COMPARATIVE ANALYSIS OF STEAM TURBINE PERFORMANCE

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ABSTRACT

The analysis of performance of the steam turbine has been carried out and the heat rate is calculated to find out the deviation between the design and the trend in the present operation condition so that the losses can be reduced in order to obtain better efficiency. Here we have calculated Gross Heat rate and Turbine cycle rate and also considered the losses in high energy drains. This analysis helped in predicting the turbine efficiency deterioration level and listed out the preliminary cause of deterioration.

Keywords — Heat rate, turbine performance, efficiency, Steam turbine, deterioration level

INTRODUCTION

Steam turbine is the heart which plays a vital role in the power generation as it converts kinetic energy into mechanical energy. The efficiency is determined by the ability to convert all the input work into output work. However, in real case scenario this condition is not possible as most of the parts have friction and the work is dissipated in form of heat thereby producing only less than 50 percentage of the work it received as input energy. In this analysis, we have discussed how to overcome this efficiency gap and produce the maximum possible efficiency of the turbine. Here we have collected several working parameters and the actual efficiency of the turbine was calculated. By these calculations, we have characterised and suggested the improvement techniques to be opted to improve the efficiency of the turbine.

Steam turbine design is based on some characteristic features such as inlet pressure and temperature, flow rate, outlet pressure etc. and turbine geometry, dimensions and performance are defined with this characteristic features. Turbine loses and irreversibilities are minimum and performance and power generation are maximum at design conditions. However, a steam turbine does not always operate at design conditions because of changing of power demand and turbine loses and this means that it always operates lower efficiency. Estimating and defining of characteristics of steam turbines at off-design conditions have been studied since 1900 and today the studies are going on more different variables and modern tools.

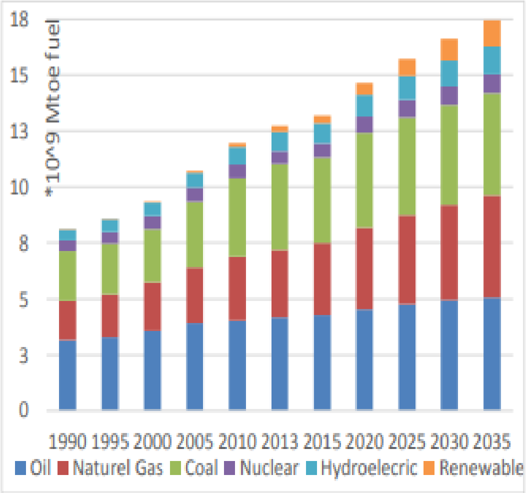

Figure: Produced power by plant (1 Mtoe = 11630 GWh)

Steam turbine is a heat engine that converts heat energy of the high temperature and pressure steam to kinetic energy and then kinetic to mechanical energy in two stages and/or electrical energy with alternators. The maximum efficiency conditions, which the specific heat for each produced power is minimum, are also corresponding the most economical condition is called turbine operating conditions or turbine design conditions. Therefore, the maximum thermal efficiency conditions have to take into account while steam turbines design. In order to increase the efficiency, steam turbine capacities have to determine wide range of values between full load and zero load conditions. Turbines are designed and manufactured taking into consideration some special conditions. Turbine blade profile and the geometric dimensions of each section are designed to take into consideration some parameters. Such as, turbine inlet and outlet parameters (pressure and temperature), specific steam flow rates, the current enthalpy drops, specific condenser pressure, specific extraction steam rates and the grid frequency are determined for specific conditions. In addition, the rotor diameter, height of the first and last blades, the number of stages and the thermodynamic cycle of system are also used to determine the design conditions.

Literature Review

Sinan Karakurt (2015) Power consumption highly increases which is related with the growing of the industrial plants and daily using. Increasing power demand can be supplied with building up more efficient plants or optimized old power plants. One of the most important items of a power plant is steam turbine which is designed according to defined parameters (inlet pressure and temperature, flow rates, outlet pressure and power) which also effect the dimensions and performance of the turbine. Turbine loses and irreversibilities are minimum and so efficiencies and power generation are maximum at design conditions. However, power plants always have to operate at off-design or part-load conditions because of the changing of power demands and drop outs of the turbines and other items of the plants. In this study, it is aimed to analyses the isentropic efficiency of a high pressure steam turbine and thermal efficiency of power plant at different load conditions. Analyses showed that both steam turbines and power plant performance were reduced when the power plant operates at partial load conditions.

Nikolay Rogalev et al (2021) Thermal power plants (TPPs) with back-pressure steam turbines (BPSTs) were widely used for electricity and steam production in the Union of Soviet Socialist Republics (USSR) due to their high efficiency. The collapse of the USSR in 1991 led to a decrease in industrial production, as a result of which, steam production in Russia was reduced and BPSTs were left without load. To resume the operation of TPPs with BPSTs, it is necessary to modernize the existing power units. This paper presents the results of the thermodynamic analysis of different methods of modernization of TPPs with BPSTs: the superstructure of the steam low-pressure turbine (LPT) and the superstructure of the power unit operating on low-boiling-point fluid. The influence of ambient temperature on the developed cycles' efficiency was evaluated. It was found that the usage of low-boiling-point fluid is thermodynamically efficient for an ambient temperature lower than 7 ◦C. Moreover, recommendations for the choice of reconstruction method were formulated based on technical assessments.

Turbine Steam Path Evaluation

The interpretation of the results of performance monitoring activities can be used to identify turbine internal problems causing a deterioration in performance, and assist in planning maintenance required to address the problems. However, to restore performance during a turbine maintenance outage, the turbine components contributing to the performance loss need to be identified. This can best be done by conducting a turbine steam path evaluation.

A steam path evaluation should include a detailed visual inspection of the steam path components and clearance measurements of the packings; and tip spill strips. The visual inspection should evaluate and quantify the performance impact of degradation effects such as erosion, deposits, damage, peening, etc. Clearance measurements at multiple circumferential positions of the diaphragm packings, tip radial spill strips, and end shaft packings should be used to quantify the effect of increased clearances. With this information, decisions can be made based on the economics associated with the repair and replacement of turbine components, and the priority of necessary repair work.

The steam path evaluation should categorize the identified stage performance losses into six components: excess diaphragm packing leakage loss, excess radial tip spill strip leakage loss, nozzle recoverable and unrecoverable losses, and bucket recoverable and unrecoverable losses. Recoverable losses are defined as those that can be recovered by cleaning, dressing, repair of the components, or replacement of clearance controls. The unrecoverable loss is that part of the performance loss that can only be recovered by replacement with new components, such as new diaphragms or buckets.

Part Load Conditions

Partial load conditions may occur energy demand variations, plant maintenances and repair so it is important to control steam flow. Partial load control can be arranged with two ways. The first is throttling governing which controls the system by changing turbine inlet pressure. If steam pressure decreases the steam flow rate and temperature are also decrease so in this system loses will be much more. The second system is nozzle governing which changes the flow rate at constant turbine inlet pressure and temperature. The second control method is much more efficient and so more common.

RESULTS AND DISCUSSION

Performance calculations at partial loads have done with guaranteed pressure, temperature and flow rates values for 100%, 80% and 60% loads which were obtained from the plant manufacturer.

Design inlet pressure of high pressure turbine does not change while the load is changing but extraction and outlet pressures of back pressure, extraction and condensing turbines vary in proportion with the load. Therefore, this will reduce the turbine and plant efficiencies. Temperature and pressure variations at a HP turbine stages for different loads are shown in below Figure.

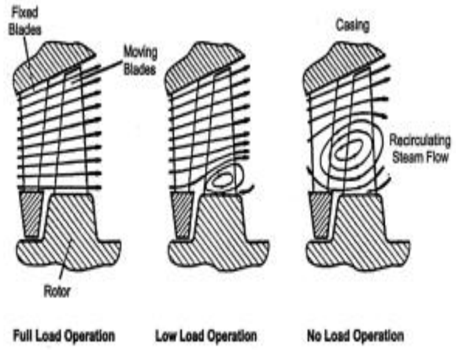

Figure: Partial load conditions at turbine blade

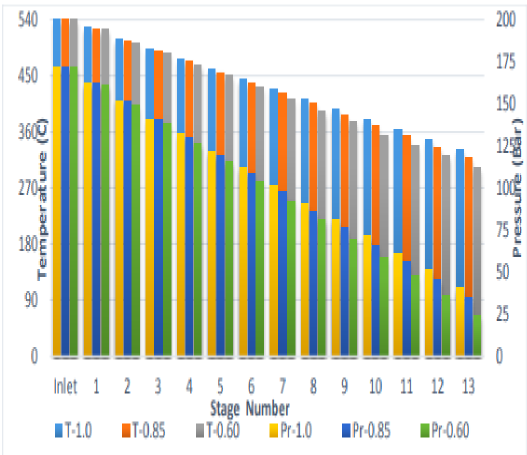

Figure: Temperature & Pressure variations in turbine stages at partial loads

Specific Enthalpy Drops and Power Variations

Specific enthalpy values change with load variation at HP turbine stages which can be seen in Figure 5. The amount of enthalpy drop and also theoretical work of HP turbine increases because of Inlet pressure and temperature generally keep constant but outlet pressure changes in proportion with load variation. However, amount of theoretical enthalpy drop and work of IP turbine and LP turbine keep almost constant, except for very low load. The power generated from the plant depends on the enthalpy drop and flow rate of turbine are main parameters to determine the plant load. Despite the increasing amount of the specific work, the generated power decreases because of the decreasing of flow rate with variation to load at the high pressure turbine. In addition to this, the enthalpy drops of the intermediate and low pressure turbines are nearly constant but generated power is also decreasing with the reduction of flow rate. The generated power from the turbines at partial loads are shown in the below Figure.

$$W = (h_{in} - h_{out}) \quad ....eq\ (1)$$

$$P = mW \quad ......eq\ (2)$$

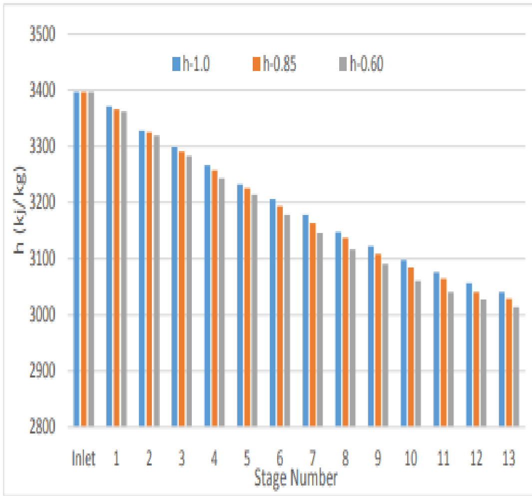

Figure: Specific enthalpy variation at turbine stages at partial loads

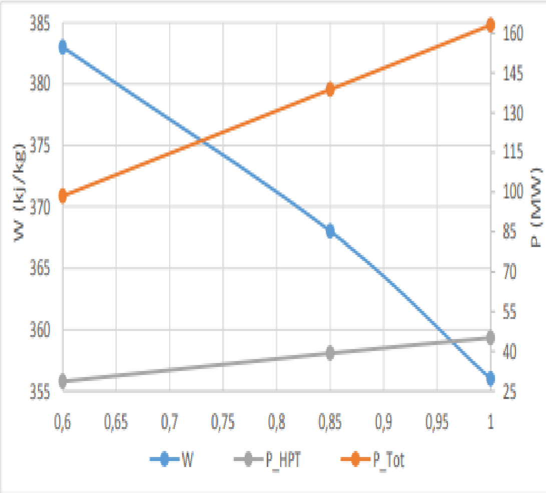

Figure: Specific work and turbine power variations at partial loads

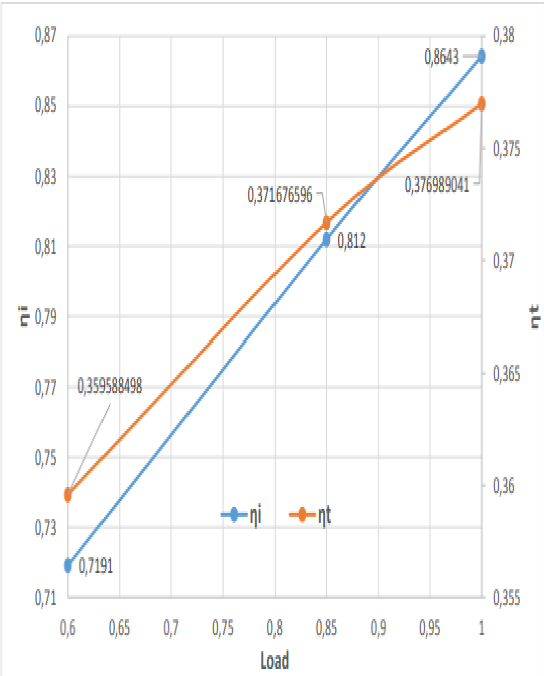

Figure: Isentropic efficiency of turbine and plant thermal efficiency variations at partial loads

Internal Efficiency of a HP Steam Turbine

How the performance of a steam turbine has changed at partial load conditions can be explained on the basis of the relationship between steam pressure, temperature and flow rate. Power output rate, the relationship between the enthalpy drop and the pressure ratio, Law of Ellipse or Stodola's Cone and Schegliaev model can describe this relationship. Turbine indicated efficiency is an important performance parameter which can be calculated from turbine inlet and outlet parameters that guaranteed by turbine producer or the difference between theoretical enthalpy drops and loses for each stage.

CONCLUSION

In the initial segment of this review, a short survey about turbine execution at fractional loads and off plan conditions has been finished and afterward broad data about power plants was given. In third piece of the review, activity standards, plan and off plan states of steam turbines have researched/presented and afterward execution examination of a high strain steam turbine and a power plant have done at off plan conditions for a genuine plant. Execution estimations at incomplete burdens have finished with ensured tension, temperature and stream rates values which were acquired from the plant maker. Investigates showed that both turbine and the power plant exhibitions decrease at fractional burden conditions. To get precise outcomes, an extensive estimation framework and norms should be improved for all sort of turbine and control frameworks.

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