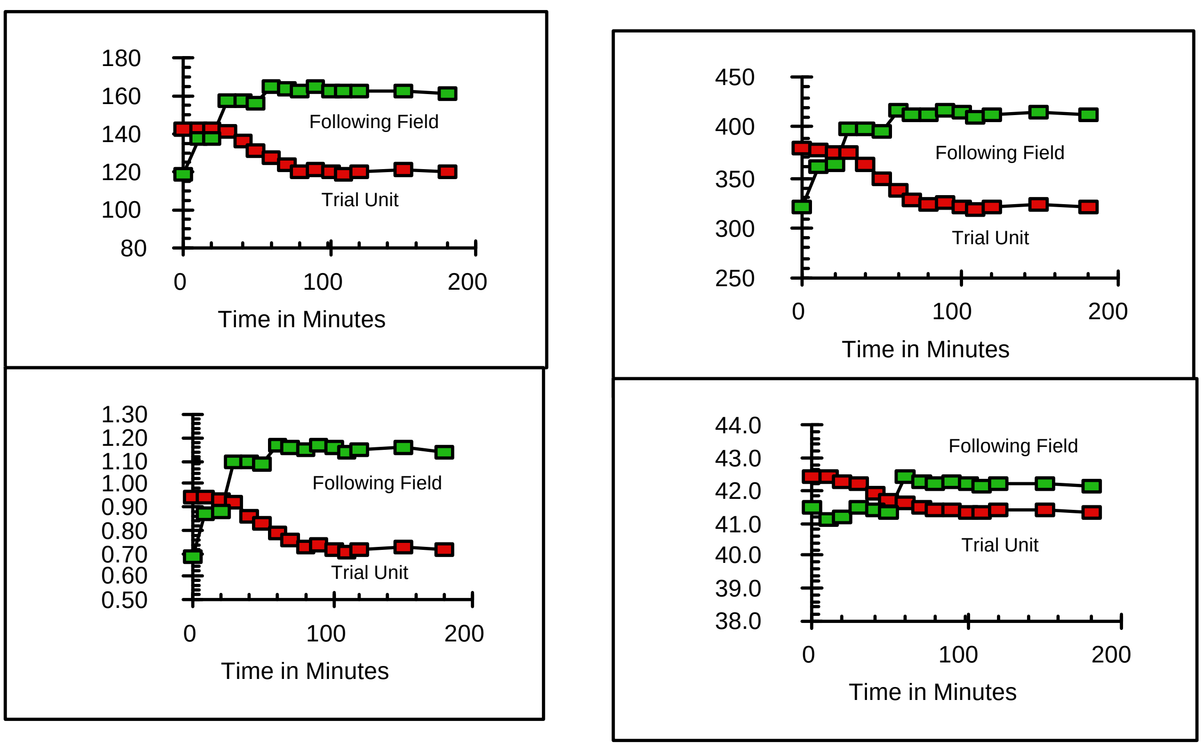
The data for T/R D3 in the field following the trial unit is particularly interesting and demonstrates the value of following field data in evaluating the performance of the trial unit. At time zero just before the trial unit is turned on, the following field is running at power levels somewhat below where C3 was operating prior to shut down for change out.

During the time C3 was shut down, its dust loading was passed on to D3. The rapping for field D is slower than for field C causing D3 to deteriorate somewhat below C3 s normal operating point.

As soon as C3 ramps up and begins to extract dust, D3 s primary current, primary voltage, and secondary current usually rise often accompanied by a small drop in KV. The readings stay at that level for 20 to 30 minutes until a rapping cycle in field D removes most of the heavy dust accumulation from the plates in D3. The rapping cycle results in a significant increase in all four D3 operating parameters. During the next 30 minutes the operating levels droop somewhat as C3 begins to decrease in efficiency. Then another rapping cycle again increases D3 s operating point. The entire precipitator reaches stability 1-1/2 to 2 hours after the trial AVC is started.

Figure 3. AVC Trial Installation Performance Data

Trial Unit					Following Field				
T/R ID________, Field______					T/R ID________, Field______				
Minutes	PI	PV	SI	SKV	Minutes	PI	PV	SI	SKV
0	143	379	0.94	42.4	0	119	321	0.68	41.5
10	143	378	0.94	42.4	10	137	361	0.87	41.1
20	142	375	0.93	42.3	20	138	363	0.88	41.2
30	141	374	0.92	42.2	30	157	399	1.09	41.5
40	136	362	0.86	41.9	40	157	398	1.09	41.4
50	131	350	0.83	41.7	50	156	397	1.08	41.3
60	127	337	0.79	41.6	60	165	416	1.17	42.4
70	124	328	0.76	41.5	70	164	413	1.16	42.3
80	120	322	0.73	41.4	80	163	412	1.15	42.2
90	121	325	0.74	41.4	90	165	417	1.17	42.3
100	120	321	0.72	41.3	100	163	414	1.16	42.2
110	119	318	0.71	41.3	110	162	411	1.14	42.1
120	120	320	0.72	41.4	120	162	413	1.15	42.2
150	121	323	0.73	41.4	150	163	415	1.16	42.2
180	120	321	0.72	41.3	180	161	412	1.14	42.1



During the stabilization period, prevail upon the vendor s service engineer to train you and at least one other person in the use of the trial AVC. You should have at least two of your personnel familiar with the controls and involved in the evaluation. Request that the vendor provide you with a manual. It may, however, be incomplete as some vendors do not provide complete schematics and system drawings with trial control manuals.

PERFORMANCE TESTING AND EVALUATION

Data Logging

With the precipitator stabilized, formal performance testing can begin. The evaluation process consists of two steps.

- Determine if new controls offer improved performance
- Determine best control for your application

In some plants, the old controls are performing so poorly that a rigorous evaluation is not needed to demonstrate the superiority of new controls. The only question to be answered is which of the trial units performs the best. Where the difference is not so obvious, the owner must first select the best performing trial voltage control and then compare its operation with the existing controls.

Data logging and analysis are the best tools for evaluating the Trial voltage controls. Plan to log at least a week of operating data for the same T/R sets and same parameters logged to obtain baseline operating data. Data should be logged at least once every hour for stable processes and more often for batch or unstable processes.

During the data logging process, watch for indications of rapping system overload. Often the rapping system is barely adequate for the existing rate of collection. Installing a trial control with markedly improved operation can result in the bus section collecting more dust than the rapping system can remove. The results will be a gradual decline in AVC operating values over a period ranging from hours to days. This can mislead the owner to conclude that the trial control is not performing well when, in fact, it has uncovered a rapping system deficiency. The solution may be as simple as speeding up the rapping frequency for the affected field, or it may require a significant rapping system upgrade. It is also possible that the increased collection may overload the hopper evacuation system necessitating a change in the evacuation program.

During the week of data logging, learn as much as possible about the trial AVCs. Become comfortable operating them. Observe visually and make notes of their gross reactions to varying precipitator conditions and particularly precipitator upset conditions.

Figure 4.
Test Data on Trial Installation

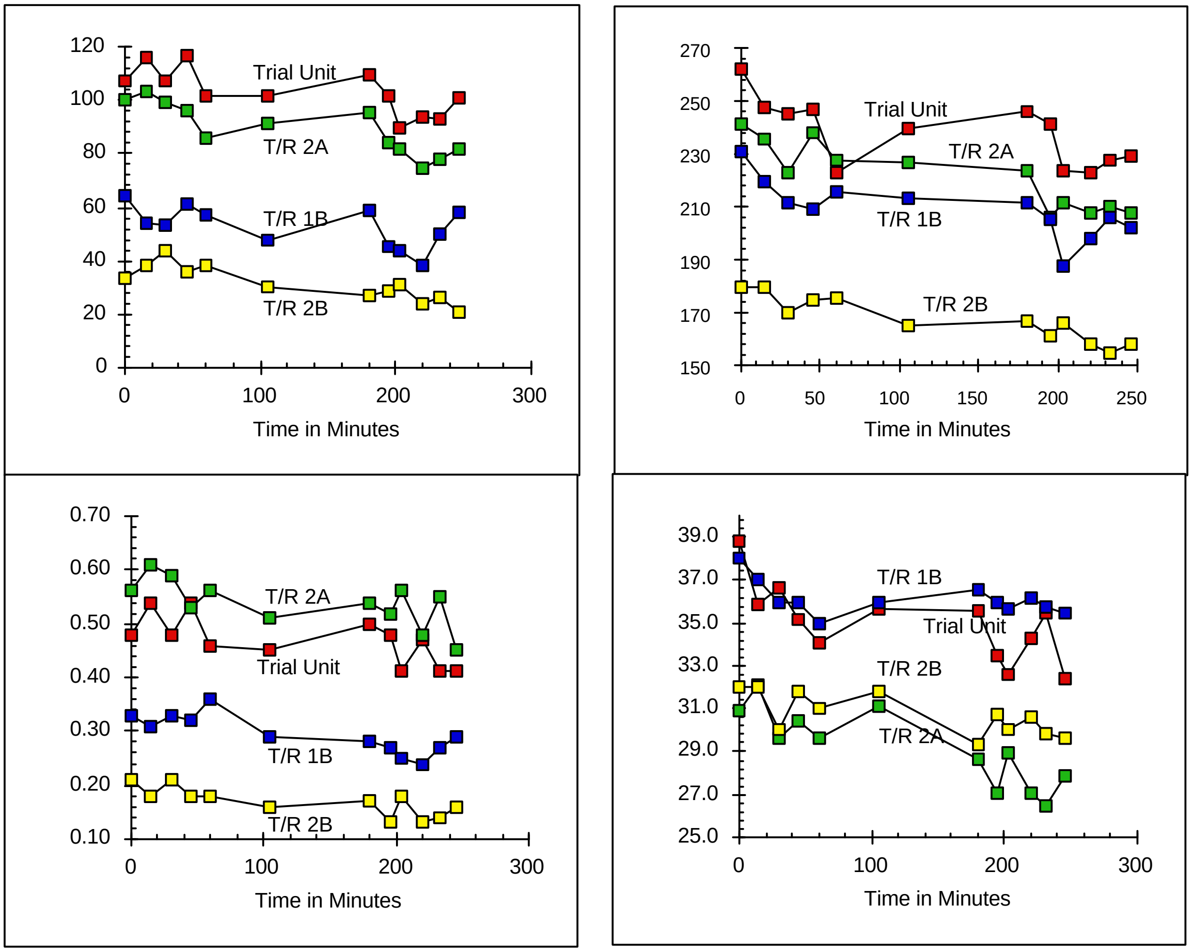


Figure 4 (above) is test data taken over a four hour period at a trial installation on a seven field deep, two chamber precipitator. The customer concluded that the trial control on the number one chamber inlet field performed better than the existing controls.

Figure 5.
AVC Trial Installation Performance Data

The owner said that the number 1 and number 2 chambers normally show similar readings.

	Trial Unit T/R #1A, Inlet Field					**Existing Unit T/R #2A, Inlet Field**				
Time	**PI**	**PV**	**SI**	**SKV**	**VA/SVA**	**PI**	**PV**	**SI**	**SKV**	**VA/SVA**
9:30	107	262	0.48	38.8	1.505	100	241	0.56	30.9	1.393
9:45	116	248	0.54	35.9	1.484	103	236	0.61	32.1	1.241
10:00	107	245	0.48	36.6	1.492	99	223	0.59	29.6	1.264
10:15	117	247	0.54	35.2	1.520	96	238	0.53	30.4	1.418
10:30	102	223	0.46	34.1	1.450	86	228	0.56	29.6	1.183
11:15	102	240	0.45	35.7	1.524	91	227	0.51	31.1	1.302
12:30	110	246	0.50	35.6	1.520	95	224	0.54	28.7	1.373
12:45	102	241	0.48	33.5	1.529	84	206	0.52	27.1	1.228
12:53	90	224	0.41	32.6	1.508	82	212	0.56	28.9	1.074
1:10	94	223	0.47	34.3	1.300	75	208	0.48	27.1	1.199
1:22	93	228	0.41	35.5	1.457	78	210	0.55	26.5	1.124
1:36	101	229	0.41	32.4	1.741	82	208	0.45	27.9	1.359

	Existing Unit T/R #1B, Second Field					**Existing Unit T/R #2B, Second Field**				
Time	**PI**	**PV**	**SI**	**SKV**	**VA/SVA**	**PI**	**PV**	**SI**	**SKV**	**VA/SVA**
9:30	64	231	0.33	38.0	1.179	33	180	0.21	32.0	0.884
9:45	54	220	0.31	37.0	1.036	39	180	0.18	32.0	1.203
10:00	53	212	0.33	36.0	0.946	44	170	0.21	30.0	1.187
10:15	61	209	0.32	36.0	1.107	36	175	0.18	31.8	1.101
10:30	57	216	0.36	35.0	0.977	38	176	0.18	31.0	1.199
11:15	48	213	0.29	36.0	0.979	30	165	0.16	31.8	0.973
12:30	59	212	0.28	36.5	1.224	27	167	0.17	29.3	0.905
12:45	45	205	0.27	36.0	0.949	29	161	0.13	30.7	1.170
12:53	44	188	0.25	35.7	0.927	31	166	0.18	30.0	0.953
1:10	38	198	0.24	36.2	0.866	24	158	0.13	30.6	0.953
1:22	50	206	0.27	35.8	1.066	26	155	0.14	29.8	0.966
1:36	58	202	0.29	35.5	1.138	21	158	0.16	29.6	0.701

A close examination of the corresponding numerical data in *figure 5* demonstrates the need for rigorous evaluation procedures. The ratio of primary VA product to the secondary VA product varies considerably from one control to the next and within the data for individual controls. It is well known that this ratio should vary from a low of about 1.05 for lightly loaded T/R sets to a high of 1.43 for sets running at current limit. In contradiction to proper procedure, the data was taken using the built-in metering in each control without any attempt to verify accuracy. No attempt was made to log pre-demo data.

Oscilloscope Evaluation

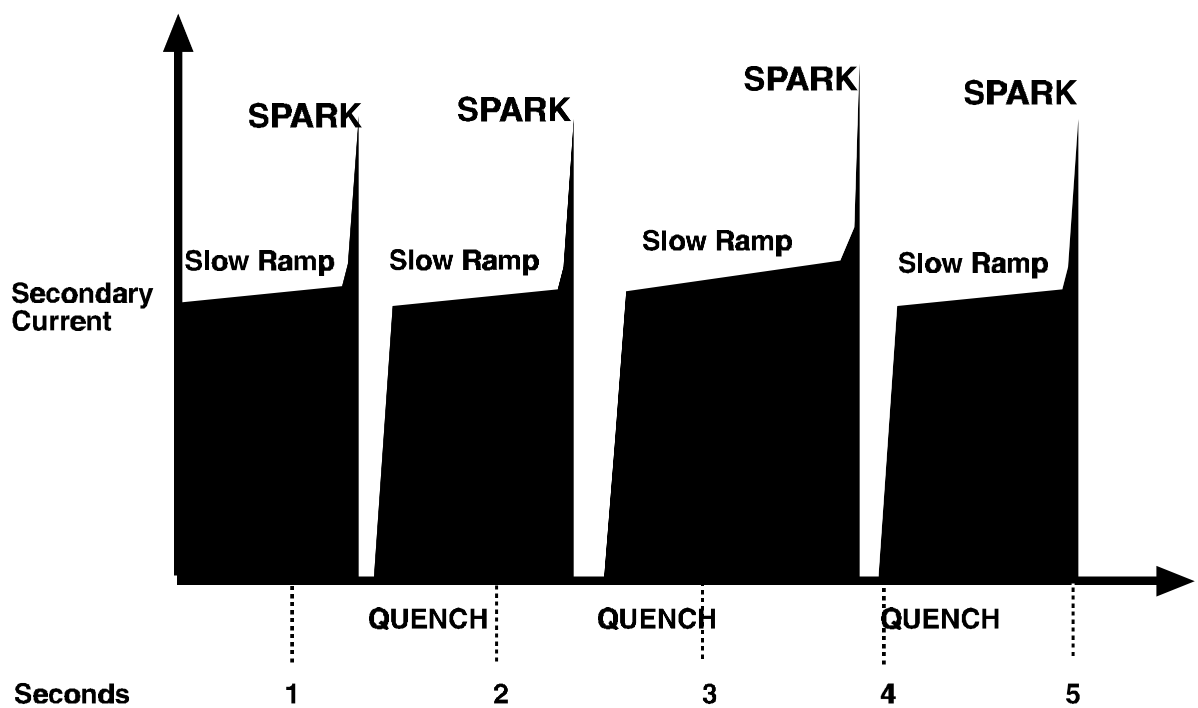
Using a storage oscilloscope, study the intimate details of the control s reactions to sparking, limiting conditions, and precipitator upsets. If upset conditions don t conveniently occur, they can be created by turning down a T/R set up stream from the test unit. If this is done, be sure to make a note in the data log.

Control manufacturers have differing philosophies for AVC response to sparking. It is not the intent of this paper to judge their merits.

Your mission will be to observe how each control reacts, determine if it complies with the manufacturer s claims, and evaluate the suitability of the algorithm to your process.

The storage scope is most often used to monitor secondary current and secondary voltage (KV). For most analysis, the scope is adjusted to trigger on the spark transient of the waveform. By running the scope at a low sweep speed of 0.1 to 0.5 seconds per division, the operating dynamics of the AVC can be observed during the entire interval from spark to spark as shown in *figure 6*.

Figure 6.
Secondary Current Pattern



At higher sweep speeds, typically 5 to 10 msec. per division, the scope can display details of the AVC s spark response. A scope with a pre-trigger function allows it to present a display combining pre and post spark data similar to *figure 7*. The spark response consists of four parts: spark, quench, fast ramp to the setback level, and slow ramp. A spark can occur any time during the half cycle of conduction. Acceptable AVCs must have a response mode capable of detecting all sparks with the possible exception of those that occur very late in the half cycle. Sparks very late in the half cycle are considered spit sparks by some manufacturers and may be purposely ignored by their controls. These sparks almost always self extinguish so ignoring them may, in some cases, increase collection efficiency by adding to power input.

Operation of the quench, fast ramp, setback and slow ramp all affect the control s ability to maintain maximum precipitator voltage with minimum risk to the discharge wires. Setback, slow ramp and spark rate are interrelated. Setting any two determines the other. Most manufacturers now provide adjustment of setback and spark rate with ramp rate being calculated by the AVC. The quench time and fast ramp may be user adjustable, permanently set in the AVC program, or dynamically adjustable as needed by the AVC.

Good control design should have a feature to self-modify the slow ramp rate for improved recovery from burst sparking conditions. It will be up to the evaluator to decide the important features and verify their proper operation.

Although manufacturers don t all agree on what constitutes a spit spark , spark , and arc , most manufacturers have a method of discriminating against spit sparks. Some manufacturers have spark detection modes that may instruct the control to ignore, not quench, or in some other way modify the classical response to certain types of sparks. These are methods to categorize sparks into several types and provide differing responses. The goal is to increase average precipitator voltage without threat of wire damage. Understand how the control is supposed to function in these various modes and verify proper operation.

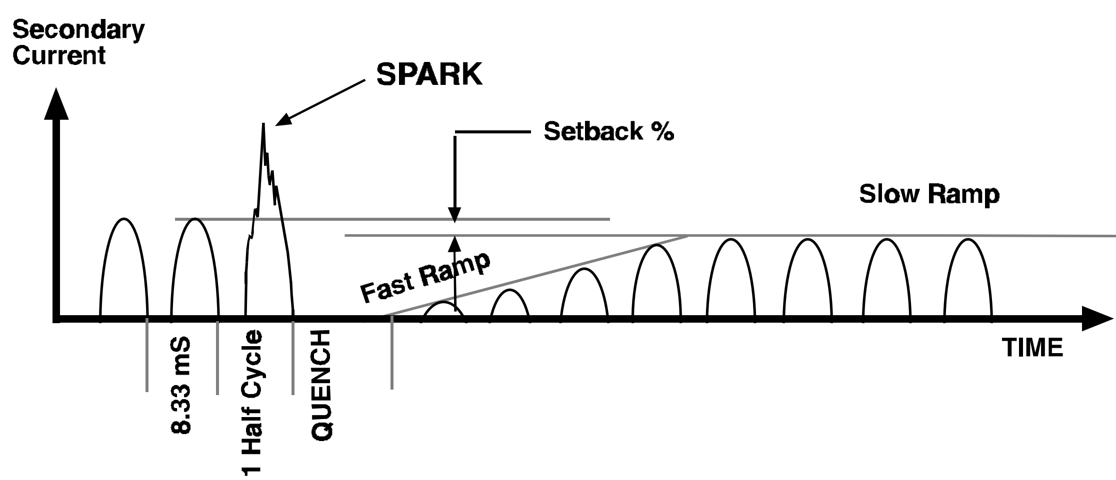


Figure 7. Typical Spark Response

CONCLUSION

By following the guidelines presented in this paper you will be able to successfully pre-qualify vendors, limiting your prospective choices to a few suppliers. You will then be able to efficiently and objectively evaluate the trial automatic voltage controls arriving at the best choice for your precipitator. A checklist is presented to the right.

NEUNDORFER™
ENGINEERED SYSTEMS

4590 Hamann Parkway
Willoughby, Ohio 44094

440/942-8990
FAX 440/942-6824
www.neundorfer.com

VOLTAGE CONTROL EVALUATION CHECKLIST

- ❈ Define and prioritize the objectives of the upgrade.
- ❈ Obtain complete precipitator control system information from vendors.
- ❈ Select vendors who will be invited to give sales presentations.
- ❈ Communicate objectives to selected vendors and arrange sales presentations.
- ❈ Study vendor information so as to be as knowledgeable as possible of the vendor s products during the sales presentation.
- ❈ Arrange for trial installations from the top four companies. Ensure that the trial equipment to be installed will be a true representation of the final installation.
- ❈ Carefully select the optimum trial bus section.
- ❈ Obtain baseline data for trial bus section and surrounding T/R sets for a one week period prior to the trial installation. Include all parameters that significantly affect precipitator operation.
- ❈ Be involved in the installation of the trial control, learning as much as possible about the control from the vendor s service engineer.
- ❈ Check control calibration against your portable meter.
- ❈ Allow bus section to stabilize for at least several hours.
- ❈ Ensure adequate rapping to remove increased dust collection.
- ❈ Log trial control s and surrounding controls operating data along with pertinent plant operational data.
- ❈ Make notes of trial AVCs performance under various circumstances.
- ❈ Perform detailed analysis of AVC using an oscilloscope.
- ❈ Evaluate all data collected to rank demo controls according to performance and preference. Budget considerations may prevent purchase of your first choice.