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Reliability of low pressure Steam Turbine for Electricity Power Generation.

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Abstract

The reliability of the low pressure steam turbine of Sapele power station of the Power Holding Company of Nigeria (PHCN) over a ten years period (1994 -2003) have been investigated. The data used were records of Low pressure steam turbine failures and repairs kept by the maintenance sections of Sapele power station. The Failure rate, Repair rate, Mean time between failure (MTBF), Mean time to repair(MTTR) and the steam turbine reliability were determined. The reliability results for seven(7) of the years investigated was less than 0.2 . Six (6) of the 10 years studied have MTBF of less than 181 hours . In other words failure was expected after every 8 days for 60% of the years investigated. This indicated that the reliability of the steam engine was very low. Aging and maintenance is suspected to be the cause of the poor reliability of the turbine and remedial actions are recommended .

Keywords: reliability, steam turbine, power station, failure rate.

1. Introduction:

Electricity supply are in three stages: generation, transmission and distribution. Electric energy is a facilitator of the technological advancement of any nation, because nearly all other sector depend on it for their effectiveness. In 1898, the first Power Station in Nigeria consisting of two 30 KW units was built at Marina , Lagos . The rapid growth of the Nigeria economy during the early 1970's resulted in a fast increase in the demand for electricity supply. The power holding company of Nigeria (PHCN) thus had to take prompt action to meet this demand by expanding its generation and transmission network. As part of the expansion programme five thermal power stations and three hydro generating stations were built : they include Afam thermal power station, Delta thermal power station, Ijora thermal power station, Sapele thermal power station and Lagos (Egbin) thermal power station. The hydro power stations are located in Kainji, Jebba and Shiroro .The breakdown of the total installed capacities of the power stations show that Kainji, Jebba, and Shiroro generate 760MW, 540MW and 600MW respectively ,while the capacity of the thermal power stations are; Afam-811MW,Delta 840MW,Sapele 1208MW,Ijora 60MW and Lagos -1320MW [1,2,3].

Reliability can be defined as the probability of a product or a system performing without failure a specific function under a given condition for a specific period of time [4] .Reliability is an important and integral feature of planning ,design, and operation of an engineering system. The reliability of a power system is very important both for the customers and power system proprietors. A reliable power system makes energy available to its customers at a required amount, quality and at economical rate where and when needed [5]. Therefore for the proper and realistic planning for an economic activity, the reliability of the power supply system must be taken into consideration by the entrepreneur. Additionally ,the reliability assessment of a power system can assist system planners in evaluating alternative facilities and also in economic justification of each of the additional facilities. it is useful in determining and ensuring a balanced or optimum allocation of resources to different segments of a power system. Adediran and Jenyo have investigated the reliability of one the generating plants in Shiroro power station of the Nigeria electric power system [6]. Megbowon and Oyebisi have since also reported their investigation into the performance of transmission lines in the system [7]

The Sapele power Station of Power Holding Company of Nigeria is one of the highest power generating stations in Nigeria with an installed capacity of 1208MW and the need to determine the reliability of its steam turbine cannot be overemphasized. The aim of this study was to determine the reliability of one of the running low pressure steam turbine unit ' ST02' and give appropriate recommendations.

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METHODOLOGY

The data was taken from BBC design data as per drawings GMDO 431897 [8] . The primary data source were records of Low pressure steam turbine components failures and repairs obtained by turbine major overhaul and records kept by the maintenance sections such as Annual reports, overhaul schedules and the records was over a ten years period from 1994 to 2003 were obtained from Sapele Power station, of Power Holding Company of Nigeria. Information was also obtained from interviews and past research works . The Failure rate, Repair rate, Mean time between failure (MTBF), Mean time to repair(MTTR) and the system reliability were determined using equations 1-5 [9**]**.

$$\text{Failure rate } (\lambda) = \frac{No.\ of\ \ failure}{Actual\ \ time\ of\ \ maintenance} \quad (1)$$

Where, actual time of maintenance = total operating time.

$$\text{Repair rate } (\mu) = \frac{No.\ of\ \ failure}{Total\ \ repair\ \ time} \quad (2)$$

MEAN TIME BETWEEN FAILURE (MTBF)

$$MTBF = \frac{Total\ \ operating\ \ time}{Total\ \ number\ of\ \ failure}$$

$$= \frac{1}{failure\ rate}$$

$$= \frac{1}{\lambda} \quad (3)$$

MEAN TIME TO REPAIR(MTTR)

$$MTTR = \frac{Total\ \ time\ \ of\ \ maintenance}{Total\ \ maintenance\ \ action}$$

$$= \frac{1}{repair\ rate}$$

$$= \frac{1}{\mu} \quad (4)$$

SYSTEM RELIABILITY

This was computed using the constant failure rate model,

$$R(t) = e^{-\lambda t} \quad (5)$$

where λ = failure rate, t = total operating time

RESULTS AND DISCUSSION

Table 1 shows that the failure rate (failure/hour) figures ranged from 0.00046 to 0.0084 failure per hour .These figures are equivalent to 4.029 failures per year and 73.67 failures per year respectively. In pratical terms, a maximum of about 6 failures are to be expected each month.This upper limit is obviously too high to be acceptable. there is therefore a clear indication that the steam turbine was very unreliable for most of years under investigation. High failure rate is a characteristic of wear region of Bathtub curve [10].This shows that aging factors are having serious effect on the steam turbine.

In the year 2003 the failure rate was 0.0024 failur per hour for the low pressure Sapele Steam turbine Power generating system (Table 1). This figure is equivalent to 2 failures per month . This compare favourably with the values obtained for Afam electric power generating station and Ibadan subsystem distribution feeder lines which was 1 failure per month and 2 failure per month in the year 2003 respectively (Table 2) [5,11] but was smaller than the value of 5 failure per month reported for Oshogbo/Akure National Grid Transmission line in 2003 Table 2 [12].

Table 1: Reliability of the low pressure Steam Turbine (1994 – 2003)

Years	No. of Failure N (hrs)	Failure rate λ (Fail / hr.)	Total repair time(hrs)	Repair rate, μ	MTBF	MTTR	Reliability

1994	51	0.00841	2700	0.01888	118.90	52.96	0.0137
1995	43	0.00621	1836	0.02342	161	42.69	0.012
1996	4	0.00046	72	0.05555	2,173.9	18	0.97
1997	3	0.000344	64	0.046875	2,906.9	21	0.98
1998	34	0.00505	2028	0.016765	198.019	59.65	0.0357
1999	35	0.00552	2422	0.014450	181.159	69.20	0.0156
2000	7	0.000811	136	0.051470	1233	19.43	0.8955
2001	37	0.00617	2768	0.013367	162	74.81	0.0383
2002	33	0.00597	3240	0.010185	167.5	98.18	0.0398
2003	17	0.0024	1680	0.010119	416.67	98.82	0.2

Table 2:Reliability Indices of some Nigeria Power System in 2003[5,11,12]

Power System	Failure rate /hour	Failure rate /Month	MTBF (Hours)	MTBF (Days)	MTTR (Hours)	MTTR (Days)
Afam Electric Generating Station(Thermal)	0.001723	1.24	524	21	60	3
Oshogbo/Akure National Gird Transmission System	0.00719	5.1	139.08	6	33.18	1
Ibadan distribution Subsystem feeder lines	0.00227	2	100	4	27	1
*Sapele power station (steam turbine)	0.0024	2	416.67	18	98.82	4

*Results from this study

The MTBF for the 10 years period investigated ranged from 118 to 2906 hrs. Six (6) of the ten (10) years studied (i.e 1994,1995,1998,1999,2001 and 2002) had values of less than 181 hours MTBF i.e less than 8 days .In other words failure is expected after every 8 days or less for 60% of the years investigated (Table 1).The inference is that preventive maintainance was ineffectively carried out during this period under investigation. However the highest MTBF was observed for the years 1996 and 1997 was 2173 and 2906 hours respectively. This implies MBTF of 90 days and 121days respectively. This high value may have been due a major maintenance carried out the previous year (1995).

In the year 2003, the MTBF was 416.67 hrs for the Sapele power station steam turbine which is equivalent to 18 days (Table 1). This figure compare favourably with the obtained for Afam thermal electric generating power station which was 21 days [11] but was less than MTBF values for both Ibadan subsystem distribution feeder lines and Oshogbo/Akure National Grid Transmission line in which was 6 and 4 days respectively (Table 2) [5,12].

MTTR ranged between 18hrs to 98hrs during the period under investigation(Table 1) .In other words a failure gets the steam turbine paralysed for between 2 to 5 days .This indicates low reliability .

In the year 2003 for example the MTTR was 98.82 hour for the Sapele steam turbine (Table 1). This figure is equivalent to about 4 days . This figure compare favourably with the one obtained for Afam generating power station which is 3 days [12] and higher than the MTTR values of 1 day for both Ibadan subsystem distribution feeder lines and Oshogbo/Akure National Grid Transmission line Table 2 [5,12].

The inference is that the either the location of faults take time or materials for repairs are not made readily available ,or maintenance personnel are inadequate or that fault rectification takes time because the maintenance crew are inexperienced.

Finally apart from 1996,1997 and 2000 with a reliability value of 0.97,0.98 and 0.895 respectively all the other reliability values for the remaining 70% of the years investigated was less than 0.2.This implies the steam turbine had very

low reliability for most of the periods during the period under investigation. The steam turbine components aging factor and maintenance problems are strongly suspected as the causes of poor reliability observed.

CONCLUSION

The assessment of the reliability indices of low pressure steam turbine in Sapele power generating station of Power Holding company of Nigeria have been carried out from 1999 to 2003.Except for1996 and 1997 with a reliability of .97 and 0.98 respectively, the reliability was less than 0.2 for 60% of the years investigated .This implication was that reliability of the power station was low most of the year investigated.Other reliability indices like the failure rate , MTBF and MTTR of the Sapele power generating station steam turbine was found to compare favourably with value reported for Afam thermal generating station.The values indicated low reliability. It is therefore recommended that preventive maintenance programme be implemented in the operation of the steam turbine in the Sapele Power station, the maintenance staff be adequate and well equipped and trained and spare parts of the power station that frequently fail be stocked. This we hope will improve the reliability of the system and increase the performance of the power station in electric power generation in Nigeria.

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