Smart logic system for interlocks and Protections of Boilers in a Thermal Power Plant

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Abstract

Main objective of the paper is to demonstrate all the protections and interlocks available for Boiler management, and show how boiler is protected from abnormal conditions using intelligent logics in a Thermal Power Plant. The existing interlocks are working with general logic system. Unnecessary tripping of Boiler leads to loss of Generation, long maintenance and high cost. To minimize this “smart logic system” system is introduced to activate control and protection only after analyzing necessary conditions according to situation. Rule based smart logic system is developed for boiler management system to improve the stability of the boiler. Simulation tests were carried out and analyzed for “long life time” of the boiler and the superiority of the present work was highlighted.

I. INTRODUCTION

A Boiler Interlock & protection is a system that monitors the safe running state of a boiler operation and if the state becomes unsafe the interlock will trip the boiler to prevent unburnt fuel from entering the furnace. Due to advancement of technology, existing system should be revised with intelligent system. In this regard several researchers contributed to develop Boiler management using latest technology. D. F. Dyer, [1] described a very interesting industrial safety problem and its solutions. Currently, boiler safety controls utilize pressure drop across various boiler elements in an attempt to guarantee adequate combustion air flow, purge air flow, and atomizing media flow. This paper described various practical situations where these flow measurements are inadequate. Various alternative measures were described to mitigate the problems presented. The paper should serve as a basis for complete re-thinking on these safety controls on both power, industrial, and commercial boilers. Siba Brata Mohanty et al [2] presented a new generation of pulverized coal fired boiler technology is currently under development which will permit generating efficiencies in excess of 42%. This paper highlighted some of today’s design improvements which target reduced emissions and expanded operability, and explores some of the boiler design implications for the ultra-supercritical conditions needed to achieve the high cycle efficiencies for the future. Peng et al [3] developed an evaluation technique for FSSS. Furnace safeguard supervisory system (FSSS) plays an important role in protecting the boiler of thermal power plant from danger. In order to evaluate the performance of FSSS itself, functional safety theories are applied in this paper to achieve hazard and risk analysis, target safety integrity level (SIL) determination and functional safety evaluation. The most important safety instrumented function (SIF) of FSSS-master fuel trip (MFT) is considered, and the probability of failure on demand (PFD) is calculated based on the method of fault tree analysis (FTA). Pingli Wu [4] designed Furnace Safeguard Supervisory System (FSSS) of gas-fired boiler, which includes the logic design of sweep control for ignition before and after shutdown, the logic design of sequence control for boiler ignition and blast-furnace gas, the logic design of Master Furl Trip (MFT) and Flame Detection. Author Sangeetha et al [5] presented the present scenario of energy demand and need for the conservation programs and policies. Efficient management of process system can lead to fuel savings, improved process efficiency, lesser operating and maintenance cost, and greater environmental safety. With the growing need for energy conservation, most of the existing process systems are either modified or are in a state of modification with a view for improving efficiency. Any new proposal for improving the efficiency of the process or equipment should prove itself to be economically feasible for gaining acceptance for implementation. P. L. Wu [6] presented a Logic Design of Furnace Safeguard Supervisory System for Gas-Fired Boiler. It is a general logic scheme. Further improvement for future research was highlighted the author.

II. CONVENTIONAL BOILER LOGIC INTERLOCKS

The interlock and safety features directly related to the boiler can be classified as either burner management or combustion control. Interlocks related to the start-up, shutdown, and operation of a boiler are implemented for the purposes sequential operation and protection. A burner management system (BMS) is primarily concerned with the interlock, sequence, and timing functions required to safely put burners into service and to stop fuel and trip the boiler on detection of potentially unsafe conditions (master fuel trip).

Purge Interlock Prevents fuel from being admitted to an unfired furnace until the furnace has been thoroughly air purged. Low Air Flow Interlock or Fan Interlock shut off fuel upon loss of air flow or combustion air fan. Low Fuel Supply Interlock shut off fuel upon loss of fuel supply that would otherwise result in unstable flame conditions. Loss Flame Interlock shut all fuel upon loss of flame in the furnace, or fuel to an individual burner is shut off upon loss of flame to that burner. Fan Interlock Stops forced draft upon loss of induced-draft fan. Low Water Interlock shuts off fuel on low water level in boiler drum. Bad combustion will give rise not only to reduction in combustion efficiency, but it will also result in deposits of soot. The soot tends to cover the pipes, and the steel plates. The heat transfer will be reduced, or worst still, the soot may catch fire inside the boiler.

If the atomization of the fuel is not good, or the nozzle itself leaks, an imperfect combustion will be the result. Very often, oil may drip inside the combustion chamber or may be sprayed on the boiler tubes.

Automatic boiler burners are often started using an electric spark over a fine mist of light fuel oil. If the flame does not start, the oil must not be allowed to continue to spray inside the combustion chamber, otherwise a dangerous explosive mixture of fuel and air will develop inside.

The water level interlock is one of the most important safety features. If the water level in the boiler becomes too low, perhaps due to feed water pump failure, or other reasons, some parts of the tubes, or shell that are exposed to the heat from the flame will not be cooled by the water. The temperature will rise up and the steel parts will eventually lose their strength due to the intense heat from the flame of the burner.

The safety interlocks will shut off the burners of the boiler and prevent further damage.

General logic for Furnace Purge logic for complete removal of unburnt fuel from entire furnace is shown in Fig 1. When all logic conditions are satisfied a command to purge will be applied and furnace purging will be initiated. ON/OFF timer will take care of the timer logic for a purge time cycle of 9 -10 min.

The Protection logic, Flame failure logic, Start/Stop logic , Elevation Monitoring, Secondary/Primary air damper control logic, Primary/Secondary air Fan, Scanner, Wind box logic are also incorporated using logic relays and switches.

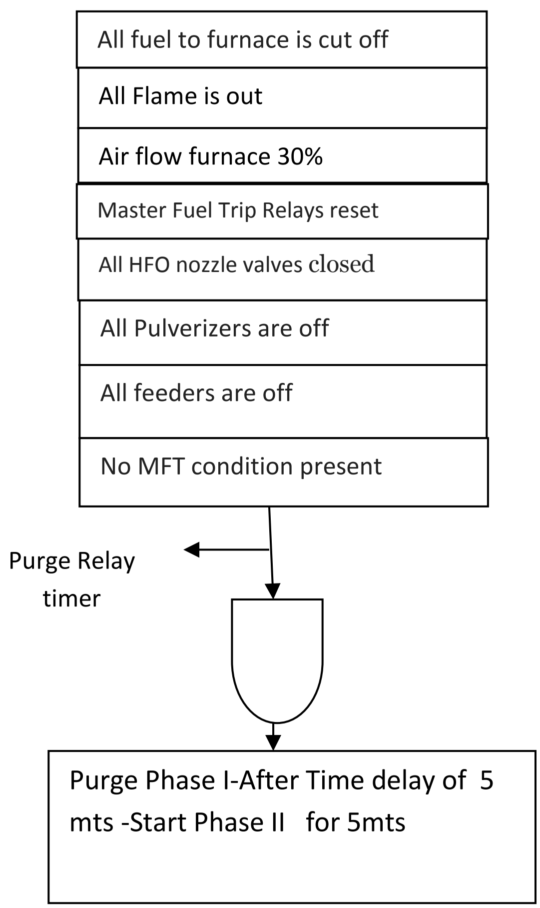

Fig.1. General Furnace Purge logic

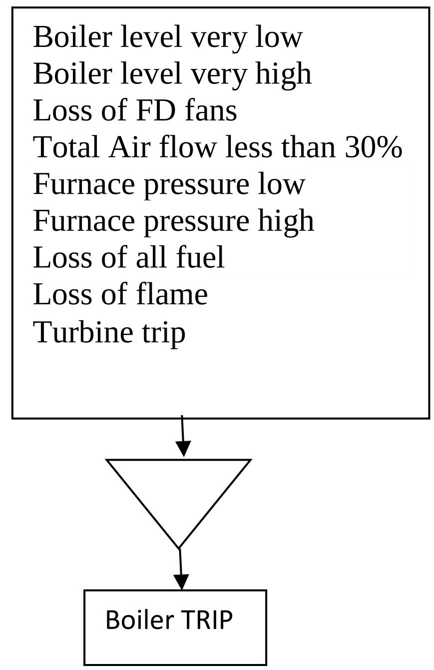

Fig.2. Boiler Protection Logic

Any of the following conditions shall cause a boiler trip to occur. This results in the shutdown of all fuel and requires another furnace purge cycle. Boiler Protection Logic is shown in Fig.2

III. SMART LOGIC SYSTEM

The Smart Logic System for boiler burner management system Consists of 1.Fuel Circuit 2.Steam and 3.Water Circuit 4.Boiler drum water and steam pressure parameters 5.Combustion Air Circuit

Interlock system consists of 1.Fuel trip system. 2. Master fuel trip system. 3. Flame monitoring and trip system. 4. Ignition subsystem.5. Main burner subsystem and 6. Elevation logic system.

The modular based Smart logic system consists of the following: 1) Signal conditioning and input module, 2) Microcontroller interface module, 3) Start-up/shutdown module, 4) Output module, 5) Display module, 6) Alarm module and 7) Protection module. The interface diagram is shown in fig.2.

Smart Corner logic, Elevation logic and Unit logic system contain additional diagnostic features for both detecting and reacting to operation failures. These features ensure that errors are detected and take decision to act protection system considering the present situation. Ability to self-organize all system logics based on current or anticipated situational requirements.

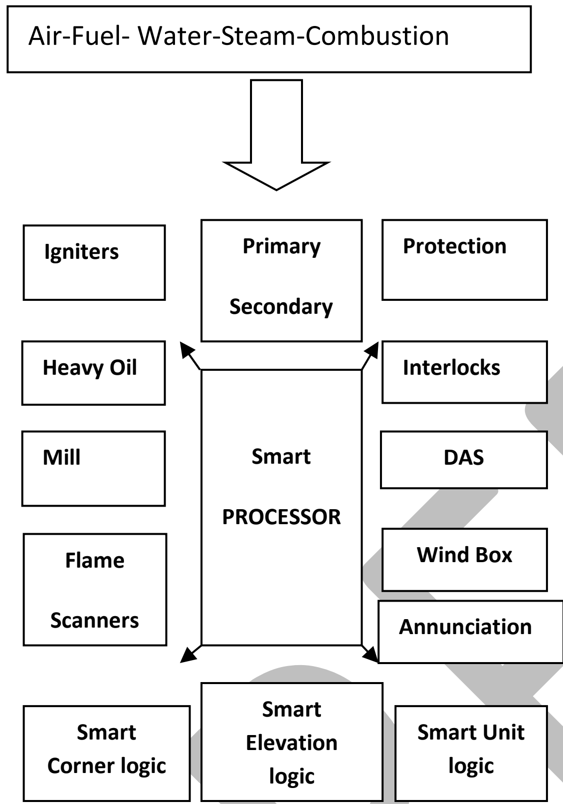

Fig. 2. Smart Logic System

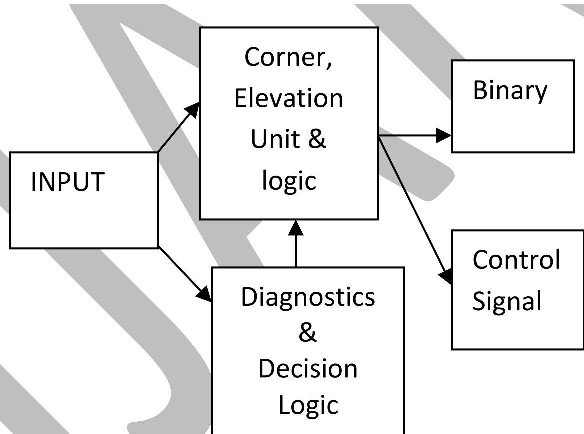

Fig 3. Smart decision logic control

Boiler protections are providing to detect the abnormal condition by constantly measuring the various parameters under normal and faulty condition. If any abnormality happened signal goes to smart decision section to analyze and predict for next level safety condition. The block diagram of smart decision logic system is shown in Fig.3. If the safety level is within the limit then smart decision logic will to continue the boiler operation without tripping. Further continuous monitoring will continue and decision making.

IV. SOFTWARE SYSTEM

Software consists of the following routines: Diagnostic, Initialization, Declaration of the inputs, Data collection, Assignment of the inputs to the variables, Computation of signals, Assignment of the output variables, Assignments of results to the respective modules, Manipulation of data for display on the monitor, recorder and printer, Data logging, Assignment of data for alarm and protection modules and data communication interface.

V. SYSTEM PROGRAM

The diagnostic routine will check whether the system is ready for operation. After initializing, the input system routine will receive the input signal from the input module and process them. The control data collection will receive the data as per the logics send output to the respective modules. The same signal is made available for information system for the monitor, printer and data logging purposes. Protection routine cyclically monitors the alarm value and when it exceeds the limit a signal will be generated for taking the protective action. Data communication routine will put all the signals on the bus with the computer. The programming language C++ is used for all the above software routines and converted into assembly language to embed in the system memory.

VI. SIMULATION RESULTS

The simulation done using lab scale fabricated experimental setup. The proposed system was tested for all conditions like start up, shut-down, load raise status etc, and performed efficiently. Unnecessary tripping of Boiler due to sudden transient condition is avoided to maintain uninterrupted functioning of Boiler.

VII. CONCLUSIONS

The Transient Disturbance will lead to tripping of boiler in the conventional system. The proposed system the boiler parameters are monitored and controlled automatically. The parameter variations of normal and abnormal conditions are analysed without causing immediate tripping.

The performance of the proposed smart logic system is more efficient due to avoiding outages during transient conditions. The safety of Boiler is also achieved with timer circuits which will activate master Fuel Trip Relay after admissible time delay.

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