Manufacturing Whitepaper

Title: Exploiting Emerging Technologies for High Pressure Boiler Tube Failures Prediction for Minimizing Unplanned Shutdown

IoT Along with AI to Predict and Prevent High Pressure Boiler Tube Failure

SUMMARY

The boiler pressure components (super-heater, re-heaters, economizers) are the critical and vulnerable systems in fossil-fuel based power plants. Failures of these components have contributed to the highest percentage of unplanned shutdown. About 38% of failures are related to failure of components like super-heaters and re-heaters, and about 40% of mechanical components fail due to creep and fatigue.

Boiler tube failures are inevitable and continue to be the major cause of forced outages. All high-pressure boilers are bound to have a tube failure during their operational life-time. It has been statistically estimated that a single tube failure in a 500 MW boiler requiring four days of repair work can result in a loss of more than $1,000,000 apart from the generation loss. The cost of boiler tube failures is comprised of three main components – the cost of repair, the cost of start-up oil to return the unit to service and the cost of lost production.

The other causes of failures include failures resulting from long-term overheating (almost 90% of failures), failure due to quality variation, operating temperature, startup and shutdown rate, etc.

Steel tubes exposed to elevated temperatures for extended periods of time will oxidize resulting into scaling. When the Unit is started, this scale blocks the steam flow and leads to failures due to overheating of the tube metal. Though it is not possible to completely avoid tube failures in a high-pressure boiler, we could take corrective and preventive actions to minimize/reduce the number of tube failures, thereby increasing the availability of boiler.

Specifically, the key is to predict long-term stress-rupture failure due to choking caused by exfoliated scales. Solutions are sought to predict the Oxide Thickness which is a function of temperature and time-at-temperature.

In a high-pressure boiler, thermocouples are generally not installed on every tube of a superheater or in the regions (e.g., bends) where creep/rupture-failures typically occur. Any prediction mechanisms based primarily on these sparse thermocouple-data will inherently be limited. We could explore cost effective mechanisms for assessing temperature of the tubes for which we currently have no measurements.

CHALLENGES

Boiler tube failures are inevitable – some are catastrophic leading to deaths while some lead to heavy losses as high as INR 6 -7 Crores, excluding the losses in terms of scales and downtime that leads to production loss. The three major components of super-heater, re-heaters and economizers fail because of creep, creep-fatigue and fatigue. Fatigue is a state of metal, when the metal is pulled and pushed several times, leads to failure.

Oxide scaling is another reason for failure of boiler tubes. Within the boiler, scaling is formed due to oxidation. When temperature changes, metals expand at different rates, while oxides don’t really expand. The internal oxide scale tends to dislodge during boiler shutdown due to the difference in coefficients of thermal expansion of the metal and oxide-scale. This results in oxide-scale exfoliating and getting accumulated inside tube bends. How to detect scaling at early stage and take corrective action is critical. If we use transducer to detect oxide scale, it may melt due to high temperature. If these are put in the tubes, it may become another reason for boiler tube failure.

The inputs that are fed to the boiler tube like fuel (type of coal) and water (quality of water – pH factor) also result in oxide formation. Various parameters contribute to oxide scaling and the problem is hidden. This cannot be controlled, so we need to look at it from the point of view of prevention and predictive maintenance.

In summary, oxidation occurs due to 3 factors- temperature, pressure and pH of water. A solution that can monitor these three factors and establish a correlation between the rate at which pressure and pH impact and form scales, can help us take preventative action helping to minimise failures.

Essentially, there are two kinds of boilers – one is below 500MW and other is above 500MW power. Boilers below 500MW can use commercially available sensors and non-IP transducer can be used to monitor the parameters leading to failure. However, challenge lies in monitoring the parameters for above 500MW where normal commercial sensors like thermocouple will melt themselves in given condition.

A boiler tube comprises of many parts and components like smaller tubes which are not visible. Placement of sensors in such hidden parts to measure the parameters is not possible. This is another big challenge.

RESULTS

A combination of parameters is needed for analysis and prediction of failures. The challenge is that the relation between these parameters is not causal or linear but is multi-dimensional across time. Amalgamation of technologies like Artificial Intelligence, Machine Learning along with Sensor technology and Internet of Things can help in creating a predictive model. Gathering data for Data analytics over neural networks and finding out relationship between the parameters takes time.

Neural Network based Solution: In Jamshedpur, Govt. of India lab has formulated a neural network-based solution. It uses proxies to detect and predict exfoliation rates. The solution uses 9 set of inputs like *pH, heat flux, temperature at proxy, rate of heat exchange, coal particles and properties and many such*, to decide the rate of oxide scaling. This solution was devised by gathering about 600k data points from all range of boilers in India. The model predicts rate of oxidation in an interesting manner by using proxies around the boiler and not from inside the boiler. The prediction rate is 90%, which is higher than the existing methods. However, this method still under testing.

Ultra-Sonic Method: When we talk about measuring parameters inside the tube, only heat flux, which is heat/ m^2 can be measured using ultrasonic method. This method is non-invasive, uses a little bit of Artificial Intelligence and can help track scale deposits at right points. Ultrasonic sensors can be used to measure the depth and leakage at joints and bends.

Use of other commercial sensors: We need to look at practical methods of placing sensors inside the system for accurate measurement. Thermocouples are expensive but can help in active monitoring. Other parameters like flow and pressure of water, pH of water and other impurities can be measured using different commercially available sensors for smaller set-ups.

Camera sensors: Visual camera sensors can be used for capturing exact situation at the bends of the pipes. However, it's very difficult to train and track changes in real-time scenario. Non-visual wavelength cameras like thermal cameras, can help detect the changes in heat and flow. The data can be then fed to the video analytics to study and make predictions. Thermal imaging can help identify leakages and this is a key input or data point for AI and neural networks. Thermographic IR cameras uses infrared radiation to form heat zone image.

CONCLUSION

There are two types of data sets needed for predictive analysis and corrective actions.

- The data set from inside the tube by placing the sensors on/ in actual system and
- The data set that's collected from outside environment.

Both of these are needed to build a great failure model that can be used for predictive analysis. Advanced high performing invasive sensors, non-contact types non-invasive sensors, IP and non-IP based sensors, can help in collecting the data. AI engine needs data for processing and training, and edge system can help is gathering the data.

Based on these data sets that are collected, **Inference model** can be is used to learn and train the systems. AI based simulation, IoT for collection of data and feeding back to cloud and advancement in sensor technology together can help in early predictions of failure and help in taking corrective actions.

IET India

The IET is one of the world's largest engineering institutions with over 168,000 members in 150 countries. It is also the most multidisciplinary – to reflect the increasingly diverse nature of engineering in the 21st century.

The IET is working to engineer a better world by inspiring, informing and influencing our members, engineers and technicians. The Institution of Engineering and Technology – India, the IET office started operations in India in 2006, in Bangalore. Today, we have over 12,000 members and have the largest membership base for the IET outside of the UK. Given the increasing global importance of India as an engineering hub our aim is to make an impact that has relevance both locally and internationally. Our strategy is to make a meaningful impact on the overall competency and skill levels within the Indian engineering community and play an influencing role with the industry in relation to technology innovation and solving problems of public importance. We want to do this through working in partnership with industry, academia and government, focusing on the application of practical skills within both learning & career lifecycles, driving innovation and thought leadership through high impact sectors. Our volunteer led panels are means through which we deliver our strategy. The IET India IoT Panel was born out of this focus.

IET IoT Panel

IET India launched its IoT panel on February 20, 2015 with Dr Rishi Bhatnagar (President – Aeris Communication) as the Chairperson. The panel, being a first of its kind in India, focuses not only on technology but the application aspect of IoT in various segments.

The focus of the panel is to facilitate discussions that will help in making the inevitable connected world more efficient, smart, innovative and safe. It will lay emphasis on technology, security and regulatory concerns and the need for nurturing capabilities and talent for quicker adoption of IoT in all spheres.

The IET India IoT Panel aims at providing a platform for stakeholders to become an authoritative, but neutral voice for the evolving movement of IoT in India. It aims to enable all the IoT practitioners (including people from the hardware – devices, portables, sensors, software, business) and IoT enablers (including people from regulatory area, training area, investors in IoT, end users) to work together on relevant areas to make this industry efficient as well as robust. The panel envisions laying a solid foundation by supporting policy makers, industry in the next step of adoption of IoT.

The panel works through 12 Working Groups - Healthcare, Social Impact, Digital Communications, Smart Cities, Skill Development, Standards, Regulatory and Legal, Cyber Security, Utilities, Manufacturing, Ganga Rejuvenation, BFSI and Agriculture.

IoT India Congress

In 2015, IET India volunteers designed and conceptualized a think tank called the IET IoT Panel of industry leaders in IoT space. The panel was formed with the objective of being a neutral and credible voice to evangelize Internet of Things in India and help accelerate the adoption of IoT. One of the outcomes of the year-long work of the panel is the flagship event called IoT India Congress. It brings together global industry leaders, researchers and technology evangelists, government policy makers and academia under one roof, making it a powerful source shaping the evolving IoT movement in India.

Over the last 3 editions, the event has grown into becoming a Platform of Platforms for the Internet of Things, gaining significant traction from the entire ecosystem. The first edition was devoted to unifying the fragmented IoT, the second edition focused on exploiting this platform for unravelling business outcomes while the third on demonstrating business opportunities and outcomes. The event has gained noteworthy support from the key ministries of the Government of India. Ministry of Health and Family Welfare, Ministry of Electronics & IT, Department of Telecommunications, NITI Aayog – India's apex planning body of India over these years.

IoT India Congress 2019 is the 4th edition of India's largest Platform of Platforms for the Internet of Things. With the clarity that IoT is now Business as Usual and a significant growth driver for enterprises across all segments, the 4th edition is themed as 'Mainstreaming the Internet of Things'.

If you are interested in volunteering for the IET or joining one of our panels, please write to us at india@theiet.in

Follow us on:

https://twitter.com/IETIndia

www.facebook.com/IETIndia

https://www.youtube.com/channel/UCu21pZYLQjIgAE1SA1QfEVw

https://www.linkedin.com/company/ietindia/