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Optimization and Design Analysis of Steam Turbine Operation and Maintainence : A Review

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ABSTRACT

In India, coal is the dominant sources of energy generation. The need and conservation of energy is important. At present 60-62% of total power production in our country is accomplished by coal fired thermal power plant. In power plant, the power is produced by converting the chemical energy of coal into electrical energy by the generator. Due to the increased steam leakages and damage to turbine components (Blade Failures) resulting in the loss of turbine efficiency. Basically the thermal power plant works on improved or modified Rankine cycle to run the plant in highest possible efficiency. Based on heat rate values, to improve the turbine efficiency and overall efficiency by determine the optimization techniques of taguchi's experimental design method, orthogonal arrays of taguchi, regression analysis, signal to noise (S/N) ratio and are employed to find the optimal process parameter levels and also to analysis the effect of that parameters. A present effect of individual parameters on performance is estimated by using ANOVA. By using ANSYS software the turbine blades stress distribution, deflection, static and fatigue are to be analyzed. By using this techniques, within the available sources the maximum efficiency of the turbine are to be acquired.

Keywords : Steam Turbine, Optimization, Taguchi Method, Stress Analysis, ANOVA

I. INTRODUCTION

In thermal power plant, the conversion from coal to electricity is achieved by raising the steam in the boilers, expanding it through the turbine and coupling the turbine to the generators which converts the mechanical energy into the electrical energy. The living standards and property of nation is very directly associated with increase in use of power. In our country the natural resources are found in coal, lignite, oil, hydro-resources and nuclear fuels. It's found that these resources are located in an uneven form in the country and to overcome this difficulty it is necessary to developed thermal power plant in the country, which contributes about 60% of the power production in the country. The primary fuel adopted in the plant is coal. In the thermal power plant steam produced out of de mineralized water and is used as a working fluid. In the process of thermal power plant, initially energy in the fuel produces a high temperature in the boiler. In the turbine, heat energy is converted into work. The work output of the turbine is converted into electrical energy by the generator. The interior of a turbine comprises of several sets of blades. The turbine blades were important components, which converts the high pressure of linear motion and into a rotary motion of high temperature steam of a turbine shaft. In this project, our main objective is to find the minimal loss which affects the performance of the turbine and in turn decrease the power production in 210MW LMW steam turbine and also to find the root cause of blades failures. This project discusses about, how to overcome this difficulties to improve the efficiency of the turbine and to implement the resultant forces and also analyse the blade failure by using a computer-based numerical technique, Finite Element Analysis (FEA) to calculate the strength and behaviour of the steam turbine blade. By using the optimizing techniques of Taguchi's experimental design method the optimum heat rate values are founded. By using this methodology's the enhancing performance efficiency of the steam turbine are to be obtained.

II. LITERATURE REVIEW

Umesh Kumar et al. discussed about the optimization of organic Rankine cycle for recovering low grade industrial waste heat by taguchi's robust design method. The parameters selected are waste steam flow rate, selected waste steam temperature, turbine speed and type of refrigent. Individual effect of parameters were obtained By using taguchi's optimum combinations of organic Rankine cycle was determined. By using Analysis Of Variance (ANOVA) a precent effect of individual parameters on performance is estimated. By the available resources an optimal cycle can be obtained for maximum efficiency. By using this approach identifying the importance of each parameter and also used in assigning effort as the experiments to be performed for cycle for optimization. By using orthogonal array for different condition of operating parameters are designed.

Sanjeev Sharma et al. described about the enhancement of steam turbine efficiency in coal fired thermal power plant. For determining different performance parameters of the turbine section the data's are collected from the power plant and then analyse are madden. Increased steam leakage and damage to turbine components are the major factors resulting in lost efficiency. The efficiency losses in turbine are mainly due to the steam leakage. An increased Mean-Time-Between-Overhaul (MTBO) demands new methods for sustaining high efficiency levels over longer periods of operation. By the recent developments of cutting-edge technologies sustained high efficiency has become practical goal for turbine operation and maintenance. By the use of improved blade profile that are significant changes in percentage heat rate of turbine and savings from up gradation of High Pressure (HP) turbine.

Naoto SAKAI et al. carried out an experiment with an application of computational fluid dynamic (CFD) to partial admission stage in a steam turbine. The requirement of the calculation of partial admission stage are unsteady analysis and full circle modelling. By using Quasi-3-Dimensional (Q-3D) analysis the main radius is conducted to reduce computational load and also the stage analysis is validated. By using the method (Q-3D) analysis the circumferential position arc is found to change wind age and turbine efficiency.

Xin Yuan et al. developed turbine blade design for three-dimensional non-axis symmetric geometry with an optimization method including end wall contouring control. The evaluation of design optimization method consists of algorithm module and 3-dimensional parametric modelling module for blades and end walls. By using a NURBS technology the two-dimensional blade profile parametrization has been carried out and for 3-dimensional blade surface is constructed by NURBS skinning technology. The most applicable optimizing methodology from a single turbine stage to two turbine stage with rotor blade tip leakage and stator hub leakage. By considering this leakages, the result of well-designed high pressure steam turbine stage efficiency has been enhanced by 0.21%.All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

Carlo carcasci et al. analyzed effect of a real steam turbine of combined cycle power plant by thermo economically. Due to the growing restrictions for greenhouse emissions and also depletion of fossil fuels that leads to the reprocess of the waste heat generation. For that Combined Cycle Gas Turbine (CCGT) provides a strong technology to obtain an effective performance. The Energy System Modular Solver (ESMS) modular code is used for the modelling the entire bottemer cycle. For the best thermo economic confriguation a two pressure level combined cycle is optimized and examined. The most essential feature of this modular simulation code is the capability to simulate a different power plant configuration without generating an additional sources program. By using these technologies the steam turbine costs are analyzed and also compared with the industrial tool. By analyzing the performance the bottemer steam cycle, the steam turbine and of the heat recovery boiler operating parameters are imposed.

Luc G. Frechette et al. developed the system level and component design of a micro-steam turbine power plant- on-a-chip which implements the rankine cycle for micro power generation. The steam turbine with micro fabricated has an integrated micro-pump, generator and also two-phase flow heat exchanges to form a complete micro heat engine unit. By using the micro electro mechanical system (MEMS) technology to the creation of power systems at an unprecedented small scale. By this technologies the possibility of high power density micro systems upto 12KW/kg with efficiency level of 1-11% based on various applications. By this development, the micro- rankine device could allow light weight and compact power source for portable application from waste heat (or) solar radiation.

P. Vaishaly et al. studied and analyzed a stress in a typical steam turbine blade by using Finite Element Method (FEA). Due to the high centrifugal and aerodynamic loading the Low pressure turbine is very critical from strength and rigidity. In order to avoid the blade failures and cracking it is required to evaluate the stress in these highly twisted blades. By using a customized software the stacking 2D profile sections including blade root attachments are created by using this profile data the 3D blades for the last stage of a typical steam turbine is generated. By using the generated model are meshed in ANSYS software and on the blade surface pressure distribution is mapped. The dynamic behavior of the blade are understand by generating Steady state stress analysis.

D.Ziegler et al. investigated the failure of steam turbine blades. The most of the blade failures are due to the fatigue, stress corrosion cracking and corrosion fatigue. By a standard wet method the chemical analysis of a blade material was carried out and also by using metallographic technique the metallographic samples are prepared. The micro structure of the blade material was analyzed using an optical microscope and JEOL JSM -35 Scanning Electron Microscope (SCM) equipped with an energy dispersive X-RAY (EDX) analysis facility the formation of pits, residual stresses are created rise to the initiation of intergranular micro –cracks types. Based on that investigation the presence of pits found on the tail of the blade profile was caused by the corrosive atmosphere, mainly sodium and chloride salts. The speed at which the pits grow depends on the concentration of these compounds and the exposure time in this atmosphere.

Loveleen Kumar Bhagi et al. discussed and investigated about the failure of L-1 pressure steam turbine blade fractographically. The investigation includes SEM fractography, visual examinations, chemical analysis, hardness measurements, and micro-structural characterization. From the visual examination it is designed that the blade was corroded by pitting mechanism. The chemical composition is determined by using Optimal Emission Analyzer Spectrometer model DV4. To determine the origin of fracture the fractography evaluation was carried out on the fracture surface of blade root using JEOL JSM-6610LV scanning electron microscope (SEM) equipped with energy dispersive spectroscopy (EDS) facility. Due to the formation of oxides of silicate and sodium on the fractured surface that leads to the corrosion pits and also for the corrosion attack.

Kiyoshi Segawa et al. developed a steam turbines blunt-nose rotating blade using Taguchi method. For the designing of blade Taguchi method was carried out, combined with the 2-Dimensional turbulent flow analysis and the inverse method. The blade configuration is expressed by four control factors which are turning angle, leading edge radius, pitch-chord ratio and maximum blade loading location. The verification tests are carried by the linear cascade experiments and 3-Dimensional analysis. Compared with the conventional one, the blade has a blunt-nose, flat incidence characteristics and low energy loss. As a result it is found that the optimal condition given by Taguchi method is aerodynamically reasonable.

Md. Abdul Raheem Junaidi et al. designed and analyzed the optimization of the steam turbine rotor Grooves. The investigations of the steam turbine rotor grooves is to reduce fillet stress concentration factor and its associated deformation. For the effective modification of the blade rotor grooves finite element analysis is performed using ANASYS work bench that is used to determine the fillet stresses. As a result of high rotational speed partly due to high pressure temperature and speed steam loading they suffer from tensile stresses due to the centrifugal force. The base line model and the modified root model were subjected to centrifugal force and resulting to the centrifugal stresses were analyzed has been carried out in ANASYS work bench. Thus as a result is to make the rotor blade of variable cross section instead of straight.

Ernst plesiutsching et al. analyzed the fracture of low pressure steam turbine, blade. At different natural frequency, the cracks were analyzed at the root of low pressure steam turbine blades. For identification of root cause of the metallographic failure investigations, fractured machines analysis and finite element analysis (FEA) combined with experimental data were used to evaluate stresses of cracks propagation. Natural frequencies Excitation by changing the rotor speed was not responsible for crack propagation. Unsteady steam forces caused the superimposed bending load and the centrifugal load was responsible for the crack propagation. For the evaluation of stresses the linear elastic fracture mechanics (LEFM) and FEA are typically used. By using this analysis the frequencies of their inspection intervals to the number of fluid flux variation in order to prevent failure.

Madddalena pondini et al. studied on the models of control valve and actuation systems of steam turbine based on dynamic analysis. For the dynamic analysis of the whole system the accurate modeling of the final power production and rotational speed devices are fundamental. The model were dynamically analyzed, for that the models are developed by using Mat lab/Simulink system as well as the failure modes. For the validation of the model the tests were conducted on the actuation system at co-generation plant. For the continuous performance improvement the Model Predictive Control (MPC) and Artificial Intelligence (AI) enables a completely new approach to face the challenge. The control of a steam turbine (ST) is directly related to its control valve system and to the deployed actuation technology.

Dennis Jarmowski et al. investigated the steam turbine flexible operation and also advanced lifetime calculation procedures. Steam Turbine (ST) protection systems onsite often are not designed for such flexible operation and therefore do not properly supervise the resulting impact on lifetime consumption, for that precise lifetime management concepts are required to increase plant reliability and flexibility. A standardized process for the calculation of creep and fatigue damage is evaluated by lifetime assessment (LTA). By the use of FEM the rotor and the boundary conditions are applied during transient operations. For more flexible operations the lifetime management is supported by improved lifetime calculation and more methods that also take into the account the additional transient events. To effectively enhance the accuracy of lifetime calculations the CFAT2 method provides the high potential and also it will be useful for the real-time investigation of the lifetime of a component.

Bernd M. schonbauer et al. investigated under cyclic loading in 12% Cr steam turbine blade steel of pit –to-crack transition. Pre-pitted and smooth specimen were tested in air and aerated in 6ppm cl-solution. Fatigue tests at different stress ratios were performed using ultra sonic fatigue testing technique. Crack initiation at a corrosion pit was observed using high-resolution scanning electrons microscopy and Fatigue Crack Growth Rate (FCGR) and stress intensity factor range were determined. .S-N test results on pre-pitted specimens at different stress ratio and in different environment were compared with result on smooth specimen which was extended by tests at fully reversed loadings. For the different fracture modes fractographic investigations are utilized.

Llias Bosdas et al. studied and developed the wet steam flow field unsteady measurements in the last stage of low pressure steam turbine. Under varying operating conditions the steam turbine need to operate effectively and safely with varies mass flow volumetric conditions. By the use of newly developed fast response probe equipped with a heated tip to operate in a wet steam flows are effectively controlled and utilized. Due to the onset of the ventilation process near at the exit of the Low Pressure (LP) steam turbine the reduced mass flow operating conditions exhibits the largest aerodynamic losses near the tip. At low volumetric flow conditions the blade will be subjected to higher dynamic load flucations at the tip region. For the wet steam flow conditions a unique high temperature fast response probe are developed and effectively tested. By this analysis of measurements the evolution of the secondary flow structures responsible for the unsteady aerodynamic loading of the blades.

III. CONCLUSION

The techniques of the Taguchi's method for investigating the effects of process rate and efficiency of the steam turbine are to be observed. By using the conceptual Signal to Noise (S/N) ratio approach, orthogonal method of taguchi, regression analysis the results in the process parameters are very much useful for the industrial requirements. The efficiency of the turbine increases with temperature, pressure, quantity of steam flow, in the operation of thermal power plant. By using this type of techniques and methodology's the steam turbine efficiency has been enhanced and implemented. Furthermore, the turbine blade failures are to be analyzed and the root causes of the failures are acquired. By using the customized software's the turbine blades are modelled. Finite element stress and modal analysis was carried out for the moving blades of a low pressure steam turbine using customized software, dedicated for analysis of steam turbine blades. Steady state stress analysis of the blade was carried out by applying the aerodynamic loading and centrifugal loading. Stress categorization at the critical location of the blade root is carried out to find out the membrane and membrane + bending stress at those locations.

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