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TECHNICAL APPRAISAL OF THE PERFORMANCE OF THERMAL POWER PLANTS USING AJA STEEL THERMAL POWER PLANT AS A CASE STUDY

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ABSTRACT

The main objective of any power plant is to reliably and regularly supply energy to consumers according to the load schedule. The concept of efficiency is closely interrelated with that of reliability. The indices of reliability are trouble free operation, operation characterised by low frequency of breakdown, minimum time of repairs after failures and mean length of service life between overhauls. The principal power indices of a condensing steam turbine plant are the specific consumption of steam and fuel and the thermal efficiency indices. Observation of the year 1993 shows that the total energy generated in that year amounted to 302727MWh with an average of 25227MWh per month which is 62.8% of the designed capacity. The lowest energy (22268MWh) generated occurred in July with plant factor of 54.4%. The total hours run in the year is 8760 hours which corresponds to the plant designed hours for the year with an average of 730 hours.

Keywords: Performance, Power plant, Reliability, Efficiency, Power indices, Thermal efficiency

INTRODUCTION

Electricity is the fulcrum for socio-economic development of any nation. The invention of turbines has brought about an upheaval in electricity generation and the subsequent formation of power authorities such as the Electric Power Authority in Nigeria. National and industrial developments are both interlinked with electricity supply and management. This had led to optimum production of goods and services, job opportunities and more profit to investors [Babcock and Wilcox, 2018]. It has also encouraged investors to build more companies without being afraid of power supply and its attendant problems. Energy industries also have direct impact on the lives of the citizenry. In order to curb the shortfall in energy supply and its attendant problems; it is pertinent to evaluate the performance of energy source [Odia, 2019]. The aim of this work is to appraise the performance of thermal power plants with Ajaokuta steel complex thermal power plant as a case study.The main objective of any power plant is to reliably and regularly supply energy to consumers according to load schedules [British E.I., 2018]. The concept of efficiency is closely interrelated with that of reliability. The indices of reliability are trouble free operation, operation characterised by low frequency of breakdown, minimum time of repairs after failures and mean length of service life between overhauls [Barringer, 2020]. Durability is defined as the mean service life till scrapping. A complex index of reliability is the availability factor, which characterises the probability that a machine is ready for operation at any particular moment, except for the time of maintenance [Barringer and Roberts, 2018].The Ajasteel steam turbine power station was built in 1987 for the production of electric power in large scale for the entire complex. The large energy source was necessary to meet the high demand for electricity in the various plants within the complex such as the rolling mills, blast furnace, coke oven plant, oxygen/hydrogen plant, power equipment shops, mechanical repair shop, steel/iron making plants, etc. The Ajasteel power station is fired on natural gas, coke oven gas, blast furnace gas, fuel oil, coal tar and mixture of these gases in certain proportion. The station consists of two steam turbines, three high pressure water tube boilers and their artillery equipment.

The turbine section comprises of two similar steam turbines, condensing plant, feed water, heater, lubricating oil pumps and other auxiliary equipment. One of the turbine nT-60-90/13 has two controlled extraction points namely production steam extraction and process steam extraction. Production steam extraction is feed to steam users in the plant such as the forge and fabrication shop for operating their steam hampers. The second controlled extraction is the process steam which is used for preheating the condensed steam and then feed water prior to pumping it back to the boiler for another heat addition process.

Each of the turbines has a rated power output of 55MW at 3000rpm and it is intended for a direct drive of AC generator (TBQ – 55 – 2T3). The turbine is designed for operation at the following basic rated parameters:

1. Absolute pressure of main steam upstream of automatic stop value = 90kgf/cm^2.
2. Temperature of mainstream upstream of automatic stop value = 54^{o}C.
3. Cooling water flow rate through the condenser at temperature of 32^{o}C = 8000m^3/h.

The maximum permissible load on the turbo generator is 55MW. In this state, the turbine must be running in totally condensing mode, that is, without controlled extraction. The maximum steam flow rate through the turbine is approximately 402t/h. The production steam pressure is 13kgf/cm^2 and the process steam (heat supply steam) pressure is 1.2kgf/cm^2.

The turbine is a single shaft, two cylinder unit. The high pressure section has a single row governing stages and fourteen pressure stages. The low pressure cylinder consists of two parts:

(a) A medium pressure part comprising a governing stage and eight pressure stages.
(b) A low pressure part comprising a governing stage and five pressure stages.

The boiler is fed with natural gas, blast furnace gas, fuel oil and a mixture of these fuels with coke oven gas and coal tar in certain ratios.

Table 1: Characteristics of the Ajasteel Plant

Rated steam output	200t/h
Working pressure	115kgf/cm^2
Super heated steam temperature	540^{o}C
Heat liberation of natural gas	553560kJ/m^3/h
Feed water temperature	215^{o}C
Super heater heating surface	1908m^3
Ceiling super heating	117m^2
Platen super heater	393m^2
Reversing chamber	68m^2
Convective super heater	1330m^2
Radiant heating surface of walls	615m^2
Water economiser heating surface	3000m^2
Air preheater heating surface	14650m^2

The boiler consists of a furnace chamber and the flue gas flow is updraft in the furnace chamber, then through a horizontal duct that connects the furnace chamber with the convective shaft. In the convective shaft, the flue gas flow is downdraft and finally through the induced draft fan where the flue gas is evacuated into the stack.The principal power indices of a condensing steam turbine plant are the specific consumption of steam and fuel and the thermal efficiency indices. For thermo-electric power stations, these indices which

are calculated for the production of electric energy are supplemented with the indices of thermal efficiency of heat generation and the specific electric energy production on heat consumption. For determining the power index of a plant, it is assumed that its electric capacity, initial and final parameters, the working cycle of steam in the turbine, the number of heaters, the parameters of extracted steam and some other data which can characterise this plant are known in advance. These characteristics can be easily established for an existing plant operating under the specified conditions. For designed plant, some of these characteristics, such as the electric capacity, the initial and final parameters, etc, can be given and the others determined by preliminary calculations.

METHODOLOGY

Plant performance is most precisely described by the input – output curve derived from tests of the individual equipment. For steam turbine, steam generator, steam station as a whole or diesel engine and station, the input is expressed in millions of enthalpy per hour and the output or load is kilowatts. In a hydraulic plant, the input would be in terms of cubic metre per second of water flow and the load in kilowatts. The performance of any individual piece of power plant equipment such as a boiler, turbine, diesel engine, pump, fan or heat exchanger may be described by an input – output curve. Since a station is made of several of these different forms of apparatus, their performance characteristics must be integrated so that the performance of a station as a whole may be expressed by a single input – output curve.For this plant under study, the relationship between the electric capacity of a plant, Ne, and the flow rate of steam, or of heat, Qo, through it can be established. The relationship D = F(Ne) is called the steam characteristic and the relationship Q = F(Ne) is the heat characteristic. Performance of generating plants is compared by their average thermal efficiencies over a period of time. Average thermal efficiency is the ratio of useful energy output during the period to the total energy input for the period. This measure of performance varies with uncontrollable conditions such as cooling water temperature, shape of load duration curve, total output and quality of fuel. It is, therefore, not a satisfactory standard of comparison unless all plant performances are corrected to the same controlling conditions.

Findings Table 2: Performance Outlook of the Plant.

Year	Mont h	Hour s	Energy Generat	Plant Factor	% Hours Availabilit	Plant Capacity	Hours Lost

		Run	**ed (MWh)**	**(%)**	**y**		
1993	Jan	727	35881.1	89.7	97.7	55	17
1993	Feb	663	32632.6	89.5	98.7	55	9
High Output	Mar	744	43718	100	100	55	–
	Apr	720	25643.2	64.8	100	55	–
	May	744	30475.5	74.5	100	55	–
	Jun	711	30285.2	77.4	98.7	55	9
	Jul	744	22387.3	77.4	98.7	55	9
	Aug	744	13425.5	32.8	100	55	–
	Sep	720	15735.9	39.7	100	55	–
	Oct	744	19661.4	48	100	55	–
	Nov	720	21749.8	54.9	100	55	–
Low Output	Dec	744	11111.5	27	100	55	–
1994	Jan	744	24187.9	59	100	55	–
High Output	Feb	672	47264.8	100	100	55	–
	Mar	744	25487.0	62.2	100	55	–
	Apr	720	31216.0	78.8	100	55	–
	May	744	23033.0	56.2	100	55	–
	Jun	720	23362.7	58.9	100	55	–
Lowest	Jul	744	22268.57	54.4	100	55	–
	Aug	744	23028.5	56.2	100	55	–
	Sep	720	22556.6	56.9	100	55	–
	Oct	744	23550	57.5	100	55	–
	Nov	720	31284.8	79	100	55	–
	Dec	744	23716.5	57.9	100	55	–

In 1993, hours lost = 44hrs
Total energy generated = 302727MWh
Average = 35227MWh
Which is 62.8% of the plant capacity
Plant capacity = 40150MWh
1994
Total energy generated = 320950MWh
Average = 26746MWh
66.6% of plant capacity
Two years average from 623683
Average = 25786MWh

$$Plant \;\; factor = \frac{energy \;\; generated \;\; per \;\; month}{\sup pose \;\; energy \;\; generated \;\; in \; that \;\; month}$$

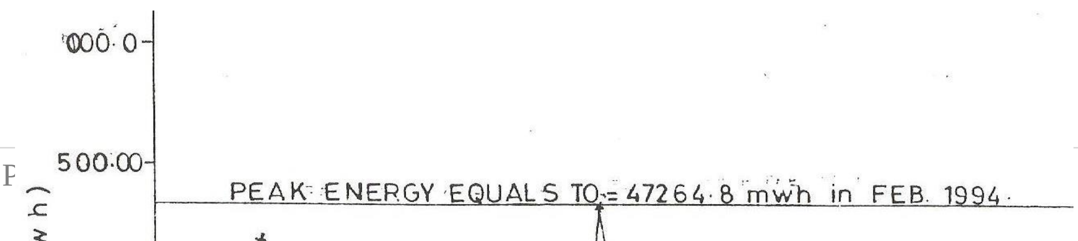

Fig. 1: Energy Generated by the Unit per Moth

The following data were obtained from the plant operation log sheet:

Inlet steam temperature	=	$540^{o}C$ = 814K
Inlet steam pressure	=	90 bar
Condenser pressure	=	0.96 bar
Steam flow rate	=	130 tonnes/hour

ANALYSIS OF FINDINGS

Observation of the year 1993 shows that the total energy generated in that year amounted to 302727MWh with an average of 25227MWh per month which is 62.8% of the designed capacity. The total energy in the year should be 481800MWh with an average of 40150MWh. The highest energy recorded (43718MWh) in the year was in the month of March with plant factor of 100%.The lowest energy (11111.5MWh) generated occurred in the month of December with plant factor of 27%. The total hours run in the year equals to 8725 hours with an average of 727 hours (99.6%) per month as against the plant designed hours of 8760 hours, an average of 730 hours. It was found out that 44 hours were lost in the year, that is, 3.67 hours per month. The total plant factor equals 775.7 with average of 64.6%. The total hours availability amount to 1193.8 that is 99% per month.The total energy generated in 1994 equals 320950MWh with average of 26746MWh, 66.6% of designed plant capacity. The designed capacity of the plant for the year is 481800MWh, average of 40150MWh per month. The highest energy (47264MWh) recorded in the year occurred in February with plant factor of 127.8%.The lowest energy (22268MWh) generated occurred in July with plant factor of 54.4%. The total hours run in the year is 8760 hours which corresponds to the plant designed hours for the year with an average of 730 hours.
There was no hour lost in the year. The total plant factor equals 777, average of 64.7% per month. The total hours availability is 1200, per average of 100%.During the period (January

1993 – December 1994) under review, the average plant running factor was (129.39/2) = 64.69%. The highest energy (47264.8MWh) generated within this period occurred in February 1994, with plant factor of 100%. The lowest energy (1111.5MWh) recorded occurred in December 1993 with plant factor of 27%. It should be noted here that there was no hour lost, yet the output read below average. It shows that the number of hours a plant is run does not mean high energy output but depends on system capability and high demand of energy from the system.The total energy generated within the reviewed period is 623683MWh, an average of 25986MWh per month (as against the required output of 40150MWh per month), 64% of the supposed total energy (963600MWh) generated. The total hours run is 11485 hours with average of 728.5 hours per month as against the required hours of 17520 hours, 730 hours per month. The lost hours still remain 44 hours within the period, an average of 1.8 hours per month.This means that component failure due to mechanical fault or otherwise, is very negligible. The plant has been run for two consecutive years without an appreciable period of standstill in terms of time. The underutilisation of the plant is mainly due to low demand of energy from the system. One can say that the operational condition of the entire plant is fair since the plant had been utilised in the months of March, 1993 and February, 1994. Its efficiency would have been increased but if the plant is operated commercially, the aim of the plant is defeated as there will be no meaningful profit from it.The practical performance showed that the power requirement for driving auxiliaries is about 33% of the total power output from the turbine. There is also a loss of power performance and loss of efficiency of the unit; this could be attributed to component inefficiencies such as internal, external losses and power for driving the auxiliaries. It is discovered that there is high rate of energy losses with the steam flow in the turbine in steam admission and in steam control valves, due to certain outlet velocity of steam and owing to steam losses through packings.

CONCLUSION AND RECOMMENDATIONS

The main aim of establishing any power plant is to generate electric energy and heat to consumers as economically as possible. This will not undermined the operating cost and capital cost. The former is primarily a function of the overall efficiency of the plant while the latter rests wholly on its size and complexity. For this to be accomplished, the plant must be operated at its economic load which is the load at which a plant operates with the highest efficiency. In the course of this study, it was discovered that the plant has not been run to its designed peak load. The load fluctuates between 60 and 64% of the designed peak load. There are two reasons for the underutilisation of the plant:-The steel complex and its environment which is the major consumer of the energy generated from the plant, demands a fraction of the total power output and PHCN which imports energy from this plant consumes power below expectation.Observation showed that the performance of the condenser is affected by the following: the spray nozzles of the cooling tower do not withstand water pressure for a long time before breaking. This contributes to non-efficient cooling; therefore water entering the condenser enters with a high temperature. Non-efficient filtering of cooling water entering the condenser results in pipe-blockage, high pressure in pipes, scaling inside the pipe, etc. The low thermal efficiency and performance loss of the plant could be attributed to the auxiliaries of the plant which are bogus and consumes 33% of the total power generated. There are losses of fuel and steam through the pipe network and the loss of steam and condensate involve a loss of heat and can cause an additional consumption of energy for their compensation.

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