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Enhancement of ESP Performance using 'ARECA' Microcontroller

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Abstract: **Thermal Power plants emit fly ash as well as other gases like Carbon dioxide (CO2), Carbon Monoxide (CO), Nitric Oxides (NOx) , Sulpher oxides (SOx) ,etc. to the atmosphere and in turn, the atmosphere gets polluted. The pollution to this effect is dangerous to our living society as well as to the plant life. The reason is the use of fossil fuel like coal to run the thermal power plants. Air pollution control equipment for today's need are Electrostatic Precipitator (ESP), Fabric Filter (FF) etc. are in greater use. But, Electrostatic Precipitators (ESP) are widely used all over the world for better performance and better dust collection efficiency. It is a reliable and proven technology which can effectively handle large quantities of abrasive type fly ash without any operating problems. Energy saving aspect on this controlling measure is really challenging. For enhancement of ESP performance, promotion of new technology and development of electronics & materials are in continuous process of improvement. This paper presents the basic technological and operational concept of ESP and performance enhancement programs/activities being taken in Thermal power generation plants, which are in accordance with the Environmental Regulations of today's world.**

Keytwords: Low Tension Main Switch Board (LTMSB), microcontroller based ARECA, high voltage rectifier transformer, electrostatic precipitator.

I. INTRODUCTION

An Electrostatic Precipitator (ESP) is a technique used to decrease the pollution content in the flue gasses. It is generally used in Thermal power plants to control the pollution caused by flue gasses. Coal-Fired boilers in thermal power plants (TPP's) cause substantial air pollution through emission of fly-ash particles. Similarly, process plants, such as cement mills and steel plants, also cause air pollution through their exhaust gases. Electrostatic precipitators (ESP's) are widely used in many industries for particle collection from flue gases. In a Thermal Power Plant, they serve to limit fly-ash pollution of the atmosphere, high collection efficiency, a low pressure drop, reliability and suitability for high temperature fluctuations in flue gases. A fly-ash concentration of about 30–60 g/nm in the flue gas is brought down, often to below 15 g/nm by using ESP's.

The increased awareness on the harmful effects of particulate emission from power plant and other industries has resulted in demand on suitable measure to reduce the emission equipment/controls. The ESP are widely used for removal of solid and liquid particles from industrial gases with collection efficiencies exceeding 99 percent for wide range of particle size (1-100)/an. They can handle large volume of gases (25-1000)/m3/s, have low pressure drop and can operate continuously with little maintenance. The performance of ESP is found to be affected with the passage of time in power plant due to (1) change in the characteristics of coal feed and hence that of fly ash.(2) The quality and quantity of the gases coming out from the boiler. (3)The charging of fly ash which depends on current suppliedby microprocessor controlled Transformer/Rectifier sets, electrical field developed on the collection electrodes, electrode spacing, configuration etc. (4) The collection and dust removal, the particles are collected at anode which are grounded, dust is removed through rapping and is collected in hoppers stationed below in electrodes in ESP.

A precipitator is a relatively simple device which separates particles from a gas stream by passing the carrier gas between pairs of electrodes across which a unidirectional, high voltage potential is placed. A high-voltage direct current is applied to a discharge wire negatively charging it, Voltage to the wire is increased until a corona (a visible electric discharge) is produced around the wire. As the particle- laden flue gas passes through corona, the particles contained in the flue gas become negatively charged. Because the discharge electrodes are negatively charged and the collection electrodes are positively charged, a strong electrical field is created between them. This electrical field propels the negatively charged particles toward the positively charged collection electrodes, where the particles attach themselves. The particles would quickly collect on the plate, creating a dust layer. The dust layer would accumulate until we removed it, which we could do by rapping the plate. Charging, collecting, and removing that's the basic idea of an ESP

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II. BLOCK DIAGRAM OF PROPOSED SYSTEM

The Block diagram of proposed electrostatic precipitator consists of power supply module, electronic controller with microcontroller based ARECA, high voltage rectifier transformer, electrostatic precipitator, rapping mechanism, switch fuse unit and intellirap controller as shown in figure 1.

The power supply is fed from LTMSB, 3-phase, 415V, 50Hz to the Electronic controller (ARECA). The regulated AC (R-Y) phase power from Electronic controller applied to the primary of the high voltage rectifier transformer which is stepped up 415V AC into 95KV DC

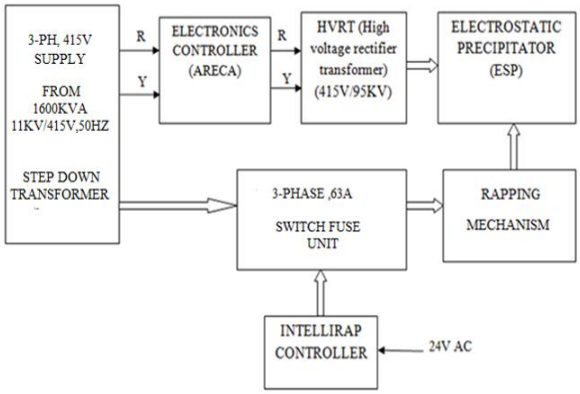

Fig 1: Block Diagram of proposed Electrostatic Precipitator (ESP).

The output DC supply is fed to electrostatic precipitator which consist of +VE and –VE terminals .The +VE terminal is connected to the ESP of collecting plate system and grounded. The –VE terminal is connected to the emitting electrodes system. The flue gases pass between electrodes and are subjected to an intense electric field. where the particles attach themselves. The particles would quickly collect on the plate, creating a dust layer. The dust layer would accumulate until we removed it, which we could do by rapping system.

The Switch Fuse Unit is fed 3-phase power from the same source and which is controlled by INTERLLIRAP controlle ,which consist of timer ,frequency operation of motor which is initial programmed accordingly rapping motor will operate and dislodge the ash into the Hopper system. The collected ash from the hopper can be evacuated through slurry (wet mode) or sillo(dry mode).

3-phase, 415V, 50HZ power supply from Low Tension Main Switch Board (LTMSB) which fed by 1600KVA, 11KV/415V Station Auxiliary Transformer, AN Dyn11, Z=8% OFF Ckt, Tap Changer ±5 in step of 2.5%.
All blocks are explained briefly.

ELECTRONICS CONTROLLER (EC)

The Electronic controller (EC) contains the antiparallel connected Thyristor pair for controlling the input voltage to the rectifier unit along with a microcontroller based control module ARECA (The name ‘ARECA’ is derived from the Areca palm tree - NASA’s top ten ranked air purifying plant). The basic function of Electronic Controller (EC) is to feed the precipitator with maximum power input under constant current regulation. Should there be any flash over between collecting and emitting electrodes. EC will sense the flashover and quickly react by bringing the input voltage to zero and blocking it for a specified period. After the ionized gases are cleared and the dielectric strength restored, the control will quickly bring back the power to preset valve and raise it to the original non sparking level. Thus the EC ensures adequate power input to the precipitator while reckoning the electrical disturbances within the precipitator. Regulated AC power from EC is applied to the primary of the transformer which is stepped up and rectified to give full wave power output.

ARECA is a new 16-bit microcontroller based HVR controller with new and enhanced features in a compact package. It permits all analog parameter settings through digital keypad entries. A 4x20 character LCD display is used to incorporate more data and command menus per page, and more user friendly. ARECA has a true spark sensing algorithm, which does away with the need for manual tuning and hence provides a maintenance free method for spark sensing.

Improved Features of ARECA

Intermittent charging : Facility to skip half cycles thus charging fields intermittently, in-order to avoid back corona. Charge Ratios upto 1:255 can be set using the ARECA controller.

Charge Ratio Optimisation Mode: Arrives at the optimum charge ratio for maximum collection without building up back-corona.
_ Based on strength of back-corona
_ Fast optimization cycle
_ Practically no degradation of performance during optimization

Base Charging: To maintain the ESP voltage close to corona onset voltages between the intermittent charging pulses. Base charging in ARECA is based on closed loop control.
Peak and Valley KV measurement: Absolute peak and valley KV detection algorithm for improved diagnosis and trouble shooting of respective ESP fields.

Upgradable Firmware: The firmware residing in the ARECA controller can be upgraded in-situ, even without removing the controller from the panel.

Tr OCSC test with a single key operation:
The transformer OC and SC test can be performed by a simple key press. If any abnormality is sensed during testing, the controller trips the power and indicates the power at which the abnormality occurred.

‘True Spark’ Sensing algorithm: No Manual tuning for spark sense level required. Spurious sparks are ignored.

Communication Channels: Supports RS-485, CAN, RS232 – Current Loop, wireless.

HIGH VOLTAGE RECTIFIER TRANSFORMER (HVRT)

The High Voltage Rectifier Transformer Unit (HVRT) consists of an oil immersed step up transformer, ac reactor high voltage rectifier, high frequency choke, measuring and protection components. Transformer-Rectifier sets supply specified DC voltage and current to ESPs. The Transformer-Rectifier high-voltage supply consists of a transformer, an optional current-limiting reactor, rectifiers and switches all kept in an oil-filled tank that is completely sealed and suitably painted for outdoor use. Semi-outdoor bushings are provided on these units and are suitable for outdoor use when enclosed in a bus duct to protect them from the elements. The Transformer Rectifier 415V/95KV, 1200mA DC supplies the power for particulate charging and collection.The transformer-rectifier is mounted on roof of the precipitator.

ELECTROSTATIC PRECIPITATOR (ESP)

Most of the plants in India use coal fuel for generating steam. The exhaust gases contain large amount of smoke and dust which are being emitted into the atmosphere. This posed a real threat to the mankind as a devasting health hazard. Hence it has become necessary to free the exhaust gases from smoke and dust.

There are various ways of extracting dust. The electrostatic precipitators (ESP) are extensively used in the thermal power plant or steam power plant for removal of fly ash from the electric utility boiler emissions. The use of electrostatic precipitators is growing rapidly because of the new strict air code and environmental laws.

An electrostatic precipitator is equipment which utilizes an intense electric force to separate suspended particle from the gases. The process involves:

- Electrical charging of suspended particle.
- Collection of charging particle on collecting electrode.
- Removal of particle from collecting electrode.

The flue gases pass between electrodes and are subjected to an intense electric field. The emission electrodes are connected to the negative polarity of HV power supply while collecting electrodes are connected to positive polarity and grounded.

THE WORKING PRINCIPLE OF ELECTROSTATIC PRECIPITATORS (ESP)

The electrostatic Precipitator utilizes electrostatic forces to separate dust particles from the gas to be cleaned. The gas is conducted to a chamber containing “positive” of vertical steel plates. These plates divide the chamber into a number of paralleled gas passages. A frame with secured wires is located within each passage. All the frames are linked to each other to form a rigid framework. The entire framework is held in place by four support insulators. Which insulate it electrically from all parts, which are grounded.

C= COLLECTING ELECTRODES
E= EMITTING ELECTRODES
S= HV SUPPORT INSULATORS
B= TRANSFORMER OUTPUT BUSHING

A high voltage direct current is connected between the framework and the ground thereby creating a strong electrical field between the wires in the framework and the positive steel plates. The electrical field becomes strongest near the surface of the wires. So strong that an electrical discharge “the corona discharges” develops along the wires. The gas is ionized due to the corona discharge and large quantities of positive and negative ions are formed. The Positive ions are immediately attracted towards the negative wires by the strength of the field. The negative ions, however, have to traverse the space between the electrodes to reach the positive plates.

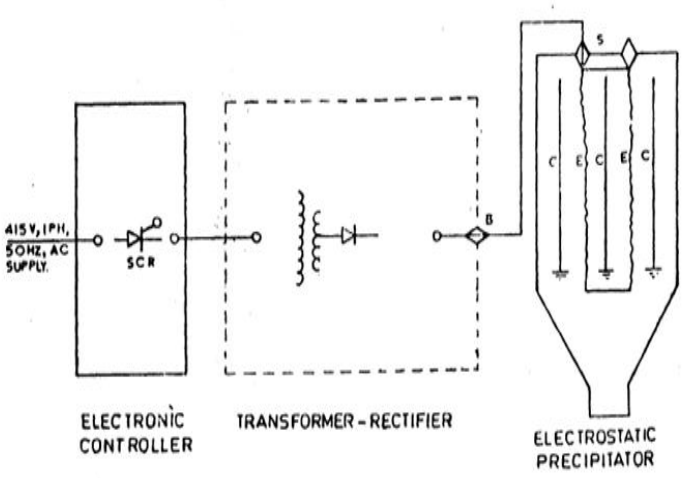

Fig 2: Working Principle of Electrostatic Precipitators (ESP)

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En route towards the steel plates, the ions collide with and adhere to the dust particles in the gas. The particles thereby become electrically charged and also begin to migrate in the same direction as the ions towards the steel plate and stick on to them. These steel plates are rapped periodically to dislodge the deposited dust, which is collected in the hoppers.

INTELLIRAP CONTROLLER FOR ESP RAPPING SYSTEM

IntelliRap is microcontroller based unit that controls and surveys the operation of rapping motors in Electrostatic Precipitators. One IntelliRap unit can control up to 24 motors. IntelliRap starts and stops motors as programmed and will give alarm indication if a rapping motor fails.

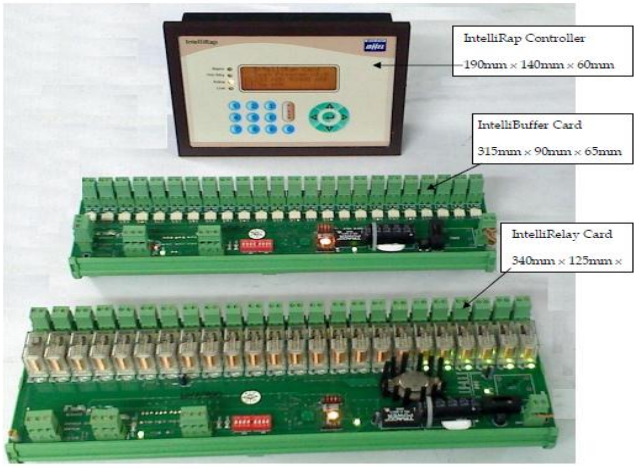

Figure3: IntelliRap Controller for ESP Rapping System

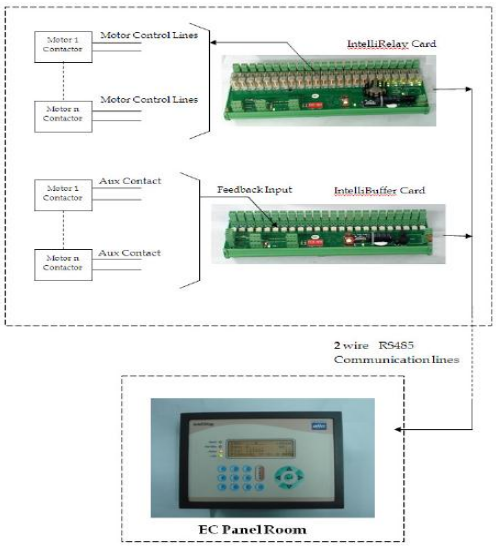

Figure 4: Installation of IntelliRap Controller, IntelliRelay and IntelliBuffercards

The IntelliRelay and IntelliBuffer cards are DIN rail mountable and should be located at the Auxiliary control Panel. They are connected to the IntelliRap controller located in the EC Panel room by 2 wire RS485 communication as indicated in figure.

Features of IntelliRap

The IntelliRap is preprogrammed with number of Rapping sequences, any of which can be selected depending on the field failure condition of the Electrostatic Precipitator. The rapping frequency of the motors can also be manually reconfigured from the IntelliRap. This sequence will be stored in the flash memory ensuring availability of this data on power failure. The IntelliRap controller gives an alarm indication if

1) Communication from the IntelliRelay card is broken.
2) Communication from IntelliBuffer card is broken.
3) A motor is switched on, but the ON feedback from the motor is not available.

- Rapping motors can be switched ON and OFF manually without affecting the operation of other motors.
- The IntelliRelay card is capable of sensing a controller failure / break in the communication channel from IntelliRap. If such a situation arises, it is capable of controlling the rapping motor operation by itself. The program set number and the real time references will continue to be valid even when the IntelliRelay card takes over control. Thus rapping operation is ensured to take place till the failed controller is replaced / communication restored.
- IntelliRap has an LCD Display (4line X 20 Characters) for motor running and error status indication. It provides better user interaction through only six comprehensive menu screens.
- IntelliRap eliminates ribbon cables with more than 100 cores wired between controller and relay & buffer card, hence simplified commissioning and maintenance.
- The IntelliRap controller can be connected to the Integrated Operating system (IOS) for monitoring and control from remote.

RAPPING MECHANISM

Dust that has accumulated on collection and discharge electrodes is removed by rapping. Dust deposits are generally dislodged by mechanical impulses, or vibrations, imparted to the electrodes. A rapping system is designed so that rapping intensity and frequency can be adjusted for varying operational conditions. Once the operating conditions are set, the system must be capable of maintaining uniform rapping for a long time. Collection electrodes are rapped by hammer/anvil or magnetic impulse systems. Rigid frame discharge electrodes are rapped by tumbling hammers and wires are rapped by vibrators.

Rapping motor with gear system

Electric motors incorporated with Power Build Limited (PBL) geared motors are Totally Enclosed Fan Cooled (TEFC) with class-B insulator and protection class IP55. The motor is having a special oil-tight shaft. All electric motors are provided with cooling fans and are suitable for bi-direction rotation. Direction of rotation can be changed by inter changing any two phase in the Terminal Box connection.

a) Collecting Electrodes Rapping motor : Geared motor ,3-phase 0.5HP,0.37KW, 1.1 RPM,415V, 50HZ
b) Emitting Electrodes Rapping motor : Geared motor ,3-phase 0.5HP,0.37KW, 2.5 RPM,415V, 50HZ

3-PHASE SWITCH FUSE UNIT (SFU)

3-phase, 63A, SFU supply power to the Rapping motors and it consists of Fuses, Power Contactor, Auxiliary Contactor, Over Load contactor, Timer, ON/OFF/Trip Indications and receives signals from IntlliRap Controller.

III. CONCLUSION

An electronics precipitator is electrical equipment where a DC voltage is imparted through emitting electrode creating an electrical field around it. Dust particles carried by the gas, while passing through the field is charged to saturation and migrate towards the collecting electrode, usually in the form of plate curtain, where they are deposited in layers. By suitable rapping mechanism dust is dislodged into the hopper. At Yarmars Thermal power plant Raichur, India . ESP unit is proposed by electronic controllers with Microcontroller based ARECA.

ARECA is a new 16-bit microcontroller based HVR controller with new and enhanced features in a compact package. It permits all analog parameter settings through digital keypad entries. A 4x20 character LCD display is used to incorporate more data and command menus per page, and more user friendly. ARECA has a true spark sensing algorithm, which does away with the need for manual tuning and hence provides a maintenance free method for spark sensing.

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