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Use of Data Analytics for Power Plant Operation Optimization

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Abstract

Optimized operation and maintenance of a power plant to improve the KPIs is the key to success. Forced outages not only make the unit unavailable but also increase the number of start-ups and hence high cost and deteriorated plant life. Fault diagnostics and prediction of future behavior of equipment by data analytic techniques will be very handy in improving reliability. On the other hand, the cost of generation depends upon how efficiently the plants are operated. Any deviation from the optimized design point, results in losses and hence as far as possible the deviations should be minimized. However, the deviations are unavoidable due to various reasons. Along with efficient operation, Environmental compliance, and flexibility is also to be ensured to meet the statutory requirements. With the advancement of computing techniques, data analytics, and Artificial Intelligence are being used for the optimization of many industrial processes. Given the background, the objective of this paper is to study and suggest how Data Analytics can be utilized for the optimization of power plant operations to improve reliability, efficiency, and flexibility, and minimize the impact on the environment. Many statistical methods are available to identify the hidden pattern in the data which can be used for optimisation of processes. AI is used for process control, diagnosing faults, and predicting of future behaviors so that advanced action can be taken to avoid surprises. The domain expertise along with data analytic methods can be utilized to find solutions to a variety of problems. In this paper, a comprehensive data analytic tool with four modules i.e., “Efficiency optimization”, “Plant Health monitoring and reporting”, “Optimization of life consumption” and “Environment protection” has been conceived for application. These Modules work in an integrated manner and shall monitor, optimize, control, and report/advise. The tool shall have a digital replica of the individual equipment for simulation individually as well as in combination with other related equipment for whole plant performance prediction and diagnosis. The replica shall use its database for machine learning and for running of diagnostic process.

Keywords: Auxiliary Power Consumption (APC), Distributed Control System (DCS), Distributed Digital Control and Monitoring System (DDCMIS), Efficiency Optimization

1. Background

Present-day plants are being operated with a Distributed Digital Control and Monitoring System (DDCMIS) also known as Distributed Control System (DCS). It is a fairly good amount of automation with very minimal operator intervention and also has data acquisition capability. The DCS is a very good system for Automatic control and protection of the plant and equipment. However, is not able to distinguish/recognize the state of the plant/equipment like its age, deterioration pattern, etc., and also not capable of performance optimization, data analysis/diagnosis.

We have lot of data stored in the form of tables, trends, graphs, and SOEs. However, by itself large amount of data does not generate insight. Insight requires expert knowledge and understanding of how best to leverage those analytics. Though the equipment/components may have been designed with the same philosophy and have the same design capability, each piece of equipment behaves differently when put in operation due to various reasons including manufacturing tolerances, differences in actual material properties, different operating conditions, etc. Hence there is no formulae to be fit for all equipment. It needs data-driven tailored advice for the operation and maintenance team to make decisions.

Going through such a large data and its Analysis is not possible manually. As the plants operate the data also gets larger and larger. The behavior of the machines also changes necessitating change in solution. It is not possible for the O and M staff to go through the vast data continuously and interpret it correctly each time. Further, the trigger for data analysis shall come only after there is a fault or failure i.e., when the damage has already been done. Only analysis is performed to find out the cause and if possible, to take action to avoid reoccurrence. Analytics of the large volume of data and further diagnosis/prediction needs domain expertise. In today's dynamic world, it is not possible to have the same level of domain expertise everywhere and every time. Doing so requires the underutilization of precious resources also and may become cost-prohibitive. However, with today's knowledge how it is possible to institutionalize the required expertise make it work for us continuously, and warn us whenever required. With the advent of Artificial Intelligence, it is also possible to predict the fault in a fair amount of reliability (though not 100%) in advance before it actually happens, appropriate action can be taken, and surprises can be avoided to a great extent. The expertise can work everywhere and every time with the same reliability and with little cost.

2. Key Performance Indicators (KPI) of a utility

The broad Key Performance Indicator (KPI) of a power plant are normally those parameters that affect the bottom line of the Company's financials. Once the plant is constructed, this will depend upon how efficiently we operate and maintain the plant. Hence Optimised operation and maintenance of the plant is the key to success. In subsequent paragraphs, some of the performance parameters which have direct relation to the above KPIs, have been quoted.

2.1 Outages of Stations

The outages are categorized in two different heads i.e., Planned outages and forced Outages. Statistics show that about 80% of the shutdowns are forced. A higher number of shutdowns means higher numbers of start-ups resulting in higher costs in terms of downtime, fuel oil consumption, coal consumption, manpower, etc. Further, each shutdown/start-up induces low cycle fatigue loading on the thick components like turbine casing, rotors, boiler headers, etc. resulting in higher life consumption and hence reducing the useful life of the plant.

2.2 Availability and Loss of Fixed Cost

Availability of the unit for power generation plays a vital role as far as return on Investment is concerned. The Plant should be available to produce power whenever demanded thereby ensuring reliable power supply. There are some mandatory shutdowns like renewal of boiler licenses, overhauling of the turbine, etc which cannot be avoided. In addition, failure of the equipment cannot be fully avoided. However, if we can have some sort of prediction of equipment behavior that may result in future failure, we can plan the maintenance activities in advance and avoid surprises.

2.3 Efficient Operation

Performance par excellence of the plant (optimum utilization of resources) is key to the success of the utility. This decides the bottom line of the company. Optimum Unit Heat Rate (UHR) and Auxiliary Power Consumption (APC) help in reducing the Variable cost of generation. Apart from the efficient and reliable operation of the plants two more focus areas have come up recently i.e., **Environmental aspects and flexible operation** of coal-based thermal power plants.

3. Analytical Method and Adoption

(The concepts and ideas used in data analytics)

3.1 A Virtual Power plant or Digital model[6,7]

Preparing a mathematical model or the Thermo-mechanical replica of the physical power plant in a digital platform, simulating the individual equipment customized for the specific unit for predicting the behavior of the equipment.

3.2 Artificial Intelligence (AI)

Artificial Intelligence shall be used for predictive Process control using concepts like state observer, fuzzy logic, etc. Shall also be used for fault diagnosis, predicting future behavior, etc.

3.3 Signal Filters

This is used to differentiate between the noises, sensor failures, and actual process faults.

3.4 Model-based Approach

A model-based approach can be used to identify the faults for well-defined processes with a limited number of variables (e.g., heat exchangers). Domain expertise is necessary for this approach.

3.5 Data Mining

Also known as Knowledge Discovery in Data (KDD) is the process of identifying valid, novel, potentially useful, and understandable patterns in data[10].

3.6 Time Series Analysis (Trend Recognition)

The technique is used to recognize any deviation from the pattern in the past and analyse the cause and warn of possible failure in the future before it actually happens.

3.7 Single Variate Analysis

Assumes individual variables without any dependency on other parameters and defines the variable. Used to check the variable within ranges or otherwise.

3.8 Multivariate Analysis

In this method, the interdependency of the data with multiple variables is exploited to analyze the process. For example, Output from equipment is dependent on the input to the equipment, etc.

3.9 Case-Based Reasoning (CBR)

This involves the collation of exemplars of past problems and the solution identified by the user from historical data and past experience. The focus is on indexing and retrieval of relevant precedents. The system is to be trained from the past information for proper working. The technique is generally used for fault diagnosis.

3.10 Clustering and Principal Component Analysis (PCA)

This method aims to discover the structure hidden within the data. Each data pattern is an attribute, and the objects are grouped that share a number of similar properties (or related data are clustered together). Once the structure is formed, the most important attributes (data pattern) can be identified. The principal components were initially determined to analyze the process before clustering was applied to distinguish distinct operating regions within the process. Then the correlation is established within the PCAs to define the process by means of attributes. This method is useful for process monitoring and sensor fault detection.

3.11 APR (Advance Pattern Recognition)

The parameters are monitored and compared with previous data. In case of any deviation, the pattern is monitored, and corrective action is taken even before it reaches the alarm/trip value, and the operator is warned. This will be used fully for Vibration, Bearing Temperature monitoring (Equipment health monitoring). The variations shall be analyzed, and RCA shall be done by Smart catch Analysis.

4. Data Analytics and its Use

To meet the objective, a comprehensive data analytic tool has been conceived for application with four modules (i.e. (i) Efficiency optimization, (ii) Plant Health monitoring and reporting, (iii) Optimization of life consumption, (iv) Environment protection). These modules will work in an integrated manner complementing each other and will share common databases and libraries. The Analytics tool shall have four distinct roles i.e., monitoring, optimizing, controlling, and reporting/advising.

Roles of Data Analytic System

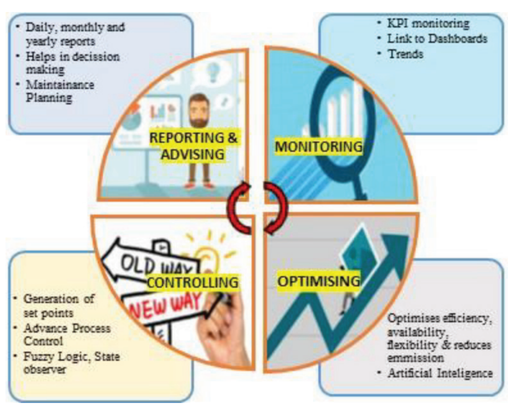

Figure 1. Roles of the data analytic system.

The concepts and principles described at 3 above are common for any data analytic system. These principles shall be used for all the above functional areas with corresponding domain knowledge to derive the maximum out of it. In the subsequent sections, the details of the above four modules are described with their operating philosophy. For a better understanding of the method of amalgamation of domain knowledge with the statistical/analytical methods one of the modules i.e., the efficiency optimization process is described in section efficiency optimizer module. Similar methods can be applied to all functional areas.

4.1 Efficiency Optimizer Module

The power plant is designed for a particular condition i.e., design point. Any deviation from this results in the off-design operation of the plant. However, it is not always possible to operate the plant at ideal conditions. Actual conditions vary from the design condition due to (i) Aging of the equipment (deposits, wear and tear, etc), (ii) Change in external factors like water/air temperature, coal quality, etc, (iii) Breakdown of some of the equipment's, (iv) Underperformance of some components, (v) Part load operation.

The higher the deviation from the design condition higher is the loss. The sensitivity of deviation is different for different parameters. E.g., the effect of condenser pressure on heat rate is much higher than Reheat spray. Hence it should be the endeavour of the control system/operating staff to minimise the deviation. The effect of these deviations depends upon many factors and varies from cycle to cycle depending upon the design.

The efficiency optimization system shall have four major optimisation processes namely

4.1.1 Turbine Cycle Optimization

To find out the best possible operating condition by simulating the plant model, find the actual parametric deviation from the model output, Control the parameters using state observers/fuzzy logic (APC), compare defined degradation with actual degradation (like aging, deposits, and erosions) and report.

4.1.2 Boiler Efficiency Optimization

To minimize the losses and thereby increase the efficiency. The boiler model shall obtain coal quality from online instruments and model the best possible combustion and subsequent heat transfer, and metal temperature distribution. Shall maintain the steam parameters with minimum metal temperature excursion and shall maintain optimum excess air by Combustion optimization. Monitor and minimize leakages and Exhaust gas losses, and report the degradation.

4.1.3 Cooling Tower Performance Optimization

This process will monitor the cooling tower performance to maintain the cold CW temperature with minimum fan power consumption. The performance of the cooling tower depends upon 3 major factors (spray water distribution, deposits/scaling in the fills, and fan performance). It shall monitor the performance and diagnose the problem if any and report.

4.1.4 Auxiliary Power Consumption

The system shall minimize the Auxiliary power consumption depending upon the plant operating condition. The main cause of high APC is the running of auxiliaries when not required, Inefficient operation of the process like throttling, and degradation/aging of the equipment like pumps and fans. The system will suggest single stream/auxiliary operation depending upon the operating condition, monitor the process losses and equipment efficiency/performance, degradation of equipment/system, Diagnosis of the cause, and suggest corrective action.

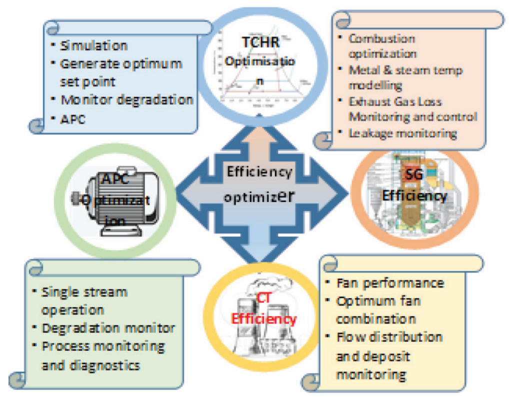

Figure 2. Functional chart for efficiency optimizer.

The plant is being operated/controlled very well by the present DCS. The function of the data analytic system is to assist DCS in achieving the specified objectives. The system shall be based on a digital replica concept at the core. Simulations can be done on the replica to predict the performance and also to find out the best operating point. It will have different libraries for data storage and shall have direct two-way communication with DCS. These libraries are common for all the data Analytic processes.

4.1.5 Design Library

Shall contain all the design information of the systems and equipment such as characteristic curves, thermodynamic information (HBDs), system fluid parameters, part load operating behavior, etc. Different types of equipment have different aging rates with operating hours. Rotating equipment like turbines/pumps/fans age faster than stationary equipment like heaters. Normal aging behavior of the equipment is also part of this library. In short, the design library is fully equipped with all the design information of the plant and equipment.

4.1.6 Influence of External Factors

There are many factors that are external to the plant and cannot be controlled either by the control system or by the O and M staff. For example, Wet Bulb Temperature (WBT)/ Coal characteristic, wind speed for ACCs/Cooling towers, etc. These factors have a direct impact on the performance of the plant. The model needs to take these factors into consideration and make a correction to the design values.

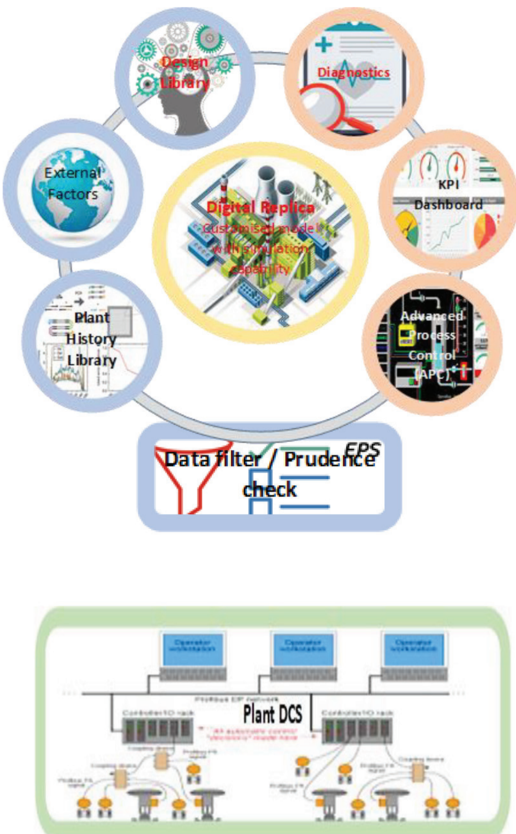

Figure 3. Typical architecture of an analytic system.

4.1.7 Plant History Library

This is a warehouse of the plant storing all operating history. The data will be stored in an organized manner and shall be used for data mining. The library shall also be used for training of AI systems and for Principal Component Analysis. For Case Based Regression analysis the data history shall be used.

4.1.8 Data/Signal Filter

For running any diagnosis or optimization process accurate and reliable measurement is of paramount importance. It is necessary to differentiate an actual fault and a faulty measurement. There are many methods to check the faulty signals and noises like redundant measurements, single-variate techniques, multivariate techniques like PCA, and the use of domain expertise. The process parameters are always dependent on other related parameters. For example, condenser pressure is very closely related to the condensate hot well temperature. If any one of the signals goes bad, it can always be cross-checked with other signals having a correlation with trend analysis of earlier saved data in the history library. The function of the data filter is to distinguish between the actual fault and the sensor fault and replace the faulty signal with calculated values for optimization.

4.1.9 Digital Modelling

The model shall consist of a digital replica of all individual equipment customized for each unit in question. Individual replicas shall be assembled together to form the virtual power plant. The digital replica shall utilize the design data from the database. Make corrections based on deviations on external factors like Cooling water temperature, ambient air temperature/humidity, and Coal quality. Based on plant operating conditions like load, availability of auxiliaries, and the plant age, determine the best possible alternative and find out the optimum parameters. Accordingly, shall generate a set point for controllable parameters. The generated set point shall be compared with actual parameters and aberration analysis shall be carried out to find out the cause of deviation. Then the deviation shall be eliminated if possible otherwise, it will be reported along with the corresponding loss. All the simulations can be done on the virtual power plant with prediction of the behaviour and warnings shall be reported.

4.1.10 Diagnostics

The function of the diagnostic module is to find the probable cause of fault by running diagnostics methods like CBR and domain expertise. By doing heat balance and simulation of equipment replica, the module shall find out the measurement errors, equipment deterioration like deposits/erosions, Turbine efficiency deterioration, seal damage/rubbing, fan/pump performances, etc.

The findings shall be used for reporting and calculating the corresponding losses.

4.1.11 Advanced Process Control (APC)

Present DCS maintains the controllable parameters based on set points. It works in the principle of deviation from the set point and generates the command for the drive through a PID logic block. The proposed APC will have a predictive control with a high-level observer which takes care of other changes in the process which may also affect the parameter in question. Instead of PID control AI based fuzzy logic shall be applied to minimize the time to equilibrium with minimum overshoot.

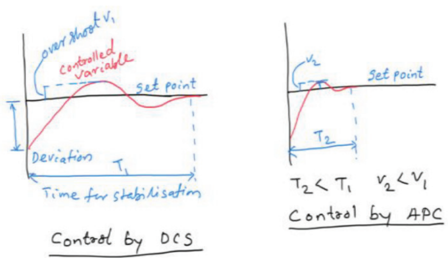

Figure 4. Stabilisation period for DCS vs APC.

4.1.12 Dashboard

This module is a reporting tool for selective information. The dashboards can be customized for different management positions. Important information from the reports shall be available on customizable dashboards on mobile devices through apps. The dashboard can be interactive with a direct interface with the server with a firewall for security. Digital twins of all critical equipment can be assessed over intranet/on clouds for remote monitoring and analysis with the trend of the parameters wherever demanded.

4.2 Equipment Health Monitor to Improve Reliability

The Equipment health monitoring module shall be the proactive medical officer of the plant who is omnipresent. It will act as an untiring watchman keeping 24x7 vigil of the whole plant. The present DCS has a warning/alarming function but only when the parameters exceed the defined limits. Most of the time either it is too late to save the unit or permanent damage has taken place to the equipment resulting in forced shutdown. Catastrophic failure never happens without prior indications/signals. These signals are to be picked up at the appropriate time and corrective actions need to be taken. Sometimes the operating staff are able to notice these indications and most of the time it goes unnoticed. It depends upon the level of vigilance and expertise of the O and M staff. For picking up these signals high level of domain expertise is required. Given the dynamism of the industry, the same level of expertise cannot be made available everywhere and always. Practically it may not be possible to detect these signals manually. The omnipresent doctor equipped with all expertise will diagnose the fault and predict the problem before it actually happens based on the past history and prescribe remedial action. The module will use the same set of libraries as in the case of the efficiency optimization module for design data and operating history.

Depending upon the characteristics, the equipment shall be grouped into different categories for monitoring purposes. i.e., the turbine, Boiler, Other rotating equipment, and Heat exchangers. For all this equipment a digital replica shall be made for diagnosis and simulation of condition. For all this equipment there will be a safety algorithm that will take care of the safety of all the components of the plant.

4.2.1 Turbine Health Monitor

Turbo Supervisory Instruments (TSI) monitors and stores the vital parameters like vibration, Bearing temperature, differential expansion, eccentricity, etc. of the turbine. Similarly, the Turbine Stress Evaluator (TSE) monitors the stress level in the turbine components. The turbine health monitor shall integrate the TSI, TSE, and the blade vibration monitoring system. The parameters will be compared with design values and past values with similar operating conditions by time series analysis. Relationship with other operating conditions shall be established for diagnosis of the cause. By the use of Trend analysis and simulation of digital replica future behaviour shall be predicted and warnings/advice shall be generated before the actual condition is arrived so that advance planning can be done.

4.2.2 Boiler Health Monitor

It will have a complete thermal model of the boiler. The heat transfer of various sections will be monitored and compared with the model to find out the deviation and possible causes. The tube metal temperature of various sections of the boiler shall be compared with the predicted temperature from the model. The model will pinpoint the vulnerable area of future Boiler Tube Leakage (BTL) based on the metal temperature and heat transfer model. Corrective signals to APC to control temperature excursion. Boiler erosion patterns shall also be predicted by the model. Based on actual and predicted heat transfer, the model will estimate the shoot deposit patterns and optimize the shoot-blowing requirement. It will advise the mill combinations for optimum heat transfer and maintaining MS and HRH temperatures.

4.2.3 Rotating Equipment's Health Monitor

The reliability of this equipment is very vital for the plant's operation. These equipment are more vulnerable to failure due to their inherent nature of operation. Fortunately, it is easy to predict their characteristic as a lot of information is available. Their behavior will be monitored from three aspects i.e., vibrations (rotor/bearing), Temperature, and inlet/outlet operating fluid parameters. The parameters will be compared with design values and past values with similar operating conditions by time series analysis. Relationship with other operating conditions shall be established for diagnosis of the cause. Using Trend analysis and simulation of digital replica future behavior can be predicted.

4.2.4 Heat Exchanger Health Monitoring

The most common cause of heat exchanger performance deterioration is fouling/deposits thereby obstructing the heat transfer. Other causes of failure could be leakages and puncture of the heat transfer elements. Heat transfer models of these equipment shall be prepared along with predicted performance at different operating conditions. Actual heat transfer shall be compared with the model output to find out the deviations and possible causes including the fouling/deposits. From inlet and outlet parameters the leakages can also be predicted.

4.2.5 Safety

The safety module shall take care of the operational hazards of the plant. It will focus more on equipment safety and shall prevent unsafe operation of the plant, thereby ensuring personnel safety working around the equipment. The system shall make use of Artificial Intelligence and machine learning techniques to learn from past incidents. The combination of process parameters leading to past accidents will be analyzed and the results shall be used for diagnosis of cause. The module will point out the failure of any instrument which may lead to safety hazards. It will predict future safety hazards if any due to departure from normal conditions.

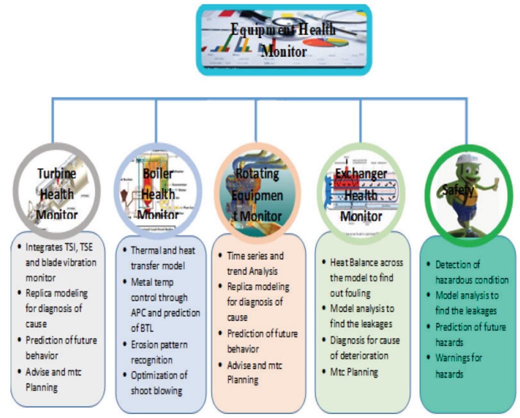

Figure 5. Functional chart for Plant health monitoring system.

4.3 Optimization of Life Consumption

The life of any machine/equipment is limited though it has been designed with adequate factor of safety. Two factors decide the life consumption of components namely Creep loading (predominant for high-temperature components) and fatigue (components subjected to cyclic loading). Net life consumption is the summation of creep life and fatigue life consumption due to the interaction of these two phenomena. During start-up and transients fatigue loading is developed due to thermal stress resulting from temperature differences. The higher the thickness of the component higher is the thermal stress and so also the higher fatigue life consumption. Hence life of thicker components becomes critical during start-up and transients. With the addition of renewable energy in the grid, which is variable in nature, it is expected that the thermal units bridge the gap between demand and generation from renewables. This requires flexible operation of the thermal units, more shutdowns and start-up, part load operation, and higher transients. With this operating regime, the life consumption of thicker components will be accelerated, and the remaining life expectancy shall be reduced. The function of this module shall be to minimize the life consumption while maintaining the flexibility of the unit. The goal is to minimize the fluctuations and also to know exactly where each component is in its life cycle and report/advise the details to the operating staff. The module will have following features.

4.3.1 Thermal Stress Optimizer and Life Consumption Calculator

All the thick components like turbine rotors, casings, valves, boiler drums, and headers shall be monitored for life consumption. The program will be dynamic and shall have elaborate measurements. It will keep records of all creep and fatigue loadings of each of these components and calculate the margins available online. It will make use of the design and plant history library to calculate the life consumption and remaining life by statistical methods like regression. The life consumption of each thick component shall be calculated and displayed dynamically to guide the operator for operation. It will also provide signals to APC and URO for corrections.

4.3.2 Advanced Process Control (APC)

The function of APC is to minimize the fluctuation during transients and load changes/ramp up/ramp down. It will utilize the predictive control technique to achieve equilibrium quickly with minimum fluctuation. With the help of AI methods and fuzzy logic, the stabilization period shall be reduced thereby reducing the thermal stresses.

4.3.3 URO (Unit Ramp Rate Optimiser)

The function of URO is to provide an optimum ramp up and ramp down of the unit during start-up and load change depending upon the actual state of different equipment. It will find out the critical/limiting auxiliary and optimize the system with the help of a life consumption calculator. The best possible ramp rate shall be calculated based on the given condition of the plant and implemented. It will take a history of ramping up/down to find out the inertia of the unit to find the suitable ramping capability.

4.3.4 Minimum Load Optimizer

The function of a minimum load optimizer is to provide stability during part load operation and guide the operator in this regard. It will have close coordination with the combustion optimizer to find out the stability of the furnace to predict the minimum possible stable load and the precautions to be taken by the operator. While predicting the minimum possible stable load, it will take the past history into consideration and the disturbances created (if any).

4.3.5 Auxiliary Scheduler

The function of this system is the automatic start/stop of the auxiliaries depending upon the requirement of the unit load demand. This will be specifically helpful for auxiliaries needing frequent start-stop like coal mills. It will find out the optimum time to start or stop the unit depending upon the past history and capability of the respective auxiliary. This will help the unit ever ready for any change. The operating staff will get somehow relieved for more important things.

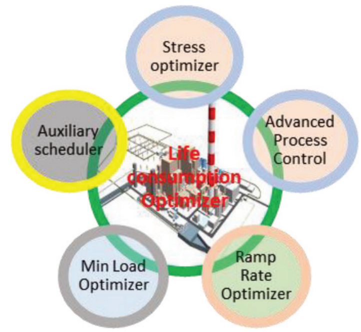

Figure 6. Functional chart for optimization of life consumption.

4.4 Environmental Protection

The function of this module is to minimize environmental impact during all operating regimes of the plant. Based on coal analysis data the level of neutralization required in FGD shall be calculated to maintain the emission level. It will interact with the combustion optimization module to minimize NOx formation. Online measurement of emission levels shall help in controlling the SOx, NOx, and particulate matter. It will provide input to the ESP control system for control of the fields depending upon the requirement. Water consumption optimization shall also be part of this module. Dynamic water balancing shall be carried out by the system and any possible leakages shall be detected and warned. The module shall have the following functions.

4.4.1 Optimisation of ESP Control

Based on actual particulate emissions, the ESP control shall be modulated to reduce the emission level with minimum power consumption. Based on the collection efficiency of individual fields the rapping mechanism operation shall be initiated instead of the regular interval operation prescribed now. The operation shall be requirement-based rather than time interval-based. The ESP fields can also be switched off or on depending upon the requirement. ESP hopper evacuation system shall be monitored based on actual ash collection and predicted future loading in the hopper.

4.4.2 *Optimisation of FGD Control*

Production of SOx is a direct function of sulfur content in coal. Higher the sulphur content concentration of SOx in the flue gas will be higher and hence higher reagent reaction shall be required to contain the SOx emission level. The function of this module will be to optimize the FGD control to reduce Auxiliary power, reduce reagent consumption while keeping the emission level under control.

4.4.3 *Combustion Optimization for Minimising NOx*

The generation of NOx in the furnace all depends upon the combustion process, though it cannot be eliminated fully. As far as possible it should be minimised by modifying the combustion process. The remaining NOx can be removed by a reduction process (if required). It is now being debated if the sustainable operation of Selective Catalytic Reduction is possible for Indian high ash coal to meet the stringent emission norms. However, reduction of NOx generation is a must by suitable combustion modification. Excess air in the combustion, Admission of Over Fire Air, Separated Over Fire Air for delayed combustion, etc are some of the methods to control/reduce NOx emission. This module will work in coordination with the combustion optimizer to minimize the NOx level.

4.4.4 *Water Consumption Optimisation*

Thermal Power plants are a very high-water consuming industry. Present norm for thermal power generation is to restrict water consumption to 3 M^3/hr per MW of electricity generation. In earlier days the norms were somewhat relaxed as at that time the scarcity of water was not so predominant. Accordingly, the plants were designed with very high water consumption. However, with very little effort it can be reduced. A most common cause of wastage is leakages. By online water balancing and keeping the design/past consumption history the module will find out the wastage if any in the system and warnings shall be issued. With consumption pattern and trend analysis, the cause of high water consumption shall be diagnosed, and corrective action shall be notified.

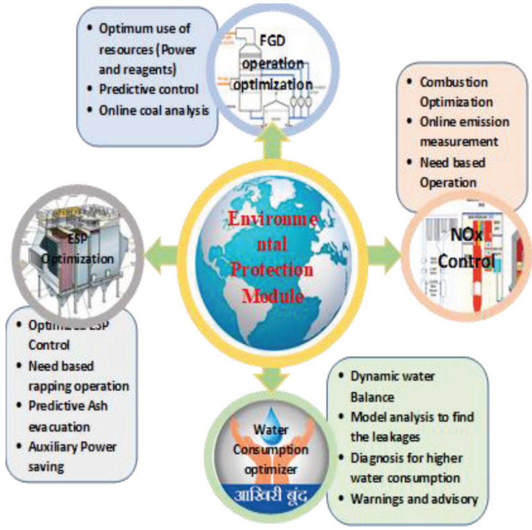

Figure 7. Functional chart for Environmental protection.

5. Conclusion

For a sustainable business model, optimum operation of the plant with respect to efficiency, reliability, flexibility with minimum impact on the environment is to be ensured. Data Analytics can be used as an optimizing tool for improving the power plant performance. Concepts like Artificial Intelligence and advanced statistical data analytics are in use for industrial applications including power plants. A Comprehensive tool for customized requirements can be developed using these techniques. The following architecture can be used as a reference for the system.

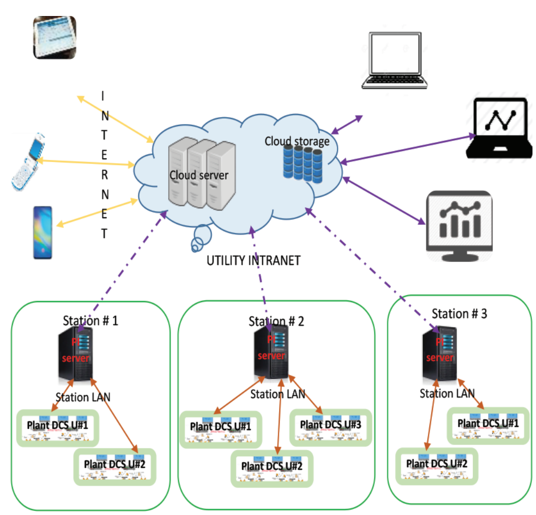

Figure 8. Cloud network configuration.

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