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Intelligent Monitoring Interfaces for Coal Fired Power Plant Boiler Trips: A Review

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ABSTRACT

A major source of contemporary power is a Coal-fired Power Plant. These power plants have the capacity to continuously supply electricity to almost 500,000 residential and business units. An essential component of a Coal-fired Power plant is automation. A feature of this automation is an Intelligent System developed for the Power Plant. These Intelligent Systems have different configurations and design. This research studies the various Intelligent Monitoring Interfaces developed for Coal-fired Power Plant Trips, their advantages, disadvantages and proposes a new Intelligent Monitoring Interface that would alleviate the disadvantages of the existing systems. Current systems that use Neural Network models are investigated. The improved Intelligent Monitoring Interface as proposed in this paper is a modification of the existing monitoring system for the Coal-fired Power Plant Boiler Trips. It is expected to improve the overall system by implementing remote accessibility and interactability between the plant operator and the control system interface. The interface will also assist the operator by providing guidelines to troubleshoot the identified trips and the remote server application will allow data collected to be viewed anytime, anywhere.

Keywords: Component, Intelligent Systems, Neural Network, Coal-fired Power Plant Trips

INTRODUCTION

Electricity is an essential utility for a household; thus, the existence of power plants that could process our natural resources such as coal or gas into energy is very important. The main interest of the present research is to report the current development of various intelligent monitoring interface system of

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thermal power plant focusing mainly on the fault detection and diagnosis for boilers. This research suggests alternate improvements to the existing monitoring interface systems. It does this by suggesting a novel interactive design using a high level programming language.

Several authors have reported on a variety of applications such as prediction, process control, and condition monitoring, diagnosing and evaluating boiler behaviour. For instance, Fast and Palmé (2010) simulated the Combined Heat and Power (CHP) plant components with an Artificial Neural Network (ANN) as the data modelling tool which is then integrated on a Power Generation Information Manager (PGIM) server. In their paper, the ANN model is continuously fed with actual data to predict the outcome of the power plant overall performance in a Graphical User Interface (GUI).

Another work includes the development of neural network models, which are trained using data collected from a power plant for simulation of a monitoring system. These developed models are reported to have a close to real-time response time which could be applied for an online monitoring system. One of the models in review implements the feed forward back propagation neural network modelling, which was trained using real plant data and reported to be quick in predicting the plant overall performances quite accurately (De *et al*., 2006). In another research, the feasibility of a coal-based or CHP power plant using neural network modelling was examined. De *et al*. (2006) developed two models which uses data from the plant for the training phase. One of the models includes the coal mass flow rate as its input parameter, while the other includes the speed of the conveyor belt as one of its input parameter. The outcome of both models were found to accurately predict real data performances even for data not included in the training, proving its usability for both online or offline real-time monitoring (Smrekar *et al*., 2009).

Another study shows the advantages of using the design of neural network modelling for a biomass boiler monitoring system. The research combines the traditional methods of monitoring using equation based modelling with the NN model. The result of the new structure proves that the new model was able to provide a close prediction with actual data reading. Thus, the conclusion of their findings was that NN is a better monitoring tool than an equation based model (Romeo & Gareta, 2005). In yet another study of a modelling method, a NN approach was used to analyse and predict a boiler's efficiency and also to generate data that could be used for efficiency enhancements. A database was created, which is combined with a soft computing assistance to identify and assess the factors that influence the critical evaluation of its current practices (Kljajicet *et al*., 2012).

This paper aim to identify the modification which best enhanced the coal-fired thermal power plant boiler trip mechanism. The enhancement can rectify the shortfall of the current system by providing an alternate solution which acts as an advisory guideline to the operator for the trips encountered while a physical examination of the equipment is conducted. The proposed project will implement artificial neural network models for the fault and diagnosis monitoring for the boiler, where Java programming language will be used to design the remotely accessible interactive interface that accurately presents the physical reality.

METHODOLOGY

Description of a Power Plant Boiler

The two basic components of the power plant are the furnace boiler and steam turbine generator. As illustrated in Fig.1 (*Thermal Boiler*, n.a.), the boiler structure is equipped with a furnace in which the pulverized coals are fed through to the load burners which ignites it, producing the maximum heat possible. Highly purified water is pumped through the water pipes to produce high pressured steam and the formed hot gases or steam is directed into the smokestack to be released to the air after desulphurization. In order to provide continuous supplies of electricity, the steam is cooled and condensed back into water which is then circulated back into the boiler to repeat the whole process.

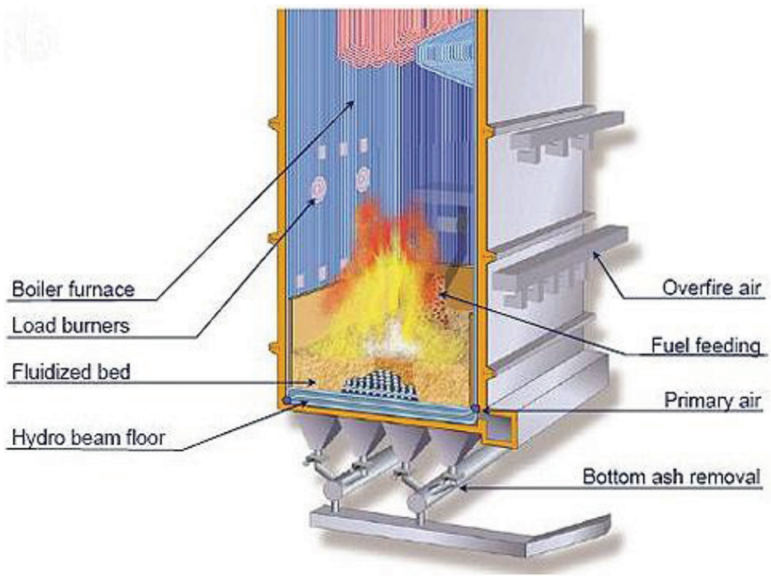

Fig.1: Components of a boiler for thermal power plant

The boilers of a power plant here in Malaysia are designed with a sub-critical pressure, single reheat and controlled circulation. Each boiler is fired with bituminous ranked pulverized coal to produce steam for the continuous generation of 700 MW of energy. The combustion circuit consists of a single furnace, with direct tangential firing and balanced draught. To comply with the Malaysian environmental requirements, the boiler has been design with a low nitro oxide (NO_x) combustion burner system which includes the over fire air (OFA) ports. An Electro-Static Precipitator (ESP) is applied to remove the dust in the flue gas at the boiler outlet and a Flue Gas Desulphurization (FGD) plant scrubs the flue gas to control the sulphur dioxide (SO_2) emission level at the stack. Apart from the boilers, the other supporting instruments of the power plant include three boiler circulating pumps, two forced draft fans, two steam air preheaters, a soot blowing equipment, two ESPs, a single coal milling plant consisting of seven vertical bowl mills and a FGD. A schematic diagram of the steam boiler is shown in Fig.2 (Alnaimi & Al-Kayiem, 2010).

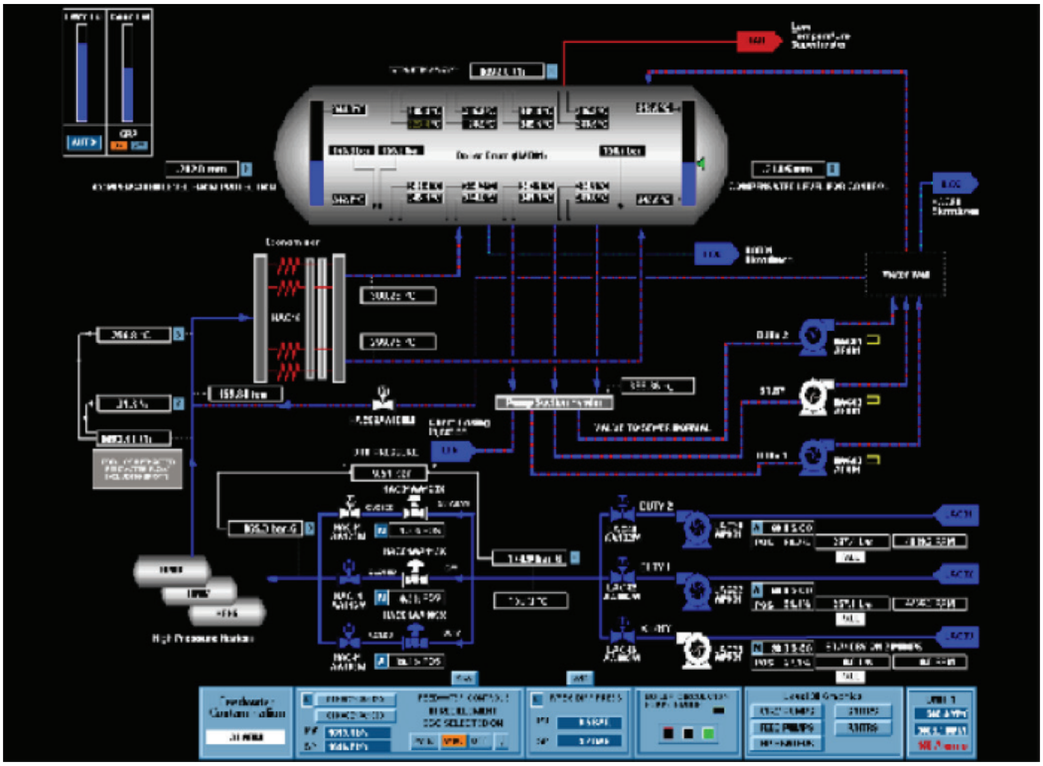

Fig.2: A schematic diagram of the steam boiler displayed on a monitoring & control room of the power plant

Monitoring System Development Phases

The improvement of a systems' output which closely resembles the desired goal can be achieved using an Artificial Neural Network. It is a group of interconnected artificial neurons, which can be trained through systematic procedures by adjusting the network parameters. The performance can be continuously improved using a performances feedback loop which implements a cost function as part of its equation. Information of these neurons is processed in parallel. Haykin (1999) describes ANN as a non-linear statistical data modelling tool that is adaptable and has the ability to learn from experience. Instead of being built from a specific set of parameter values, the parameters are automatically set from external data in its system (Principe *et al*., 2000).

Phase I: Neural Network modelling

In order to develop the NN model, there is no specific structure that can be referenced. It is determined by the complexity of the desired outcome. Hence, the appropriate number of neurons and hidden layers can only be decided through trial and error procedures. However, it should be noted that fewer number of neurons is preferable, as long as the accuracy of the prediction is not compromised (Fast & Palmé 2010). For example, Alnaimi and Al-Kayiem (2010) developed their NN model based on the lowest value of the Root Mean Squared Error

(RMSE) achievable using a single hidden layer with only one neuron and Broyden Fletcher-Goldfarb-Shanno (BFGS) Quasi-Newton training algorithm.

Phase II: Real data acquisition using neural network

It is common practice for operational data in a power plant to be recorded and stored as historical data in the system's database for future references. These readings can be beneficial for a power plant simulation programme development using ANN model.

It has been proven in a number of research that ANN has the capabilities to establish corresponding communication between the points of input and output domain in order to interpret the behaviour of energy conversion plants. The reason for ANN models is simply because it can be trained with the latest data to assess and predict the degradation of plant equipment, and hence,, providing easy, fast responding offline and online applications (Smrekar *et al*., 2009).

Data acquisition is an important step because the results will determine the success execution of the following phases. Here, real-time data were captured from the thermal power station control room, pre-processed and pre-randomized for training, validation and testing.

INTERFACES FOR BOILER TRIPS MONITORING SYSTEM

An extension to the model is the interface development for both client side data representation and control and maintenance operations.

On-Site Server Interface Application

The most common implementation of a monitoring system is through an on-site server which allows authenticated user to have access to the data using their local workstation connected to a Virtual Private Network (VPN).

Fast and Palme (2010) developed an on-site server monitoring system interface using MS EXCEL which was linked to a PGIM server. The operational data are continuously fed into the server which is integrated with an ANN model to generate prediction of the CHP plant performance. When any abnormal readings are generated, alerts and warning will be triggered and sent out to the operators through the main view of the GUI. The advantage of this GUI structure is that all the data is made available to any workstation connected to the server. This allows any authorized user to conduct individual analysis of any chosen parameter in any time intervals whenever they are required.

Remote Server Interface Application

A remote server monitoring system allows data collected on site to be sent to a remote server and be accessible through any standard web browsers (e.g., Mozilla, Internet Explorer, or Google Chrome). Anyone with an authentic username and password can view the data without installing client software. Furthermore, plant staff, analyst and equipment and maintenance operators and technicians can simultaneously look at the data to collaborate on remedial actions (Baxter & De Jesus, 2006).

Rather than delivering machine data in-house only (on-site control rooms), the Internet offers information to be accessible from anywhere, anytime. One such system is implemented on a Nucor mill, Arkansas (Rainey & Henderson, n.d.). They benefit from the system by allowing the monitoring and reading of the machine condition to be carried out without the physical presence of plant personnel on the site. Any changes on the machine condition such as its load, speed and operation will be monitored from a secure workstation or a control room using the local area network connection.

Improved Interface System

An alternate system would be developed using a high level programming language. In this case the alternate system should also be accessible from the internet. So Java programming language would be a good choice as we can create Java applets and also because it is platform independent. In addition, Java offers good possibilities for programming numerical calculations and creating visualization suitable for simulations (Bistak, 2009). These simulations can run online, thus giving the operator the chance to react with it. A diagram in Fig.3 (*Remote Monitoring System*, 2006) illustrates the plant boiler operator's experience with the improved interface.

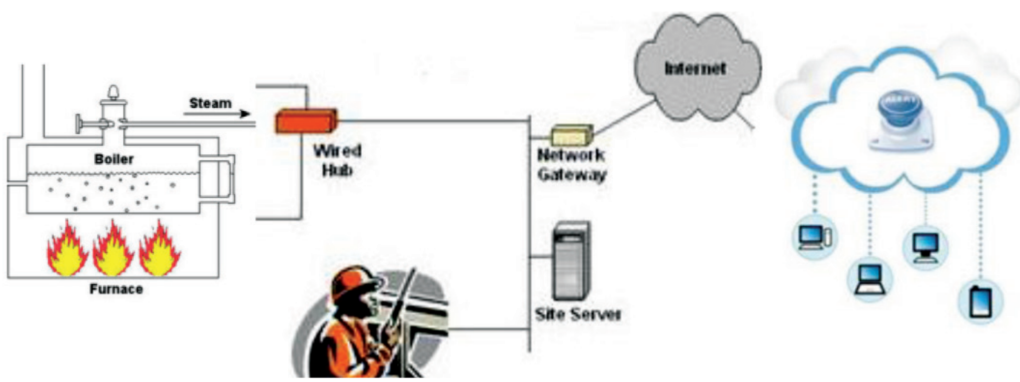

Fig.3: An improved interface monitoring system

The concept of Object Oriented Programming (OOP) became popular in the 90s when the internet hit the public domain. One of the most sought after programming languages for embedded system development is JAVA. Its distinctive features are unique and flexible allowing the developed system to be executed on any operating system platform. These features include robustness, extensive compiling and run time checking, distributed and secure, portability, high performance, dynamic and multithread (Gosling, 2006).

However, with all its high recognition of advantages, there are limitation to the real time performance and feedback. To overcome these issues, RTSJ has been specifically developed to allow JAVA to be used for real-time applications. This is achieved by using a scheduler to dispatch the execution of the logic periodically (Alhussian *et al*., 2012). With this continuous development, RTSJ can be considered as a starting point for JAVA to be widely used as a programmable real-time system such as the monitoring system of a thermal power plant boiler.

In addition, Ventura *et al*. (2002) stated in their paper that industrial automation is becoming increasingly decentralized, relying on distributed embedded devices to acquire and pre-process data and run increasingly sophisticated application software programs for control and self-diagnosis. Increasingly, these systems are employed in safety critical environment, where human life and health depends on the proper functioning of the computer systems. Hence, the safety and accuracy of these systems are of utmost importance. Therefore, they proposed the implementation of High Integrated Distributed Object Oriented Real-time Systems (HIDOORS) as an improvement to Java's shortcomings.

With automated, remote monitoring, health metrics are collected at whatever frequency is needed – without the expense or hazard associated with manual round. This paradigm is based on the concept that a plant will become more efficient if it is smarter about how equipment is monitored (Baxter & De Jesus, 2006).

Over the past few years, the internet technology has developed rapidly to ensure usability and accessibility is available for use in any industry. One of these advancements is the wireless technology. It has enabled plants to wirelessly collect data and make it available via the web browsers. Thus, a machine analyst can be at an airport, home or in a motel with a wireless internet connection and is able to view the machine condition and send correspondence to operations on whether the equipment will make it to the next outage.

Baxter and De Jesus (2006) highlighted the 10 reasons to embrace remote monitoring to ensure that a plant facility can operate more efficiently:

1. Spend more time analyzing data and less time collecting it
2. Collect data from previously inaccessible machine
3. Increase safety
4. Automated data collection
5. Collect additional metrics
6. Consistent data collection
7. Increase collection frequency for problematic machines
8. View plant-wide data
9. Setting of accurate alarms
10. Ability to monitor supervisory panels mounted on vital machines

CONCLUSION

Many approaches to the development of an intelligent monitoring systems used Matlab environment. This is due to its usefulness in designing an ANN model which can be trained to predict the expected performances of a plant's facility. The data collected from these monitoring systems are then recorded and stored on an on-site server for analysis and maintenance. On the other hand, a remote server interface application utilizes the internet to allow monitoring of plant performance to be accessible anytime, anywhere via the internet. Such systems are commonly implementing the Visual Basic and C++ programming language to develop its interface. The existing monitoring systems can be improved by implementing the proposed alternate interface with a high level programming language such as Java. In this case, the alternate system should also be accessible from the internet. So Java programming language would be a good choice as we can create Java applets and also because it is platform independent. By combining the intelligent feature of trainable networks using ANN and Java's portability and secured features, a plant with a remotely accessible, interactive and intelligent monitoring system will become more efficient.

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