



GENERATOR – SEAL OIL SYSTEM

Eskom power utility utilized Flownex SE simulation capabilities to mitigate system shutdowns caused by Generator Hydrogen (H₂) Seal ring failures. Engineers modelled the Hydrogen seal systems and used the simulated results to identify the cause of their system trips.

Flownex allowed the engineers to form an improved understanding of their systems and identifying the main contributing factor to these failures, thus preventing numerous future outages due to seal oil repairs, which in turn led to a financial benefit to Eskom.



FOSSIL FUEL POWER GENERATION

CHALLENGE:

The challenge was to perform a root cause analysis of system trips caused by generator seal ring failures, a Flownex model was used to:

- Identify the relationship between system pressure and seal clearances.
- Plot system pressure at various shaft speeds thus explaining why this failure was picked up at higher rotor speeds.
- Propose monitoring requirements (be it flow, system pressure, etc.) to anticipate seal failure.

BENEFITS:

The benefits in using Flownex for this situation were as follows:

- Flownex SE quickly determined the root cause of system inefficiencies and unexpected responses (low seal oil pressure).
- The model could be used in future to determine system operation when changing certain parameters.
- Flownex allowed engineers and operators to make calculated decisions during operation to ensure that the highest quality and standards were met.

SOLUTION:

The information gathered from conducting the different scenario simulations indicated that the float gap might be the obvious problem for a Seal Oil trip. It was illustrated by Flownex that the float gap clearance was out of specification and this enabled an increase in flow and decrease in pressure.

"The sealing interface, float and baffles are considered as one seal. Flownex assisted me in breaking down the seal into sub-components in order to understand and evaluate the flow characteristics. Using the results gathered from these sub systems together with the overall input and output simulations it was evident that the float gap insufficient."

Jacobus Hodgman (M.Eng), Plant Engineer, Turbine Plant Engineer, Eskom

INTRODUCTION

Power Stations can suffer from Hydrogen (H₂) Seal ring failures on generation units. These failures are not detected when the machines are in standstill or turning gear operation. It is only detected when the machines pick up speed above 2500 rpm.

In order to inspect and or replace the dysfunctional H₂-seals, the machine are shut - and cooled down for three days which in turn leads to substantial financial implications.

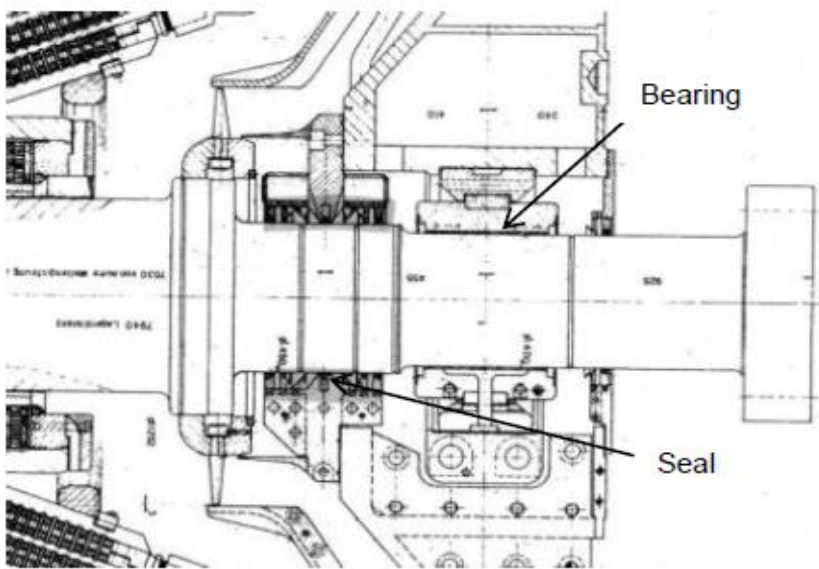


Figure 1: Schematic of the generator shaft seal and bearing pedestal

Various opinions on the cause of these failures exist, with most being attributed to consequences in the loss of the H₂- and Seal oil differential pressure.

SYSTEM DESCRIPTION

The AC-seal oil pumps supplies degassed oil through the cooler and filter to the generator bearing seals, which is then pumped into the pressure chamber V¹. The oil passes from the pressure chamber V and is forced through the apertures in the sealing ring and radially onto the shaft before escaping axially at both sides through outlets. This prevents the direct escape of gas from the generator and at the same time prevents the ingress of air direct into the generator.

“In order to inspect and or replace the dysfunctional H₂-seals, machines are shut - and cooled down for three days which in turn leads to substantial financial implications.”

¹ The pressure chamber V is the part of the seal that contains the sealing ring

There are two chambers on the shaft:

- The Air chamber (A) and
- The Hydrogen chamber (H)

The oil flowing through chamber A absorbs air whereas the oil flowing through chamber H takes in hydrogen. The oil which contains air drains into an air defoaming tank where it settles and allows the trapped air bubbles to escape. The same process occurs in the hydrogen defoaming tank with the oil containing hydrogen.

The oil is then transferred to the main tank where the physically dissolved gasses are removed under vacuum (degassed oil).

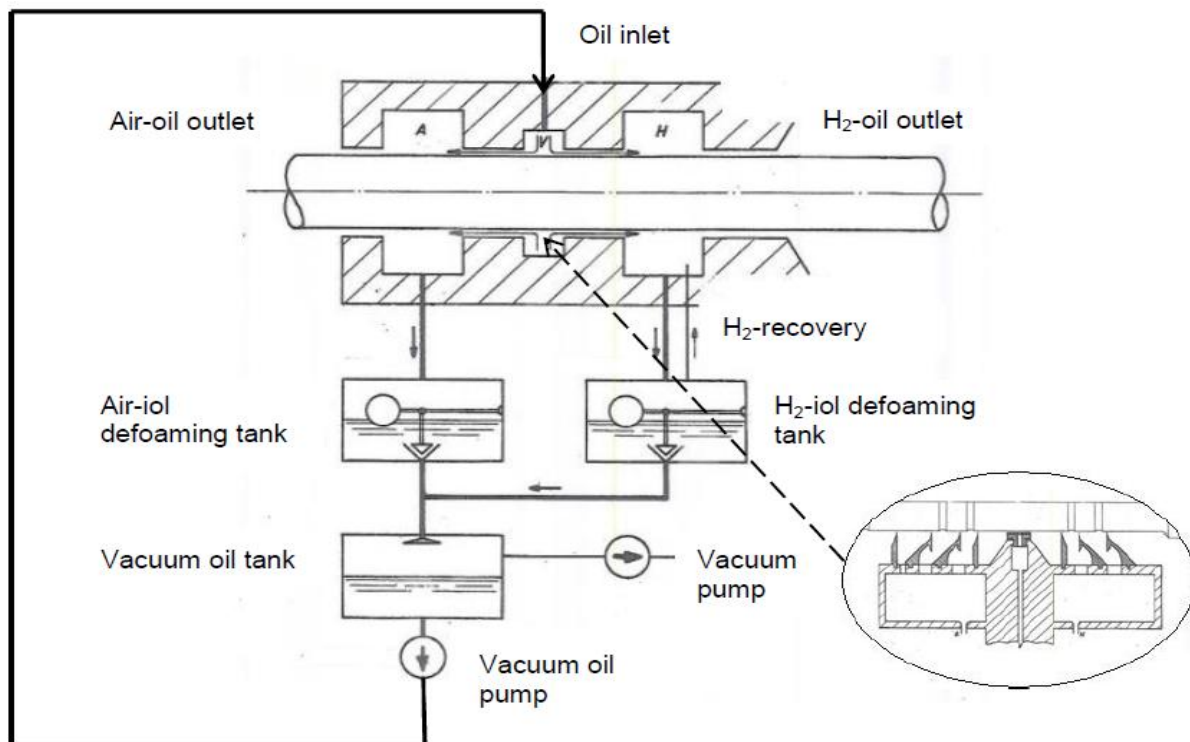


Figure 2: A basic layout of the seal oil system

Pressurisation of the system is controlled by the cutting in of the AC- or DC seal oil pumps when oil over-pressure relative to hydrogen pressure is too low. When the oil pressure drops below the minimum permissible level the capa-regulator comes into operation. After a two second delay this switches the second AC-oil pump on.

Should the AC-pump not start after a further one second delay the DC-pump receives a switch on command. This switch to the DC-pump activates an alarm that is installed for the implementation of turbine trip protection.

OBJECTIVE OF SIMULATION

The Hydrogen seal was simulated in Flownex in order to determine reasons for the system trip. The expected deliverables for this simulation were as follows:

- A Flownex model that showed the relationship between system pressure and seal clearances.
- A Flownex model that showed the system pressure at various shaft speeds thus explaining why this failure was picked up at higher rotor speeds
- A proposal as to what monitoring was required (be it flow, system pressure, etc.) to anticipate seal failure.

FLOWNEX MODEL

A huge sum off technical data was necessary to construct the entire Flownex model. Some of the technical data that was used is listed below:

- The physical measurements for the H2-Seal Ring Clearances and the H2-Seal Bore Clearances was implemented into the Flownex model and provided by on-site engineering consultants.
- The minimum nominal bores of piping, valves and associated items were gathered from a plant walk down as all of the system information was not documented and available.
- Together with the on-site engineering consultants a dimensional analysis was done on all baffles, seals, inlet, outlet and seal clearances.

From this data a basic model was created and solved to ensure that no errors occurred within the program. The system components were implemented in individual phases to allow the monitoring of the system and ensured that the correct outputs were achieved.

"The system components were implemented in individual phases to allow the monitoring of the system and ensured that the correct outputs were achieved."

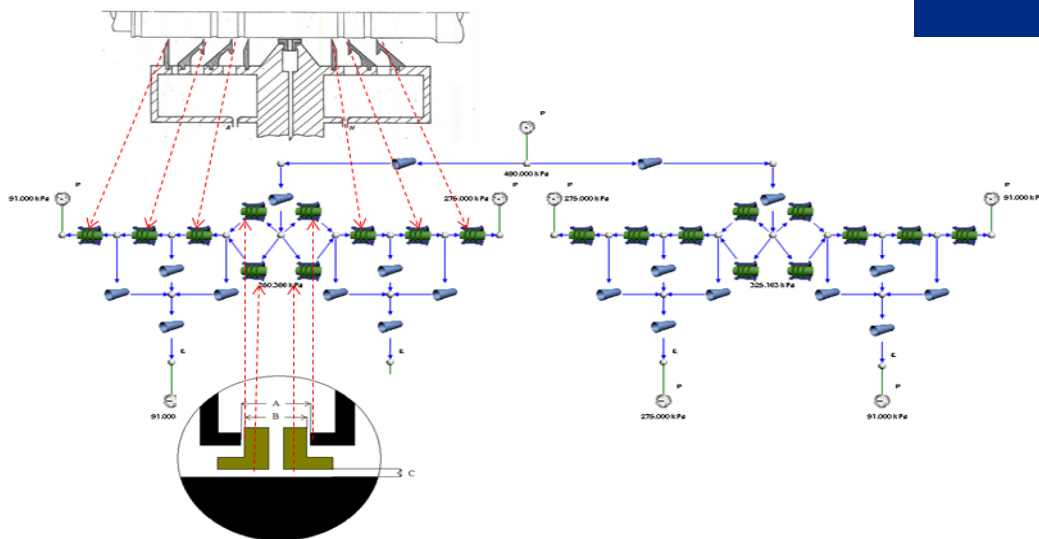


Figure 3: The constructed Flownex model

The seal was divided into different components for each baffle as well as for the actual sealing surface and the float gap. The oil that exited through the floating clearance and the actual seal were represented by two labyrinth seals in parallel. This was done for both the Non-drive-end and Drive-end on the air- and hydrogen side.

The three baffles on each side (Air and Hydrogen) were represented by labyrinth seals connected in series.

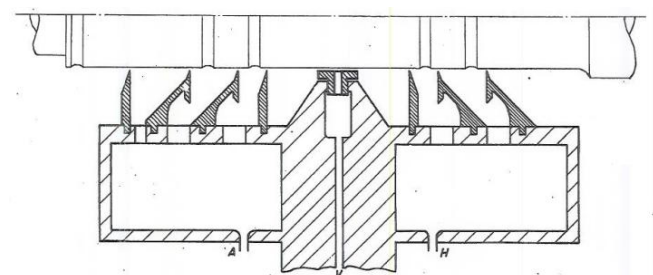


Figure 4: Detailed drawing of the oil seal

DESCRIPTION OF SIMULATION

Components that were used in populating the Seal Oil model were: Nodes, Boundary conditions, Labyrinth Seals and Piping.

Different scenarios were modelled and simulated in order to get a better understanding of how the system behaved. The process of modelling different scenarios allowed us to get an estimation of which clearances had the biggest impact on design pressure and flow.

Table 1: Five different scenarios used in the simulations

Scenario	Variables	Description
Scenario 1	Seal clearance	Baffles and float gap based on design values with the variation of seal clearances for both the NDE ² and DE ³ .
Scenario 2	Float gap clearance	Baffles and seal clearances based on design values with the variation of float gap for both NDE and DE.
Scenario 3	Baffle clearance	Seal clearance and float gap based on design values with the variation of baffle clearances for both NDE and DE.
Scenario 4	Seal and float gap clearance	Baffles based on design values with the variation of seal clearances and float gap for both NDE and DE.
Scenario 5	Normal and design clearances	Comparison between design values and measurements taken by Rotek Engineering.

"Different scenarios were modelled and simulated in order to get a better understanding of how the system behaved."

² NDE – Non-drive end (shaft bearing)

³ DE – Drive end (shaft bearing)

RESULTS

From our simulations it was obvious that the steam turbine tripped due to insufficient inlet oil pressure during the run-up. This cause was investigated in using 5 different scenarios.

Simulation 1-3:

The reason for these specific scenarios was to determine the impact that each of these components (sealing surface) would have on the oil pressure.

The results from these scenarios were as follow:

- The seal- and float gap clearances had a major effect on oil inlet pressure.
- The baffles had no impact on the oil pressure (the baffle only acts as a scraper to prevent the flow of oil to the generator)

Simulation 4:

Scenario 4 was based on the assumption that both the seal- and float gap clearances increased simultaneously. The float gap was in the direction of the oncoming oil and the distance for oil to travel was much shorter than for the actual seal.

It was concluded from our results that even the smallest float gap clearance could have had a major impact on the oil pressure.

Simulation 5:

This part of the simulation included comparing the design dimensions of the seal to the actual measurements in scenario 5.

The results from this scenario were as follow:

- The seal clearances differ immensely from the original design.
- When the measured values were run, a turbine trip automatically activated. The reason being that the allowed ΔP for the system was exceeded as soon as the turbine ran-up.

CONCLUSION

The information gathered from conducting the different scenarios simulations indicated that the float gap might be the obvious problem for a Seal Oil trip. It was illustrated by Flownex that the float gap clearance was out of specification and this enabled an increase in flow and decrease in pressure.

From our results it was evident that the float gap was wearing on both sides (seal and generator casing). It was recommended that a flow measurement be installed on both the DE and the NDE inlet piping. This installation will enable the operator to correlate

"From our simulations it was obvious that the steam turbine tripped due to insufficient inlet oil pressure during the run-up."

between system pressure, seal wear and flow. If the seal wears the pressure will drop and the flow will increase.

By identifying the main contributing factor to these failures may lead to the prevention of numerous future outages due to seal oil repairs, which in turn will result in less investigations and financial benefit to Eskom.

TESTIMONIAL

Testimonial provided by Jacobus Hodgman (M.Eng), Assistant Mechanical Eskom Plant Engineer, Turbine Plant:

"The sealing interface, float and baffles are considered as one seal. Flownex assisted me in breaking down the seal into sub-components in order to understand and evaluate the flow characteristics. Using the results gathered from these sub systems together with the overall input and output simulations it was evident that the float gap insufficient."

"Flownex assisted me in breaking down the seal into sub-components in order to understand and evaluate the flow characteristics"