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Maintenance of Steam Turbine Power Plant for Improvement of Operation

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Abstract—*Thermal electrical power generation is one of the major methods, used in Indian thermal station. The major components of Indian thermal station are boiler, steam turbine, condenser and the feed pumps. The objective of this research was to study and enumerate profound solutions in order to minimize the risk of failure and effectively manage the reliability of the substation equipment, stemming from a proper maintenance strategy. The operation and maintenance of Thermal station was examined and the conclusion was that it was challenged with The heat rate of a plant is affected by the following factors Ageing of the plant, Operating load of the plant, Quality of fuel as compared to design quality, Operating parameters like Main Steam Pressure, Main Steam Temp., Reheat Steam Pressure, Reheat Steam Temp. Etc. This occurrence has had a massive setback on the power plant, hence a proper maintenance strategy needs to be designed to curb the effect and develop a long lasting solution to prevent further potential disaster.*

Keyword:— *operating parameters*, *Rankine cycle, Steam Turbines, Fuel-cells, Photovoltaic Solar Cells, Fusion Reactor.*

1. INTRODUCTION

The working fluid is "water" which is sometimes in the liquid phase and sometimes in the vapor phase during its cycle of operations. A fossil fuelled power plant is an example of bulk energy converter from fuel to electricity using "water" as the working medium. The energy released by the burning fuel is transferred to water in the boiler to generate steam at high temperature, which then expands in the steam at high temperature, which then expands in the steam turbine to a low pressure to produce shaft work. The steam leaving the turbine is condensed into water in the "condenser" where cooling water from a river or sea circulates, carrying away the heat released during condensation. The water (condensate) is then feedback to the boiler by the pump and the cycle goes on repeating itself. Steam turbine power plants operate on "Rankine cycle" for the production of electric power. If the steam from the waste heat boiler is used for process or space heating, the term "cogeneration" is the more correct terminology (simultaneous production of electric and heat energy). Steam turbine plants generally have a history of achieving up to 95% availability and can operate for more than a year between shutdowns for maintenance and inspections. Their unplanned or forced outage rates are typically less than 2% or less than one week per year. Modern large steam turbine plants (over 500MW) have efficiencies of about 40-45%. These plants have installed cost approx between 34,759 and 1, 18,246 /KW, depending on environmental permitting requirements[1].

This work presents an assessment of the state of the thermal plants with a view to suggesting solutions to remedy the deteriorating states of the plants, in order to improve the power supply system in the country.

2. CLASSIFICATION OF POWER PLANT

a. Conventional

- Steam Engines
- Steam Turbines
- Diesel
- Gas Turbines
- Hydro-Electric
- Nuclear

b. Non conventional

- Thermoelectric Generator
- Thermionic Generator
- Fuel- cells
- Photovoltaic Solar Cells
- Fusion Reactor
- Biogas, Biomass Energy
- Geothermal Energy
- Wind Energy
- Ocean Thermal Energy Conversion
- Wave and Tidal Wave
- Energy Plantation Scheme

All the above mentioned power plants are classified according to the ways in which steam is being generated. Some of the ways are explained below.

Nuclear Power Plant: uses a nuclear reactor's heat to operate a steam turbine generator.

Geothermal Power Plant: uses steam extracted from hot underground rocks.

Renewal Energy Plant: may be fuelled by waste from sugarcane, municipal solid waste, land fill methane or other forms of biomass. In Integrated Steel mills, a blast furnace exhaust gas is a low cost although low energy density fuel. Waste heat from industrial processes is occasionally concentrated enough to use for power generation, usually in steam boiler and turbine.

Solar Thermal: Electric plants use sunlight to boil water which turns the generator. Fossil fuelled power plants may also use a steam turbine generator or in the case of natural gas fired plants many use a combine turbine. Fossil fuel power plants are designed on a large scale for continuous operation. In many countries, such plants provide most of the electrical energy used. A fossil power plant always has some kind of rotating machinery to convert the heat energy of combustion into mechanical energy, which then operates an electrical generator[6]. The mover may be a steam turbine, a gas turbine or in small isolated plants, a reciprocating combustion engine. By- products of power plant operation need to be considered in both the design and operation. Waste heat due to the finite efficiency of the power cycle must be released to the atmosphere, often using a cooling tower, or river or lake water as a cooling medium. The flue gas from combustion of the fossil fuels is discharged to the air; this contains carbon dioxide and water vapour, as well as other substances such as nitrogen, nitrous oxides, sulphur oxides, and (in the case of coal-fired plants)fly ash and mercury. Solid waste ash from coal-fired boilers must also be removed, although some coal ash can be recycled for building materials. Gas burning is much simpler as the fuel is ready for combustion and requires no preparation. The other advantages are:

- Cleanliness
- Ease of control of furnace temperature
- Ability to produce a long slow burning flame with uniform and gradual heat liberation
- Ease of temperature regulation

Natural gas is used for steam generation in gas producing areas or in areas served by gas transmission lines and where coal is costlier. The proportioning, mixing and burning of gas air mixture can be achieved in many ways. Natural gas is often informally referred to as simply "gas", especially when compared to other energy sources such as electricity. Before it can be used as a fuel, it must undergo extensive processing to remove almost all materials other than methane[10]. The by-product of that processing include ethane, propane, butanes, pentanes, and higher molecular weight hydrocarbons, elemental sulphur, and sometimes helium and nitrogen. Natural gas is the major source of electricity generation through the use of gas turbines and steam turbines. Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. Natural gas burns cleaner than other fossil fuels such as oil and coal and produces less CO per unit energy released. For the equivalent amount of heat, burning natural gas produces about 30% less than carbon-dioxide than burning petroleum and about 45% less than burning coal.

3. THE CARNOT VAPOR CYCLE

The Carnot cycle is the most efficient cycle operating between two specified temperature levels making use of steam as the working fluid. Thus it is natural to look at the Carnot cycle first as a prospective ideal cycle for vapor power plants. If we could, we would certainly adopt it as the ideal cycle[7]. But as explained below, the Carnot cycle is not a suitable model for power cycles. The assumption is that steam is the working fluid used since it is the working fluid predominantly used in vapor power cycles.[1].

Consider a steady-flow Carnot cycle executed within the saturation dome of a pure substance. The fluid is heated reversibly and isothermally in a boiler (process 1-2), expanded isentropically in the turbine (process 2-3), condensed reversibly and isothermally in the condenser (process 3-4), and compressed isentropically by the compressor to the initial state (process 4-1). Several impracticalities are associated with this cycle.

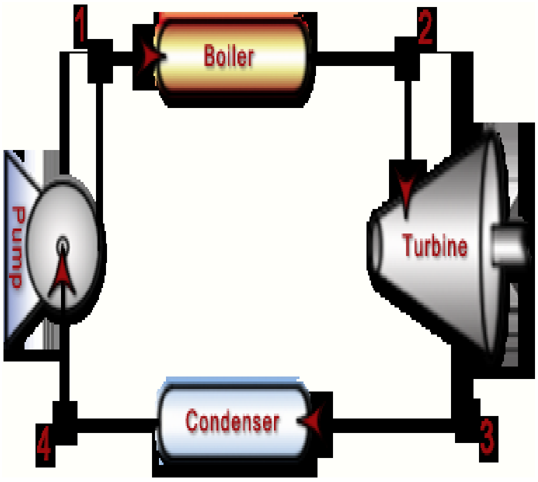

Figure 1. Carnot vapor cycle T-S diagram

Isothermally heat transfer to or from a two-phase system is not difficult to achieve in practice since maintaining a constant pressure in the device will automatically fix the temperature at the saturation value. Therefore, processes 1-2 and 3-4 can be approached closely in the actual boilers and condensers. Limiting the heat transfer processes to the two -phase systems, however, severely limits the maximum temperature that can be used in the cycle (it has to remain under the critical-point value, which is 374ºC for water)[9]. Limiting the maximum temperature in the cycle also limits the thermal efficiency. Any attempt to raise the maximum temperature in the cycle will involve heat transfer to the working fluid in a single phase, which is not easy to accomplish isothermally.

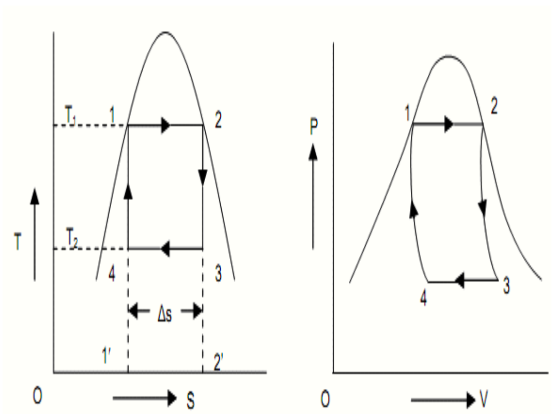

Figure 2. Carnot Cycle on P-V and T-S Diagram

The isentropic expansion process (process 2-3) can be approximated closely by a well- designed turbine. However, the quality of the steam decreases during this process as shown on T-s diagram. Thus the turbine will handle steam with low quality, that is, steam with high moisture content. The impingement of liquid droplets on the turbine blades causes erosion and is the major source of wear. Thus steam with qualities less than 90% cannot be tolerated in the operation of power plants. The problem could be eliminated by using a working fluid with a very steep saturated vapor line.

The isentropic compression process (process 4-1) involves the compression of a liquid-vapor mixture to a saturated liquid. There are two difficulties associated with the process. First, it is not easy to control the condensation process so precisely as to end up with the desired quality at state 4. Second, it is not practical to design a compress that will handle two phases[13].

4. RANKINE CYCLE

The ideal for vapor power cycles

Many of the impracticalities associated with the Carnot cycle can be eliminated by superheating the steam in the boiler and condensing it completely in the condenser as shown schematically on T-s diagram. The cycle that results is the Rankine cycle, which is the ideal cycle for vapor power plants (P.K. Nag, “Power Plant Engineering,” Tata McGraw Hill, New Delhi, 2007 The ideal Rankine cycle does not involve any internal irreversibility and consists of the following four processes:

- 1-2 isentropic compression in a pump
- 2-3 constant pressure heat addition in boiler
- 3-4 isentropic expansion in a turbine
- 4-1 constant pressure heat rejection in a condenser

Table: 1. Key performance index

No.	Description	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
1.	Msx lcad (W)	108	104	109	110	205	215	215
2.	Av. Load (MW)	85	81	89	85	177	185	186
3.	Aux. Power Cons.(%)	9.50	10.22	9.14	9.86	10.69	9.74	9.91
4.	Sp Coel Cons. (rg/ SkWH)	0.82	0.82	0.82	0.82	0.798	0.798	0.798
5.	Sp Oil Con:. (ml/kWH)	3.80	4.60	2.94	3.07	2.68	1.43	2.71
6.	PLF (%) (As per CEA definition)	64.46	51.5	67.60	67.42	79.42	78.62	77.88
7.	Availability (%) (As per CEA definition)	86.82	73.22	87.73	90.89	89.83	89.18	88.01
8.	IIed1rae kCal/kWH	3046	3053	3038	3039	2973	2962	2974
9.	Running Hrs.	7605.49	6414.25	7685.24	7961.47	7868.52	7811.44	7709.31
10.	Planned outages (%)	5.48	25.86	6.28	0	0.83	6.53	4.21
11.	Forced outages (%)	7.69	0.91	5.99	9.11	9.34	4.3	7.79

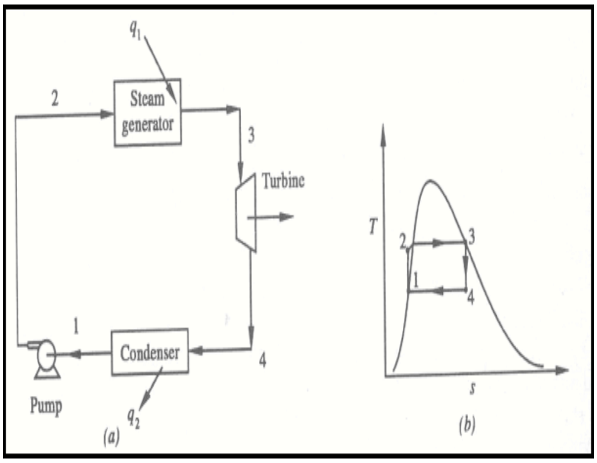

Figure 3. Rankine cycle

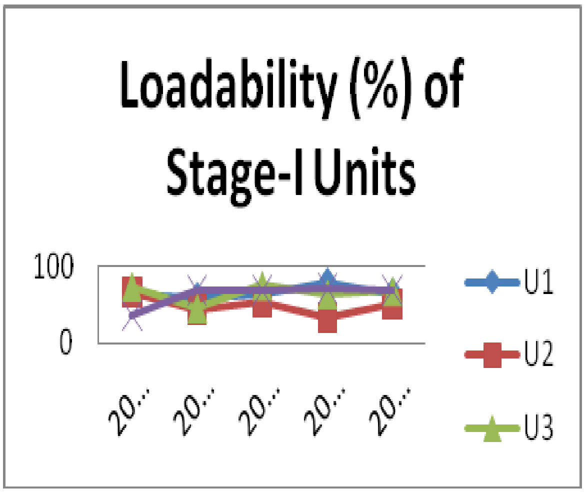

Figure:4. Loadability (%) of Stage-I Units

5. CONCLUSIONS

The reliability of a power plant unit is one of the most important performance parameters which reflect the quality and standards. The great care and effort devoted to increasing the reliability and quality of electrical power is an indication of the economic implication for the power industry. This study has investigated the reliability and availability of Indian power station units in relation to implementation of a preventive maintenance programmed. The availability analysis shows different results for each unit indicating differences in their system installation, maintenance and operation. The availability and reliability of them turbines presented in this study reflect on site behavior, including the effects of changes in auxiliary systems maintenance policy. Identifying the effects of component failure on the system under analysis, based on the failure effects classification, a maintenance policy can be formulated to reduce their occurrence probabilities. Better aims and specific targets are needed for the Indian power station to improve maintenance management systems and productivity. This should be based on a new maintenance paradigm that will improve maintenance control and other technical activities. The managers must formulate wise strategies, make decisions and monitor progress against plans by collecting, retrieving and analyzing data. To reduce downtime and achieve high production capabilities, the aim should be to find ways to increase equipment reliability and extend the equipment life through cost effective maintenance. To achieve these, PHCI, must move away from the traditional reactive maintenance mode to proactive maintenance and management philosophies. There should be maintenance processes that fully address Total Quality Maintenance (TQM) and Total Productive Maintenance (TPM) operating modes. Such change requires a complete shift to a Total Planned Quality Maintenance (TPQM) approach, which is a maintenance and management philosophy that advocates planning all maintenance (*i.e.* preventive, predictive and corrective), as well as the control of quality in maintenance operations. The reliability evaluation of Indian thermal power station was calculated with the help of the key performance indicator (kpi). It can be seen from the analysis that the key performance indicator of the month of October is the highest among others in terms of percentage generation efficiency, percentage availability factor, average generation and energy generated, and this happened after a shutdown in August so that the annual maintenance routine can be carried out. It is also discovered that the plant is generating below its maximum capacity.

- It is highly recommended that adequate maintenance of equipment is carried out so as to meet the demands of consumers.

- It is also recommended that the Government should set up programs that will aid the effectiveness of the equipment at the plant.
- Supply of gas is also a major setback, so therefore availability of gas should be in abundance for the running of the plant for effectiveness.
- There should be adequate personnel operating each unit.
- It is also recommended that the two units that have been out of service since 2007 should be fully repaired and restored to normal working condition.
- It is also recommended that only demineralised water should be used as a working medium in the plant to avoid scaling or crevices to the boiler or turbine parts.
- It is recommended that the plant should be expanded by the addition of more units to boost power supply.

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