Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

SENSITIVITY OF RELIABILITY INDICATOR FOR THE GAS TURBINE COGENERATION POWER PLANT

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Abstract: *This paper proposes an analysis procedure for a gas turbine cogeneration power plant (CHP) from the point of view of the sensitivity of the reliability indicator. The relevant indicators for the reliability of a CHP are considered to be the yearly mean time to failure and the sensitivity of the yearly mean time to failure. The reliability indicators are calculated based on an exponential distribution for the uninterrupted operation duration and for the failure duration. A block diagram is created for determining the reliability of the CHP subcomponents based on the thermo-mechanical diagram. The exception to the block diagram calculation method is the electrical subsystem which uses the binomial method. The reliability indicators of the block diagram components come from standards or literature. An application for a CHP is presented.*
Key words: *reliability indicators, gas turbine cogeneration power plant.*

1. INTRODUCTION

The reliability of the GTI is essential for the cogeneration cycle. Failure of a component may result in failure of a subsystem or of the whole power plant, (Jesus et al, 2009).

The paper analyzed the influence of equipment reliability on CHP reliability. This helps optimize preventive maintenance action leading to a reduction in maintenance costs and in plant damage caused by breakdowns, (Felea et al, 99).

A relevant indicator for CHP reliability was the yearly mean time to failure (total or partial) of the CHP installations.

Another indicator used is the sensitivity of the reliability indicators in relation to the individual quality of the equipments that compose the CHP.

This analysis is exemplified for a CHP.

2. EVALUATING THE RELEVANT RELIABILITY INDICATORS

The value of the yearly mean time to failure of the CHP depends on the success state imposed to the CHP. This relevant indicator is calculated as, (*** NTE 005/06/00, 2006):

$$T_{an} = T_{ran} + T_{man} \quad \text{[h/year]} \qquad (1)$$

Where T_{ran} is yearly mean time to failure removed by repairs, [h/year]:

$$T_{ran} = N_r T_r \quad \text{[h/year]} \qquad (2)$$

N_r is the yearly mean number to failure eliminated through repairs, [inter/year];

T_r - mean duration of one interruption removed through repairs, [h/intr];

T_{man} - yearly mean time to failure removed by manoeuvres, [h/year];

$$T_{man} = N_m T_m \quad \text{[h/year]} \qquad (3)$$

N_m - yearly mean number to failure eliminated through manoeuvres, [inter/year];

T_m - the duration of one manoeuvre, [h/inter].

An indicator used to appreciate the influence of components on overall reliability is the sensitivity of the yearly mean time to failure, T_{an}, reported to the failure rate of the components:

$$S_i = \frac{\partial T_{an}}{\partial \lambda_i}, \quad i = 1,2,.., m \quad \text{[h/an]} \qquad (4)$$

where λ_i – is the failure rate of element i expressed in relative units.

To see the significance of this indicator we will express the variation of T_{an} on decrease of λ_i with $\Delta\lambda_i$:

$$Tan_{new} = Tan + \frac{\partial T_{an}}{\partial \lambda_i} \cdot \Delta\lambda_i = Tan + S_i \cdot \Delta\lambda_i \qquad (5)$$

if $\Delta\lambda_i$ = -1 (in relative units, ur), that is $\lambda_i \rightarrow 0$, T_{an} will decrease with S_i, which means that S_i is the value with which T_{an} decreases when element i is an element that never fails.

This indicator allows the identification of the components with an important contribution to the overall reliability of the installation.

3. APPLICATION TO A GAS TURBINE CHP

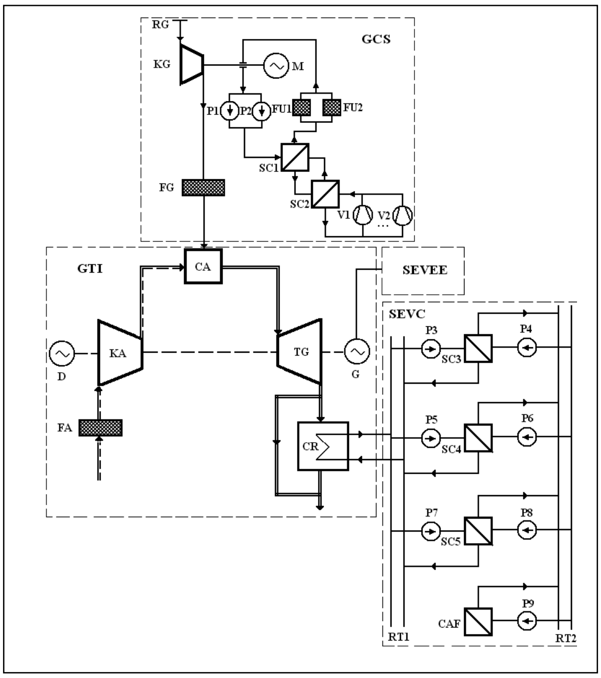

Fig.2. Thermo mechanical scheme of CHP: RG – gas metan network; KG – gas compressor; FG – gas filter; M – engine; P1...P10 – pumps; FU1, FU2 – oil filter; SC1...SC5 – heat exchangers; V1, V2 – air fan; D – starter; FA – air filter; KA – air compressor; CA – combustion chamber; TG – gas turbine; CR – recovery boiler; CAF – hot water boiler; RT1 – heat water collector distribution; RT2 – heating network

As a numerical example, the sensitivity of the reliability indicator is analized for a gas turbine CHP supplying hot water for district heating and electricity for the National Electric System (SEN). The thermo-mechanical scheme including the compression gas system (GCS), the gas turbine installation (GTI), the exhaust system electricity (SEVEE) and the exhaust system heat (SEVC) is shown in figure 1. For each of these subsystems which constitutes a failure group and for the overall CHP, reliability indicators have been estimated, (Hazi et al. ,2010).

Reliability indicator	Failure group				CHP
	GCS	GTI	SEVC	SEVEE	
yearly mean time to failure removed by repairs	754.27	795.23	58.97	478.07	1798
yearly mean time to failure removed by manoeuvres	1.04	0.79	7.46	0.48	7.97
yearly mean time to failure	755.31	796.03	66.43	478.55	1806

Tab. 1. Yearly mean time to failure, [h/year]

No.	Equipment	Sensitivity of T_{an} [h/year*ur] GCS	Sensitivity of T_{an} [h/year*ur] CHP
1	Gas compressor	3.448	1.218
2	Engine of gas compressor	406.207	305.51
3	Oil pump	0.875	*
4	Oil cooler	0.364	*
5	Water circulation pump	214.36	160.56
6	Water cooler	36.57	26.24

* Insignificant influence

Tab. 2. The sensitivity of the yearly mean time to failure to the failure rates of equipments for SCG and CHP.

No.	Equipment	Sensitivity of T_{an} [h/year*ur] GTI	Sensitivity of T_{an} [h/year*ur] CHP
1	Air compressor	3.41	1.218
2	Combustion chamber	173.74	131.22
3	Gas turbine	11.94	7.73
4	Recovery boiler	0.792	*
5	Generator	127.19	95.69
6	Air filter	4.34	1.929

* Insignificant influence

Tab. 3. The sensitivity of yearly mean time to failure to the failure rates of equipments for GTI and CHP.

No.	Equipment	Sensitivity of T_{an} [h/year*ur] SEVC	Sensitivity of T_{an} [h/year*ur] CHP
1	Water-water heat exchanger	0.03	*
2	Hot water boiler	7.243	4.08
3	Water circulation pump	9.405	4.98

* Insignificant influence

Tab. 4. The sensitivity of the yearly mean time to failure to the failure rates of equipments for SEVC and CHP

The success state is considered to be: 100% of electricity supply and 100% of heat supply.

The failure rate and repair rate of components have been considered those of the standard, (*** NTE 005/06/00, 2006) and of the literature (Bendea, 2002).

In table 1 we presented the yearly mean time to failure with two components: for each subsystem and for the overall CHP. This indicator shows that:

- The yearly mean time to failure removed by repairs is higher for thermo-mechanical equipments, GCS, GTI
- The yearly mean time to failure removed by manoeuvres is lower for electrical equipments, SEVEE
- The yearly mean time to failure is the smallest for SEVC due to the high reservation of the equipment.

The sensitivity of the yearly mean time to failure for subsystems (GCS, GTI, SEVC) and for the overall CHP are presented in table 2 through 4. From these results we can see that the reliability of the installations is significantly influenced by the following components:

- The gas compression system and the water circulation pump for the GCS
- The combustion chamber and the generator for the GTI.
- The CAF and the water circulation pump for the SEVC
- The reserved equipments have an insignificant influence on the CHP. Therefore the sensitivity of the yearly mean time to failure to the failure rates of equipments for SEVEE was not presented in the paper.

4. CONCLUSION

The objective of this work was to find a way to estimate the influence of the reliability of equipment components on the reliability of the equipment and on the reliability of entire plant. For that purpose we used the sensitivity of the yearly mean time to failure to the failure rates of equipments.

From the numerical example we can conclude that this sensitivity is significantly higher for thermo-mechanical equipments and insignificant for the reserved equipments.

The calculated sensitivity allows us:

- To establish which equipment significantly influences the reliability of the installation and to appropriately plan for preventive maintenance activities.
- To determine, using equation (5), the effects of increased reliability on the reliability of the power plant equipment.
- To establish the amount of reserve equipments and spare parts for the equipments which significantly influence the reliability of the power plant.

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