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Comparative Study of the Conventional Electrostatic Precipitator and the Proposed Smart Electrostatic Precipitator Based on the Various Electrical Erection Challenges

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ABSTRACT: Aninsight view of the various electrical equipments and working of Electrostatic precipitator is explained in this paper along with the challenges that are being faced while carrying out the erection of the various electricalequipments, testing and commissioning of the Electrostatic precipitator. As a case study an Electrostatic precipitator that is commonly usedin an integrated steel plant is analyzed.A new proposal of the smart Electrostatic precipitator is being done in this paper. This minimizes the total cost that includes the erection costs, the time required for erection,testing and commissioning.

KEYWORDS: Electrostatic Precipitator, ZigbeeTransceiver, Rapping Motor, Transformer Rectifier Unit

I. INTRODUCTION

An electrostatic precipitator (ESP) is a device that will collect the particles and removes it from a flue gas by using the force of an induced electrostatic charge from the transformer rectifier unit which is located at the top of the ESP. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream. Nowadays these ESPs are gaining importance as to obtain the environmental clearance for setting up of new industrial plants and green environment.

II. REVIEW OF LITERATURE

Many Research work is being carried out Worldwide in designing the better ESP in terms of their operation, mechanical and electrical design. But there are less research work in order for reducing the tedious electrical erection and commissioning of the ESPs. XU Guosheng et.al, has discussed about the principle and application ofElectrostatic Precipitator [1].Durga Prasad et al., has proposed an automatic control technique and management for electrostatic precipitator [7]. H E Jianet l., has briefly described about the V-I Characteristic Principle of Electrostatic Precipitator [4].

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III.THE ELECTRICAL EQUIPMENTS AND INSTRUMENTATION SYSTEMS FOR ESP

The major electrical and instrumentation system of ESP are described below:

1. **Transformer Rectifier Sets:** This is used to step up the input AC supply and rectify it into DC supply and feed the positive into the emitting electrode and the negative will be grounded.
2. **Controllers:** Microcontroller based controllers are used to control the input to the rectifier transformer with SCR .The input for the controller is based on the mA and KV feedback from the field andcontrolsthe firing of SCR further controlling the input voltage to the transformer.
3. **Rapping Geared Motors**: These motors are used for rapping the dust that is collected in the collecting plates, emitting electrode and inlet gas distribution screens.
   There are three types of Rapping motors:
   i. Rapping motors for Emitting Electrodes
   ii. Rapping motors for Collecting Electrodes
   iii. Rapping motors for Inlet Gas Distribution screen
4. Support and shaft Insulator Heaters
5. Hopper Heaters.
6. Thermostat for Hopper & Support Insulator Heaters
7. Dust Level Switches for Hoppers
8. Double Cone Valve Motors
9. Chain Conveyor Motors
10. Zero Speed Switches for Chain Conveyor Motors
11. Position Limit Switches for DCV Motors
12. Position Limit Switches for Live and Earth position status
13. Mechanical Safety Interlocks
14. RTD & Temperature Transmitter at ESP Inlet & Outlet
15. Pressure Transmitter at ESP Inlet
16. CO Analyzer at ESP Inlet duct
17. PLC and SCADA system with HMI (Human Man Interface) Screens

The Power and control cable Erection scheme is illustrated in the figure1 of the Existing ESP.

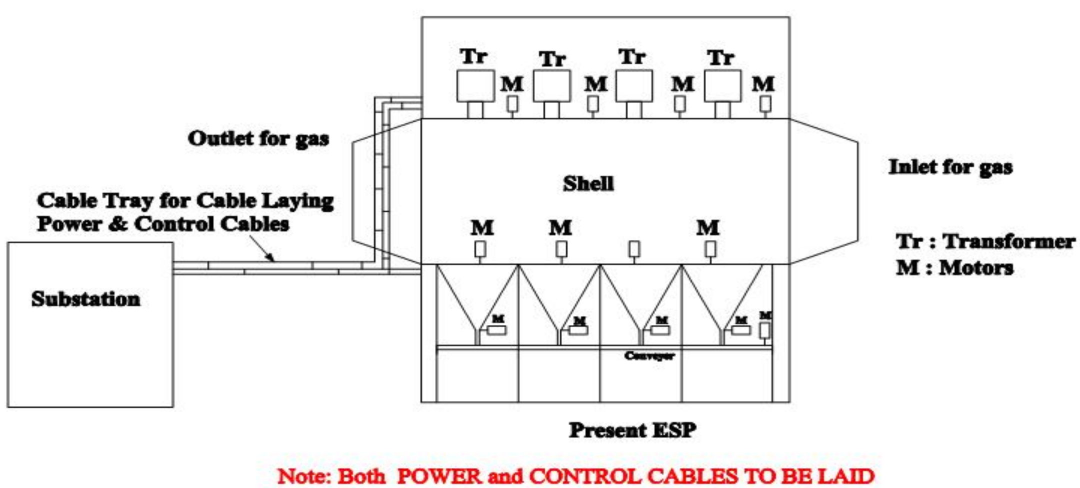

Figure 1.The Present Electrostatic Precipitator Model

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IV. OVERCOMING THE ERECTION CHALLENGES OF PRESENT ESPAND BENEFITS OF PROPOSED SMART ESP

The erection challenges that are faced in the present ESP isthat the location of the Transformer Rectifier set is on the top of the ESP which is approximately 36 meters above the ground level. So cable tray work and cable laying is to be carried out form the substation where the respective panels are kept to the transformers and motors. Hence the total power and control cables length required will be up to 20 kilometers. Thus a new concept of smart ESP equipped by wireless means with Zigbee Technology arises. As all the erection work is to be carried out in several heights above the ground level there are many safety concerns related to it.

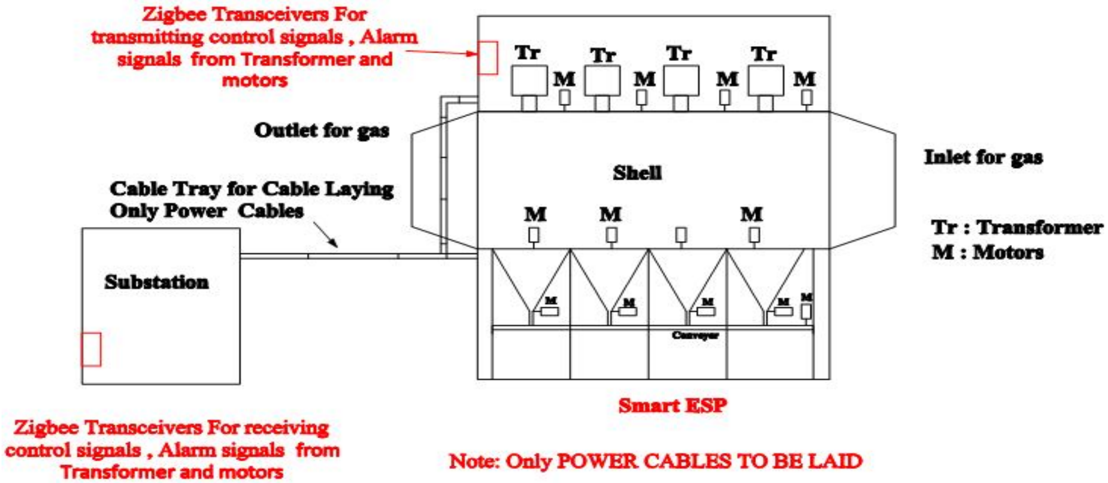

Figure 2.The Proposed Smart Electrostatic Precipitator Model

Some of the Benefits of the smart ESP from the present ESP areexplained below:

1. Reduction in the Quantity of Control Cableand Perforated Cable Trays: The total length of control cables used for erection will be around eight to nine kilometers as the location of the Transformer Rectifier is on the top of the ESP which is approximately 36 meters above the ground level.Thus a concept of new Smart ESP where the length of the cable can be reduced to 300to 400meters as loop cable is only required inside ESP. Thus a huge cost reduction occurs in the total project.

2. Reduction in the Erection cost for cable Trays and Cable Laying: The Electrical contractor will cost huge amount for the erection of the cable trays and cable laying as because of the height in which the work is to be carried out. If the Smart ESP is introduces the cost for cable laying and the perforated cable tray work can be reduced.

3. The Erection and time saving: Inturnkey projects the time for completion of the project will be too short. As the smart ESP is introduced the time can be saved in the electrical erection of cable tray and cable laying. It can also save the commissioning time of the total work.

4. Control Cable Ferules and termination work and making Commissioning easy: As the control cables used is reduced drastically in the smart ESP, the ferules and the cable termination work is reduced. During the time of commissioning the number of Inputs and Outputs and loop checking for PLC can be reduced as the Zigbee transceiver is used.

5. Safety Concern: The major erection challenge that faced is the height in which labour has to work in order to carry out the erection of the cable tray work and then the cable laying. The safety factor is to be considered as more caution as there is a more prone to accidents .So by the concept of smart ESP the erection work and control cable is reduced.

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V. THE POWER AND CONTROL CABLES SCHEMES FOR THE PRESENT ESP AND PROPOSED SMART ESP

The major electrical equipments in the ESP are the Transformer Rectifier Sets and The rapping motors. The Power and the Control cable for the present and the proposed smart ESP scheme is illustrated below in the figure 1 and 2. In the Present ESP control cables is to be laid to the LCS(Local Control Station) in order to control the rapping motor.There will be around two emitting rapping motors and one collecting rapping motors and two gas distribution rapping motors in the field 1 of the ESP .The field wise configuration of ESP is shown in the table 1.

Table 1.Illustration of the Field Position and Electrical Equipments of the Present ESP.

Field 4	Field 3	Field 2	Field 1
Transformer4	**Transformer3**	**Transformer2**	**Transformer1**
No Gas Distribution Rapping Motors			**Gas Distribution Rapping Motors 1&2**
Collecting Rapping Motors 5	**Collecting Rapping Motors 4**	**Collecting Rapping Motors 3**	**Collecting Rapping Motors 1 & 2**
Emitting Rapping Motors 7& 8	**Emitting Rapping Motors 5& 6**	**Emitting Rapping Motors3& 4**	**Emitting Rapping Motors 1& 2**
Two Double Cone Valve Motors	**Two Double Cone Valve Motors**	**Two Double Cone Valve Motors**	**Two Double Cone Valve Motors**

Inlet Gas Flow Direction

Table 2. Equipment wise Control cable Requirement for Present ESP and Proposed Smart ESP

Equipment Name	Present ESP Control cables	Proposed ESP Control cables
For Total Rapping Motors (15 Motors) (For one Raping Motor1 control cable is required)	**15 Cables**	No Cable is need as Zigbee Transceiver is used
For Total transformers (Four Transformers) (For One Transformer 2 control cables is required)	**8 cables**	Only 1 cable for mA and KV feedback is required for one transformer
For total Double Cone Valve Motors (8 Motors) (For one Double cone valve Motor 1 control cable is required)	**8 cables**	No Cable is need as Zigbee Transceiver is used
For Total limit Switches of Double Cone Valve (8 switches) (For one Limit Switch 1 control cable is required)	**8 cables**	No Cable is need as Zigbee Transceiver is used
For Total Hopper Level Switch (8 nos) (For one Hopper level switch one cable is required)	**8 cable**	No need as Zigbee Transceiver is used
Limit Switch for HT interlock of transformers (4nos) (For one Limit Switch 1 control cable is required)	**4 cable**	
Thermostat for shaft and support Insulator Heaters (16 nos) (For one Thermostat 1 control cable is required)	**16 cables**	
Zero speed Switches of Chain Conveyor Motors (2nos)	**2 cables**	
Total Cables Required	**69 cables (approx eight to nine kilometers of cable required)**	**Only 400 to 500meters of Loop cables to connect Zigbee Transceivers inside ESP is required Total 3 transceivers to be used.**
Erection Cost of cable laying and Perforated cable tray work	**Yes needed**	**No**

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The Equipment wise control cable requirement is given in table 2 and the number of control cables and the approximate length can be saved.

A. ILLUSTRATION OF THE POWER AND CONTROL CABLES SCHEMES FOR THE TRANSFORMER RECTIFIER UNITS AT THE ROOF TOP OF ESP

The power and control cable schemes for the Rectifier Transformers in the present and proposed ESP is illustrated in the figure 1 and 2respectively. In the proposed Smart ESP, instead of the Control cables the signals can be transmitted using Zigbee Transceiver. The Loop control cable will be used in order to connect to the Zigbee transceiver. Another Transceiver is located in the substation and it will be connected with the respective control panel.

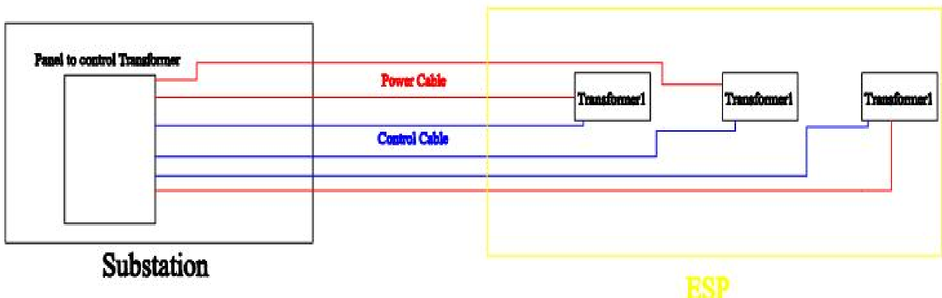

Figure 3.The Power and Control cable Scheme for Transformer Rectifier Units in the Present ESP.

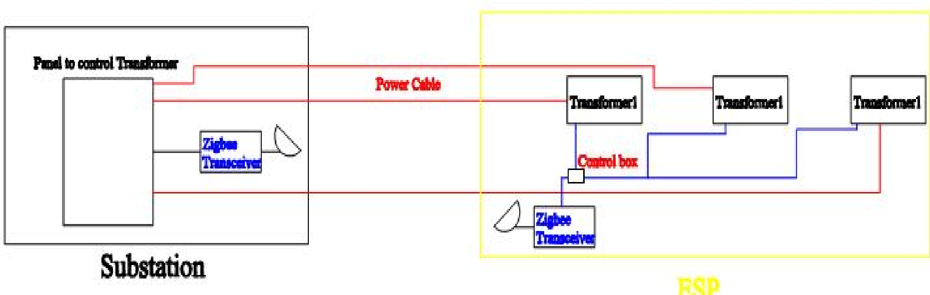

Figure 4.The Power cable and Control Scheme using Zigbee forTransformer Rectifier Units in the Smart ESP.

B. ILLUSTRATION OF THE POWER AND CONTROL CABLES SCHEMES FOR RAPPING MOTOR

The Power and control cable schemes for the Rapping Motors in the present and proposed ESP is illustrated in the figure 3 and 4respectively. In the proposed Smart ESP, instead of the Control cables the signals can be transmitted using Zigbee Transceiver. The Loop control cable will be used in order to connect the LCS to the Zigbee transceiver. Another Transceiver is located in the substation and it will be connected with the respective motor control panel.

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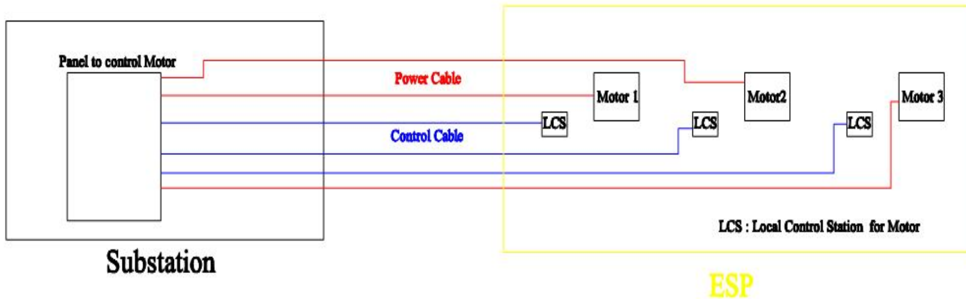

Figure 5.The Power and Control cable Scheme for Rapping Motors in thePresent ESP.

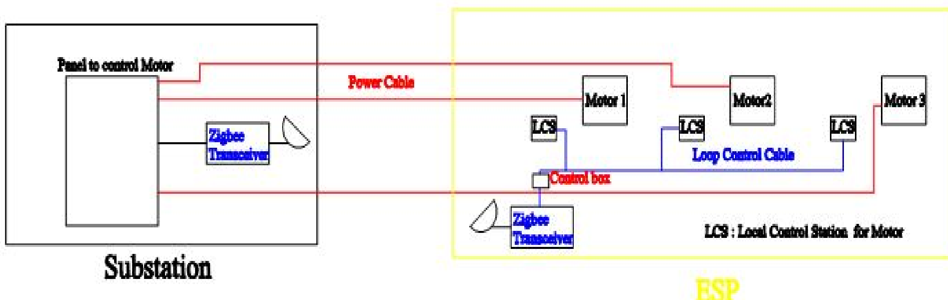

Figure 6.The Power cable and Control Scheme using Zigbee Rapping Motors in the Smart ESP.

VI.CONCLUSION

The Proposed Smart Electrostatic Precipitator Model can save a huge cost in the ways of saving the Control cables used, the erection cost for the cables, cable trays. It also saves a lot of commissioning time and the time for completion of the project time.The erection challenges that are faced in the present ESP are overwhelm in the proposed smart ESP. The tedious task of Control cable feruling and termination is reduced in the proposed Smart ESP.

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