Enhancing Quality of Gas Distribution Tests in Electrostatic Precipitators

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Abstract:

Air pollution control companies are continually working to develop new technologies to improve the performance and safety of their equipment. In this line, a new product has recently been developed to carry out automatic Gas Distribution (GD) tests in Electrostatic Precipitators (ESP) in a safe, convenient, cost effective and quick manner. The GD tests are done to ensure uniform gas distribution across ESP cross section (typical size: 15 m high x 12 m wide) which is critical for ESP's performance. Conventional method of GD test includes manual measurements (up to 400 points) of air velocities at various heights and widths across whole ESP cross-section. As generally the environment inside ESP is very dusty and without any proper arrangements to reach all measurement points, this method is unsafe, monotonous and tiring for inspector as well as expensive.

In this paper, the automatic gas distribution and measurement system with most advanced robotics and data transmission technologies is presented. The system consist of a compact robotic crawler to carry and position the velocity probes at desired positions in the ESP, the advanced wireless data capturing to display/store the measurement values in a PDA and a convenient application software for automatic data interpretation, analysis and report generation. The crawler automatically detects and maneuver obstacles if any. Automation of GD testing process eliminates the efforts of climbing up in ESP and taking the measurements and recording manually. In this way the new system increases the onsite-safety of operator, reduces his retention time in dusty environment, improves quality of data (by eliminating errors in measurements due to manual data capturing and enabling more nos. of measurements in less time) which, in the end, results in better performance of ESP and reduced emissions.

[**Key words:** electrostatic precipitators (ESP), gas distribution test, flue gas, crawler, HMI (PDA), base unit, application software, uniform gas distribution, ESP efficiency, anemometers, coefficient of variation]

Introduction:

In industries, the emission of dust particles (generated from fuel burned in boilers, kiln etc) to ambient air needs to be kept at a minimum level and electrostatic precipitators (herein after referred to as "ESP") are the most widely used equipment to precipitate the dust particles suspended in flue gas. For optimum collection efficiency of an ESP, the flue gas flow must be uniformly distributed over the ESP's entire cross section. An inlet transition nozzle and gas screens are used at the entrance to reduce the gas velocity and evenly distribute it across ESP cross section. The effect of gas distribution on ESP performance is shown in Figure 1.

In order to evaluate the uniformity of the distribution of the flue gas in an ESP, offline 'Gas Distribution Test' is generally conducted. In this test, the flue gas velocities are measured over the entire cross section of the ESP (generally in the end of first field or in start of second field) and then the coefficient of variation (Cv) is calculated which represent the flow variation in the ESP statically.

Conventionally this test it is done by person(s) who manually measures the air velocity at various points across the ESP cross-section and then compiles the data to calculate the Cv. To carry out this test, the space inside ESP is too little, dusty and dark for manual work. Large ESP can be up to 15 m high and for measurements the operator has to climb at such heights either through ladders in small space or use scaffoldings, which are dangerous from the safety point.

These difficult working conditions and a lengthy & monotonous process of measuring velocities at more then 400 points, make this task a very tiring & fatigues for operator and often the quality of data collected is not best. This in turn may lead to wrong interpretation of gas distribution inside the ESP and may affect ESP's performance. Errors in test data can come from

- Inspector's fatigue
- Wrong positioning of velocity probe
- Mistake in data recording (generally done by another person)
- Reduced / skipped measurement points (in very large ESP, to keep the efforts reasonable, measurements are done at lesser measurement points)

In few ESP designs, where human access is difficult due to small gaps, direct measurement of gas distribution is not feasible at all.

For addressing all these issues and to improve the quality of Gas Distribution Test in ESP i.e. to help in improving ESP performance, a new robotic system is developed and presented in this paper.

System Overview:

Automatic gas distribution and measurement system is an integrated hardware and software package, designed to carry out gas distribution measurement test inside the ESPs with minimum manual efforts. It function by moving inside the ESP automatically on end profile of the collecting electrodes and collecting the gas velocity at desire grid points and reporting the captured values into readable results.

The robot comprises of a Crawler (for probe carrying and positioning), HMI (for control and data capturing), Base Unit (for power supply & communication), Anemometers (velocity probe) and application software (for analysis & report generation). A schematic is shown in Figure 2.

Crawler is a robotic device, which is driven by DC motors and gear assembly. It carries two anemometers (one on each side) and travel on the end profile/edge of the collecting electrode to position the anemometers across the cross section of the ESP. The motion and positioning of the probe carrier is controlled remotely using an onboard controller and wireless HMI.

The gripping of the crawler to electrode is guaranteed by set of magnetic wheels. The crawler can also be fitted with a special probe arm and with its extension cable for measuring the sneakage inside the ESP.

Base unit is electronic device used for supply power to crawler and enable its communication with HMI. It can provide connectivity for one or two probe carriers.

HMI device and application software together will facilitate interfacing and controlling of crawler as well as calculation the data and reporting.

Operation of GD testing robot is quite simple; after making the necessary connections, operator need to enter settings like ESP code, measurement grids, etc, and start measurements. For measurement, he needs to clamp the crawler on one collecting electrode either from top/bottom and start the test. The crawler moves on the electrode and stops at desired grid points and captures data with its anemometers and sends those data to the HMI and it gets automatically filled in corresponding cells of the tabular column. Once measurement for particular electrode completed, crawler automatically comes back to its home position. The operator may unclamp the crawler from that electrode and clamp it on to an alternate electrode to capture readings for the next two-gas passage. Once all readings are captured, data from HMI can be transferred to computer and final report can be generated using application software.

System Performance:

The results of initial field trials of the tool have been very promising. It not only speeded up the Gas Distribution Measurement process but also improved the quality of data by positioning of measurement probe more precisely, measuring velocity at more points, eliminating possibility of human induced error and preparing report automatically. The automatic gas distribution measurement result for a 44 field ESP is provided in Table 1. In Table 2 results from manual measurement in same ESP are also provided. Clearly the measurement at more points enables a better representation and understanding of gas distribution in ESP compared to manual method. Table 3 illustrates the overall result from both tests are compared.

The manual measurements referred here were done with extra care to allow a comparison of the results from both methods, hence the Cv value is very close but in some other trials (where operators were not aware about a parallel measurements by tool) the result obtained from robot were more representative of actual gas distributions in ESP compare to manual measurements.

Conclusion:

The new robotic tool for doing gas distribution test offer following distinctive advantages over conventional method:

- *Higher accuracy:* No human error in data capturing, logging or transferring.
- *Quality data:* Can take more measurements in same time. Good data quality means good gas distribution in customer's ESP which intern increases the ESP performance or in other word further advantage in getting emission reduced.
- *Faster:* Saves up to 50% of time needed for testing. This reduces the ID and FD fan operating cost for the customer.
- *Enhanced safety:* No need to climb up, lesser resident time in ESP.
- *Cost:* Since only one person required, reduces the cost of GD test, could be comparably cheaper than conventional method.
- *Flexibility:* Possibility to do GD test in most of the ESP.
- *Reporting:* Quick reporting with uniform format.

With distinct advantages of better quality data, speed, safety and convenience the robotic tool is certainly a help in improving performance of ESP.

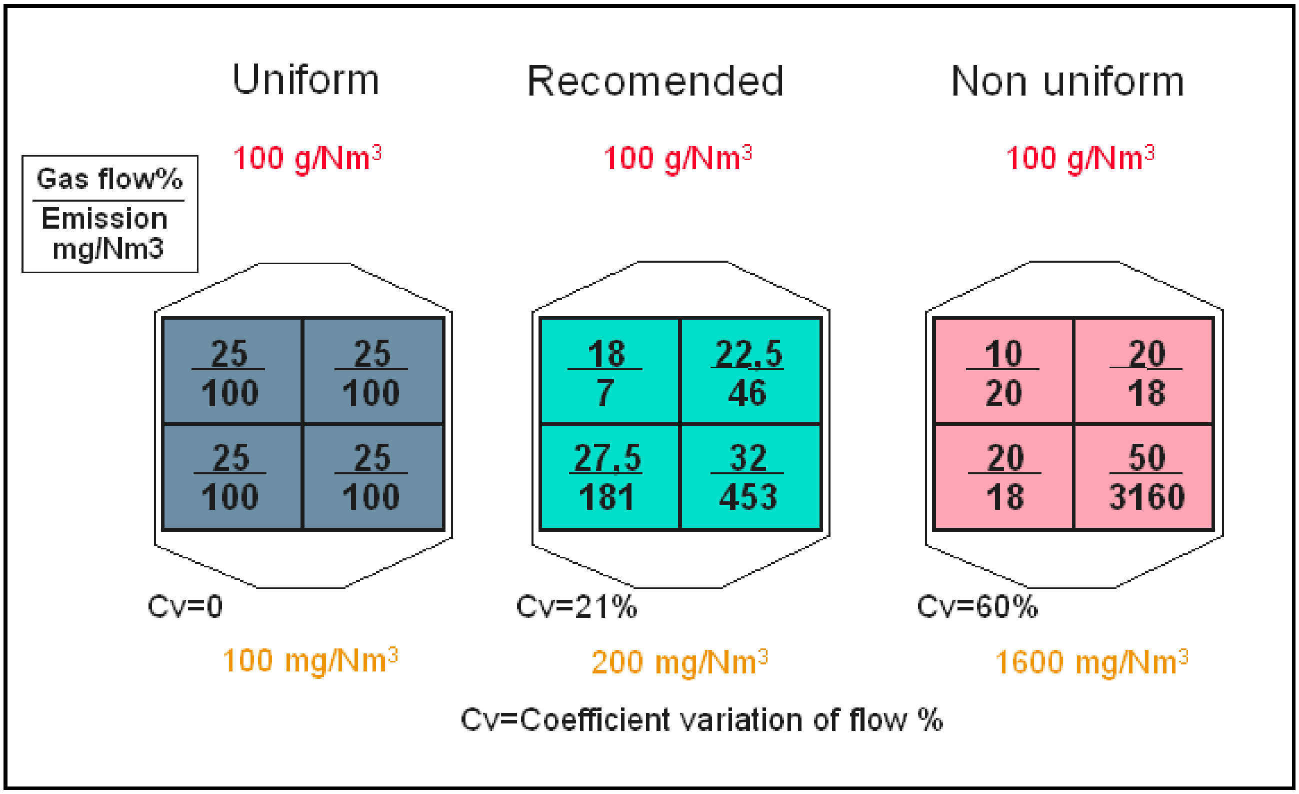

Figure 1 Effects of Gas Distribution in an ESP

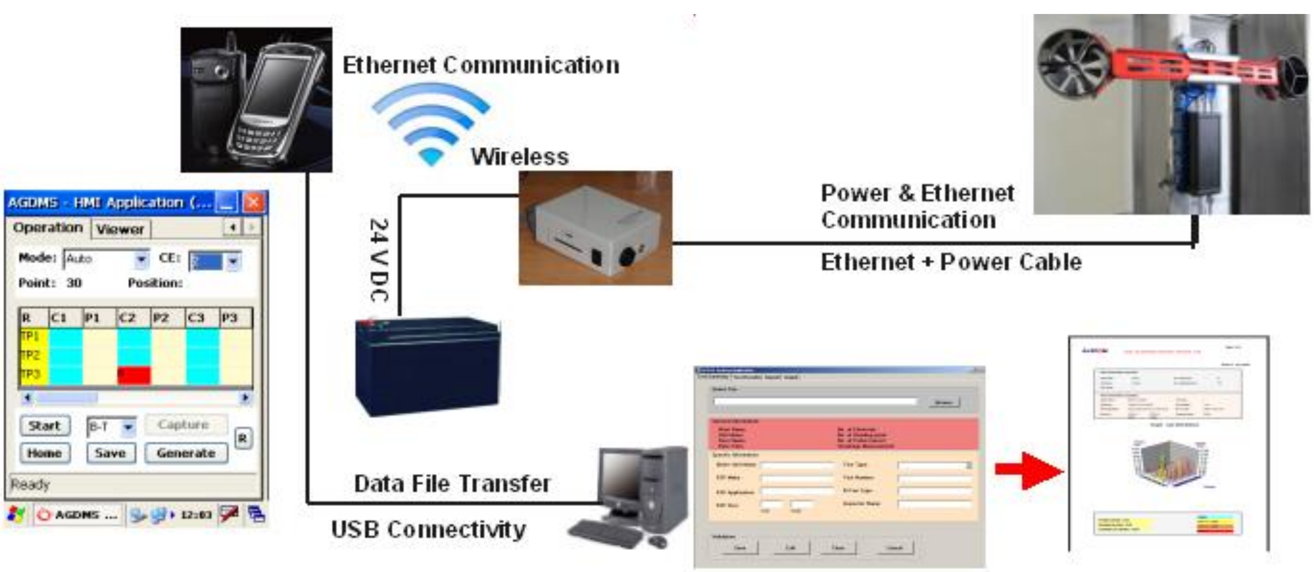

Figure 2 Automatic Gas Distribution Measurement System overview

Table 1 GD test report from robotic measurement

R/C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.72	0.49	0.94	0.69	0.94	0.72	0.84	0.47	0.82	0.48	0.78	0.6	0.77	0.69	0.47	0.52	0.57	0.5	0.66	0.48	0.57	0.58
2	0.86	0.76	0.95	0.74	0.86	0.69	0.8	0.62	1.02	0.85	0.91	0.85	1.04	0.84	0.8	0.78	0.97	0.83	1.09	0.85	0.86	0.67
3	0.84	0.7	0.81	0.6	0.95	0.75	0.96	0.65	0.97	0.79	0.91	0.86	0.85	0.81	0.96	0.87	1.06	0.9	1.05	0.76	0.96	0.8
4	0.85	0.59	0.75	0.59	1.04	0.81	1.12	0.63	1.08	0.83	0.97	0.96	1	0.97	1.05	0.88	1.16	0.94	1.14	0.88	1.03	0.91
5	0.87	0.63	0.77	0.61	0.89	0.74	1	0.58	0.98	0.71	0.89	0.85	0.96	0.95	1.02	0.85	1.09	0.86	1.07	0.75	1.02	0.87
6	0.88	0.88	0.83	0.69	0.86	0.68	0.83	0.57	0.88	0.66	0.81	0.8	0.78	0.73	0.75	0.73	0.89	0.77	0.97	0.75	1.03	0.84
7	0.84	0.81	0.87	0.71	0.83	0.7	0.73	0.54	0.86	0.66	0.77	0.65	0.7	0.63	0.67	0.6	0	0	0.81	0.64	0.87	0.75
8	0.72	0.74	0.83	0.69	0.82	0.64	0.63	0.51	0.71	0.59	0.71	0.64	0.64	0.59	0.56	0.59	0.73	0.57	0.65	0.45	0.62	0.47
9	0.99	0.87	0.89	0.71	0.77	0.56	0.7	0.6	0.64	0.55	0.56	0.48	0.29	0.29	0	0.26	0	0.29	0.59	0.46	0.54	0.46

R/C	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
1	0.59	0.68	0.74	0.65	0.54	0.49	0.38	0.29	0.41	0.41	0.61	0.49	0.56	0.42	0.54	0.6	0.73	0.7	0.76	0.62	0.67	0.62
2	0.73	0.73	0.83	0.69	0.92	0.81	0.73	0.63	0.72	0.66	0.82	0.76	0.95	0.65	0.89	0.8	0.88	0.84	0.97	0.75	0.72	0.79
3	0.78	0.75	1.02	0.88	1.1	0.96	0.94	0.82	1.22	0.95	0.96	0.85	1.06	0.81	0.89	0.82	1.1	0.9	1.05	0.85	0.79	0.71
4	0.92	0.79	1.02	0.89	1.29	1.1	1.03	0.95	1.25	0.95	1.19	0.98	1.15	0.94	1.01	0.96	1.11	0.86	1.08	0.91	0.77	0.73
5	0.99	0.76	0.96	0.83	1.09	0.9	1.12	1	1.3	0.98	1.09	0.92	1.07	0.87	0.86	0.83	1.04	0.8	0.97	0.87	0.69	0.66
6	0.73	0.67	0.87	0.78	1.16	1.07	1.1	0.85	1.21	0.94	1.16	0.97	1.19	0.85	0.94	0.91	1.06	0.82	1.04	0.81	0.88	0.65
7	0.66	0.59	0.61	0.6	1	0.9	0.92	0.83	1.12	0.89	0.95	0.79	0.87	0.73	0.72	0.69	0.79	0.61	0.96	0.83	0.82	0.69
8	0.49	0.39	0.55	0.59	0.68	0.6	0.63	0.59	0.69	0.66	0.77	0.67	0.81	0.67	0.72	0.66	0.82	0.65	0.82	0.71	0.87	0.7
9	0.35	0.31	0.36	0.41	0.53	0.41	0.49	0.44	0.56	0.49	0.57	0.39	0.53	0.51	0.73	0.63	0.74	0.63	0.8	0.71	0.86	0.63

Table 2 GD test report from manual measurement

R/C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
8.5		0.62		0.70		0.94		0.88		0.75		0.93		1.02		0.95		0.7		0.9		0.68
7.5	0.87		0.92		1.12		1.06		0.97		1.02		1.08		1.12		0.88		0.84		1.12	
6.5		0.78		0.68		0.86		0.68		0.99		0.99		0.95		1.04		1.07		0.92		0.86
5.5	0.8		0.7		0.94		0.9		0.98		0.92		0.94		0.99		1.04		1.1		0.95	
4.5		0.65		0.74		0.63		0.55		0.77		0.86		0.9		0.94		0.77		0.7		0.83
3.5	0.62		0.85		0.85		0.62		0.85		0.86		0.98		1.05		0.85		0.62		0.85	
2.5		0.95		0.88		0.84		0.74		0.8		0.82		0.69		0.78		0.85		0.82		0.89
1.5	0.82		0.9		0.78		0.59		0.57		0.65		0.54		0.59		0.53		0.42		0.39	
0.5		0.98		0.8		0.58		0.5		0.58		0		0		0		0.46		0.65		0

R/C	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
8.5		0.72		1		0.85		0.6		0.77		0.75		0.54		0.44		0.3		0.7		0.76
7.5	0.92		0.9		0.95		0.94		0.7		0.84		0.86		0.74		0.68		0.95		0.65	
6.5		0.81		1		1.12		0.96		1.16		0.98		0.99		0.98		0.85		1.05		0.73
5.5	0.79		0.99		1.18		1.11		1.3		0.99		1.13		1.02		1.02		1		0.75	
4.5		0.78		0.86		1.1		0.98		1.17		1.07		0.88		0.98		0.92		0.82		1.05
3.5	0.62		0.85		1.04		1.02		1.2		1.15		1.12		0.94		1.07		0.84		0.98	
2.5		0.66		0.67		0.7		0.87		0.97		0.99		0.92		0.99		0.66		0.96		0.98
1.5	0.46		0.64		0.72		0.71		0.77		0.75		0.71		0.54		0.84		0.7		0.8	
0.5		0.41		0.51		0.53		0.6		0.56		0.57		0.42		0.63		0.8		0.74		0.67

- Red cells – Very High velocity zone [>115% of avg velocity]
- Orange cells – High velocity zone [>=100% to 115% of avg velocity]
- Yellow cells – Low velocity zone [<100% to 85% of avg velocity]
- White cells – Very Low velocity zone [< 85% of avg velocity]

Table 3 Robotic vs Manual GD Testing

Parameters	Robotic GD Testing	Manual GD Testing
Pass	B	B
ESP	2FAA-4*36F-110-90-A2	2FAA-4*36F-110-90-A2
Position of test	End of 1st field, facing inlet funnel	End of 1st field, facing inlet funnel
Method	Linear (Bottom-Top)	Zig-Zag
Readings captured	396	198
Reading capture time taken	2hrs & 30min	2hrs & 40min
Report preparation	<5min	40 minutes
Mean velocity	0.77	0.81
Standard Deviation	0.21	0.22
Co-efficient of variation	27.27%	26.96%
Colour code	Fine	Fine but in zig-zag fashion