

# IoT based Control and Management of Thermal Power Plants for Robust Operation

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**Abstract**—In today's world, the requirement for power is increasing with waxing population. So, it is necessary to have the capability of producing uninterrupted power to all the consumers. Among the solutions available in today's global market, Inter-Networking is considered to be most effective in terms of cost and efficiency [1]. As we start looking into the epitome of automation it exists as one single structure which can be implemented for a limited number of tasks, in order to overcome such barrier, the concept of Internet of Things (IoT) is utilized. IoT gives a simple and optimum solution to complex system's complex challenges. Although there are several tiny units of automated processes, there is no proper centralized control unit which can act as a backbone to connect these individual automated units to reduce the complexity of the system [2]. Internet of Things (IoT) is an extension of the current internet to provide communication, connection, and internetworking between various devices or physical objects. In this paper, a novel application of Internet of Things in the automation of thermal power plant through simulation using contemporary tools has been proposed.

**Keywords**—IoT, Thermal Power plants, Automation Control, Industry 4.0, Autonomic computing and communication

## I. Introduction

The Internet of Things (IoT) is a complex adaptive system consisting of sensors, processors, and controllers connected to a mainframe network. The sensors embedded in the target objects are connected to this network are highly intelligent and more capable of interacting with humans. The Internet of things extends the cloud computing concept beyond the existing computing and communication boundaries to include every aspect of the system irrespective of its existence. Generally, thermal power plants are commissioned in an extensively vast area that is near to its source of fuel with multiple mechanical pieces of equipment in position.

Hence, the wired communication lines for developing the network of mechanical components for data assimilation becomes more hectic, thereby deploying IoT into such industrial environment brings down the communication constraints extensively. This acts as the cognitive network to fetch, analyze, decide and communicate the data among the network created. Through a combination of advanced data analytics, IoT connects the machines, computers, and people to enable intelligent industrial operations. Industrial automation is a domain in which Internet of things can bring with many benefits. The real-time data collected from a large number of these interconnected hardware units can be used for

the operation and maintenance of the thermal plants [2]. However, building a smart power plant results in many challenges, including both general IoT challenge such as security, and industrial automation domain specific requirements such as reliability and availability that remain to be fulfilled in the new IoT context. The main objective of this paper is to deploy internet of things concept in the today's power generation sector, i.e. Thermal power plants. This paper discusses some scenarios such as transportation of coal from the coal yard to bunker, monitoring power consumption of electrostatic precipitators and the motoring actions of the drives.

## II. Related Work

Automation process enhances the current methodology into an isolated process without or with less interruption of humans. This kind of activity has a major impact in the Industrial 4.0 revolution. A Steel industry has enabled its continuous steel casting system with IoT and have achieved much higher efficiency [1]. [2] presents the technical solutions and best-practice guidelines adopted in the Padova Smart City project, a proof of concept deployment of an IoT island in the city of Padova, Italy, performed in collaboration with the city municipality. This also clearly explains the flawless way of communication between the devices over large areas. A detailed survey on the working, implementation, advantages and disadvantages of IoT is depicted in [7]. [8] gives the complete view on secure communication for smart IoT Objects.

## III. Proposed Method using IoT

### A. Transportation of coal from coal yard to bunkers

This process involves the movement of coal from the offshore unloader to boilers. This involves a number of stages between it- from offshore unloader to open yard coal storage, then to primary mills and to bunkers through the conveyor and the secondary mills. Now, this whole process is automated using internet of things. Appropriate sensors are placed in the required fields say, temperature sensor – to find the internal temperature of coal bunds, laser level sensors are placed inside the bunkers – to find the level of the coal, and on belt gamma sensors are placed on the conveyor belts – to find the presence of coal in the conveyor belt. The operation of this is as follows: the level sensors placed in the secondary bunkers. If this reads a value less than threshold value i.e. half of the capacity of the bunker, then these sensors send an intimation signal to the conveyors to fill these bunkers. The conveyor

Figure 2. Front Panel Diagram of Simulation Output

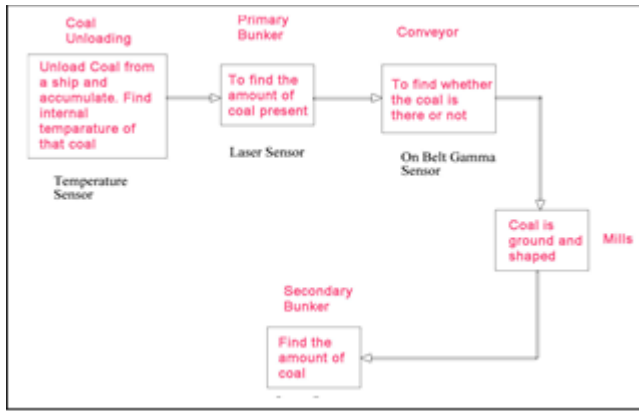


Figure 1. Block Diagram of Coal Transportation methodology

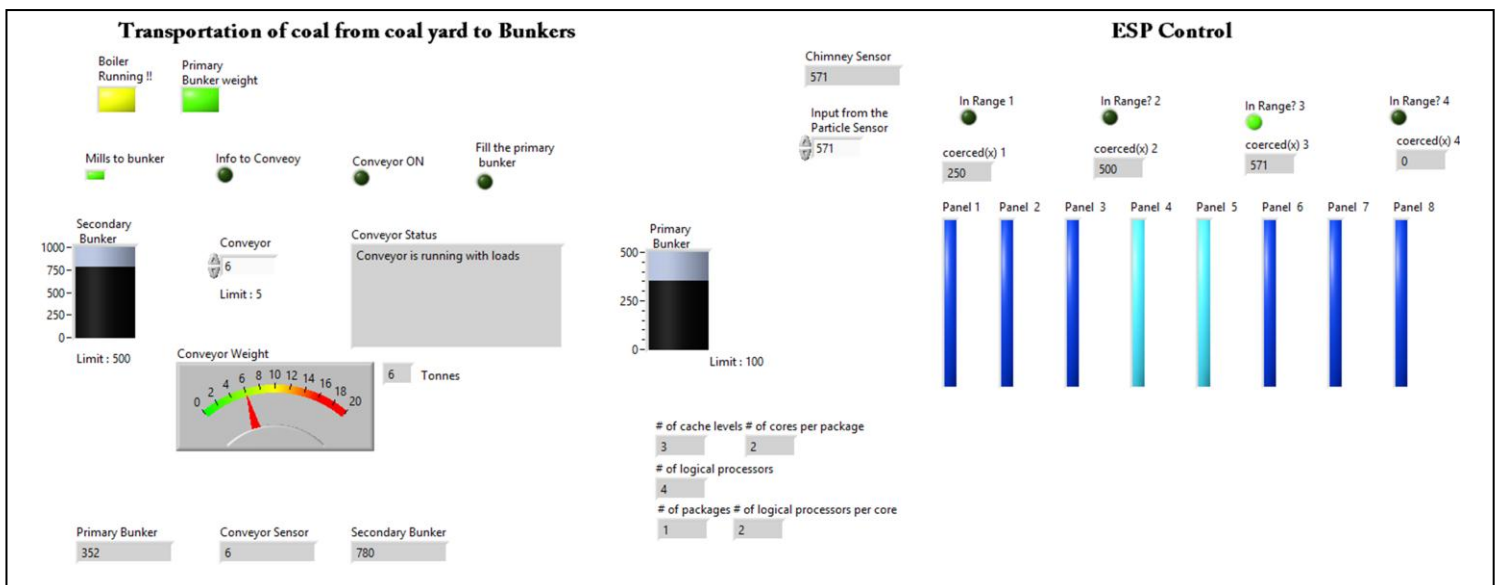
checks whether the conveyor is loaded with the coal using the on belt gamma sensors. If the conveyor is loaded and the bunker requests to fill, then the conveyor runs to fill this secondary bunker. The conveyor fills the secondary grinding mills which grind the coal and fills the secondary bunker with fine particles of coal. If the conveyor starts running the load in the belt reduces gradually, so the primary bunker starts to load the conveyor. The level sensors in the primary bunker pass a signal to the control room if the level of the primary bunker goes below a threshold value. The control room passes the information to the shore unloader to fill the primary bunker. Another scenario to be observed here is to maintain the internal temperature of the coal bunds in the open coal storage yard. In today's world, it is tough to address this scenario, and industries are using fire engines to control the fire upon an accident. But it can be easily solved using IoT technology, small temperature sensors can be placed the huge heap which transmits the temperature wirelessly to the nearby node. If the temperature exceeds the threshold values the sprinklers automatically sprinkles water to reduce its temperature. And the whole process from coal unloading to boiler is enhanced using WSN. Figure 1 illustrates the proposed idea.

## B. Monitoring the Motoring action

Thermal power plants have a number of electric drives for motoring action right from the importing of coal till ash handling. These devices are governed by the speed governors to have a control over these motors, which is also used to sense whether the motor is working. But in some remote areas such as zero meter slack conveyor (the ash collecting conveyors directly from the boiler) the huge ash blocks causes physical damage these external speed governor and intimate the control rooms as an emergency even during the normal function. To avoid this pathetic situation, it is proposed to embed an accelerometer in the rotor part of the motor drive which gives a three-coordinate graph during the rotation of the motor and shows nil if the motor is in OFF condition. This helps to avoid the emergency situation under normal operation condition. This is possible as Internet of Things can work using Wireless Sensor Nodes (WSN).

## C. Monitoring of Electrostatic precipitators

The electrostatic precipitators are one of the most important arrangements in the thermal power plants to reduce the air pollution. The electrostatic precipitators (ESP) are the arrangement of long steel plates; it is supplied with high voltage. This repulses the ash particles and collects these in the separate containers without mixing with the air through the chimneys. The number of plates to be operated is directly proportional to the ash produced which is, in turn, proportional to the power production. Although this involves various parameters such as the calorific value of the coal, impurities present in coal, etc. But here it is neglected and assumed that power production is proportional to the ash produced. In this scenario internet of things is deployed to control the operation of a number of plates as per the requirement. A particle counter sensor is placed on the outlet of the chimney which is powered through the AC mains auxiliary supply. This sensor



is directly connected to the ESP units wirelessly which in turn operates the ESP. Because of the unavailability of this technique now a huge amount of current is used as auxiliary consumption.

#### D. Labview Simulation

The ideas are also simulated in Laboratory Visual Instrument Engineering Workbench (LabVIEW). It is used for data acquisition, instrument control, and industrial automation. For simulation purposes, this paper uses the cloud monitoring technique accessible through the internet. Here a cloud platform – Ubidots has been used, which helps to send data, receive data and monitor the overall proposed system.

Figure 2 represents the front panel output diagram of the simulation and Figure 3 represents the back panel (Logic Diagram) of the simulation – LabVIEW.

### iv. Architecture of the Communication System

Since a Thermal Power plant spans several Square Kilometers the usual wireless technologies like Zigbee and Bluetooth -LE can't be used for communicating between various devices. Because of its short range communication and increased vulnerability of being hacked. Bluetooth connects to different devices i.e. even to employee mobile phones or some other nearby devices which would lead many misinterpretations.

#### A. Various Wireless Standards for communication

A new and upcoming standard of Wi-Fi called IEEE 802.11af fits the bill perfectly for this application. IEEE 802.11af, also referred to as White-Fi and Super Wi-Fi is a wireless computer networking standard in the 802.11 families, that allows wireless local area network (WLAN) operation in TV white space spectrum in the VHF and UHF bands between 54 and 790 MHz. Cognitive radio technology is used to transmit on unused portions of TV channel band allocations, with the standard taking measures to limit interference for primary users, such as analog TV, digital TV, and wireless microphones. Communication between IoT devices

#### B. Description of IEEE 802.11 af

The physical (PHY) layer in 802.11af is based on the orthogonal frequency division multiplexing (OFDM) scheme specified in 802.11ac. The propagation path loss, as well as the attenuation by materials such as brick and concrete, is lower in the UHF and VHF bands than in the 2.4 and 5 GHz bands, which increases the possible range compared to 802.11 a/b/g/n/ac. The frequency channels are 6 to 8 MHz wide, depending on the regulatory domain. Up to four channels may be bonded in either one or two contiguous blocks.

MIMO operation is possible with up to four streams used for either space-time block code (STBC) or multi-user (MU-MIMO) operation. This wireless standard is geared towards

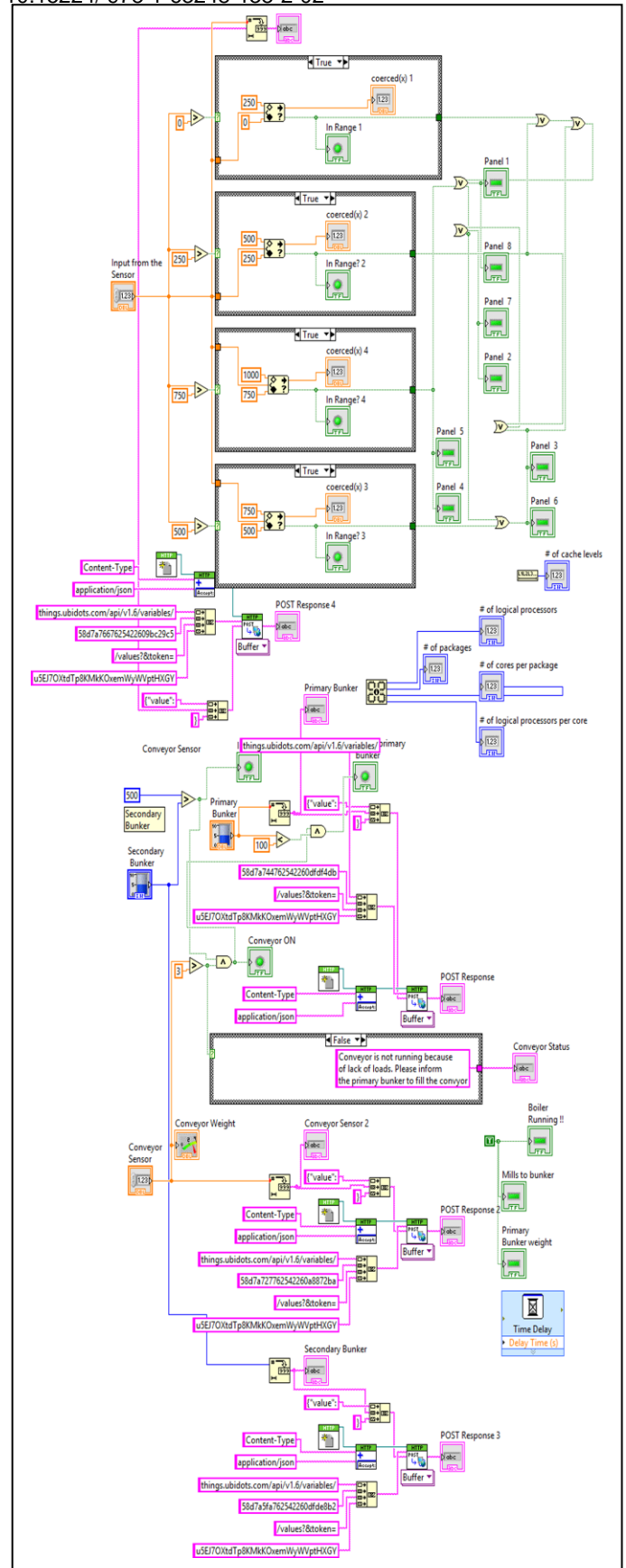


Figure 3. Back Panel Logic Diagram of Simulation



the future IOT Devices which may be separated by a long distance.

**Advantages:** Because AF can use several unused TV channels at once, it can be utilized for very long range devices - potentially more than a Kilometer with high data rates. Because it isn't deployed in the mass market, interference and hackability are very low. Since many Thermal Power plants are pretty far from big cities, unused TV bands are available.

**Other potential standards:** In addition to 802.11af, the IEEE has standardized another white space cognitive radio standard, 802.22. While 802.11af is a wireless LAN standard designed for ranges up to 1 km, 802.22 is a wireless regional area network (WRAN) standard, for ranges up to 100 km. This standard may be used in very large Thermal Power plants to serve as a reliable and secure channel for communication between various devices.

**Communication Protocol:** The higher data rates of 802.11af and 802.22 give the luxury of choosing from various protocols. The main criteria for the selection of a protocol were the overhead, efficiency, and security. The XMPP-IOT Protocol was chosen based on the above-mentioned criteria. The XMPP-IOT is a modified form of the XMPP Protocol which is very popular in Instant Messaging Services.

**Description of Architecture:** XMPP is an open, secure, spam-free, ad-free, decentralized alternative to consumer IM silos like AOL Instant Messenger, Windows Live Messenger, and Yahoo Instant Messenger. Under the hood, XMPP is a set of streaming XML protocols that enable any two entities on the Internet to exchange messages, presence, and other structured information in close to real time. XMPP-IOT aims to make communication machine to people and machine to machine interoperable. XMPP is used because of its stability, security and decentralized operation. Most of the connected devices are closed and have a defined business model. But it is also possible to open up sensors to be used in smart cities and wider.

### C. Implementation of a sensor - server network using 802.11af and XMPP:

A primitive form of the network consists of a server and a trusted device (i.e.: the sensor). The basic concept of using XMPP is the notion of friends. To exchange data between two devices they need to be friends. The concept of "friends" gives the layer of security required in the use of sensitive systems. The sensor is given a JID (Jabber ID) or a X.509 certificate (verified over the HTTPS Protocol) to make it a trusted device. A simple script (using Python, Node.js or JavaScript) can be used to interface between the server and the trusted device. The data from the device can be read and control values can be sent to the various actuators using the XMPP Protocol. Since a sensor can't connect directly to 802.11af Wi-Fi networks, a PCB with a built-in microcontroller which supports the XMPP Protocol is required between the sensor and the Server. In the case of several sensors being close to each other, the various sensors can connect to the same microcontroller either wirelessly or through wires in order to communicate with the server. This process makes

communication between the devices more secure than in the more common IOT devices found in the market today while still being reasonably simple. This approach is scalable. Hence any future additions or upgradation of the sensors would never be a tough task.

## V. Results and Discussions

TABLE I. COAL TRANSPORTATION

Laser Sensor – Primary and Secondary bunker threshold value is 500 (capacity 1000 Tonnes); on belt gamma sensor's output signals is either 1 or 0; Temperature Sensor – Threshold value is 250 (Bituminous coal - glow point is 457 degree Celsius)

Laser Sensor – Primary bunker	On belt gamma sensor	Laser Sensor – Secondary bunker	Temperature Sensor	Status
750	1	750	200	Conveyor belt is OFF
450	1	750	200	Conveyor belt feeds the primary bunker
450	0	750	200	Secondary bunker fills the conveyor and in turn fills the primary bunker
750	1	450	200	Secondary bunker sends a signal to local control station to fill the secondary bunker from the coal bunds
750	1	750	300	Temperature sensors sends a signal to start the sprinkler system to avoid firing in the coal bunds.

TABLE II. MONITORING THE MOTORING ACTION  
 g – Measures the position of the sensor with respect to gravity

Current reading of accelerometer				Previous reading of accelerometer				Difference	Status
Deg	X (g)	Y (g)	Z(g)	Deg	X (g)	Y (g)	Z (g)		
0 / 360	0.5	0.5	1.0						Initial States - OFF condition
90	0.5	1.0	0.5	90	0.0	0.5	0.5	Yes	Transient Condition
180	0.5	0.5	0.0	180	0.0	0.5	0.5	Yes	Motor is Running
270	0.5	0.0	0.5	270	0.0	0.5	0.5	Yes	Motor is Running
270	0.5	0.0	0.5	270	0.0	0.0	0.0	No	Not Running
270	0.5	0.0	0.5	270	0.0	0.0	0.0	No	Not Running

TABLE III. ESP MONITORING

Particle Per Million Sensor		Plates currently working	Status
Threshold Value	Sensor Reading		
0	0	None	No plates are being operated
250	153	1 and 8	2 plates are operated
500	456	1,2,7 and 8	4 plates are operated
750	652	1,2,3,6,7 and 8	6 plates are operated
1000	987	1,2,3,4,5,6,7 and 8	8 plates are operated

TABLE IV. SENSOR SELECTION [2]

Sensor Type	Energy Source	Network type	Traffic Rate	Tolerable Delay	Feasibility
Temperature Sensor	Battery powered	Wi-Fi	1 pkt every 10 sec per device	30 sec for data, 10 sec for alarm	Does not present major difficulties, but requires intervention on existing accuracy levels
Laser Sensors	Battery powered	Ethernet, Wi-Fi	1 pkt every 5 min per device	10 min for data	Possible to realize, but requires more attention to get better accuracy
On belt gamma sensor	Electrically powered – 3 Phase AC Systems	Ethernet, Wi-Fi, 3G, 4G	1 pkt every 10 sec per device	5 min for data	Does not present major difficulties
Accelerometer	Battery powered	Wi-Fi	1 pkt every 10 sec per device	1 min for data	Easy to realize, but graph may be difficult to integrate

## VI. Conclusion and Future Work

The Centralized control of power generation industries is crucial in without the advanced communication and data processing techniques. This paper presents a novel solution for a fully automated system using IoT technology. The proposed framework introduces an IoT-based fully process automated system architecture and communication protocol for increasing the work efficiency of thermal power plants. The communication part deals with a large amount of heterogeneous data and provides a data interface. A simulated case study of this application shows that the system performs well in the real power production plants. The proposed system architecture offers enough flexibility to integrate new hardware and software capabilities. This technology can be well applied to other similar industrial environments for real-time controlling.

Our future research will focus on applying advanced communication protocol and machine learning techniques to improve the functionality and performance of the proposed system - Every node is made to learn itself in a way to find the useful data through metacognitive learning methods [3]. This can be further extended to infer results from the opted data through supervised and reinforced learning.

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