

# Root Cause Failure Analysis of Stator Winding Insulation failure on 6.2 MW hydropower generator

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**Abstract.** Insulation failure on generator winding insulation occurred in the Wonogiri Hydropower plant has caused stator damage since ase was short circuited to ground . The fault has made the generator stop to operate. Wonogiri Hydropower plant is one of the hydroelectric plants run by PT. Indonesia Power UBP Mrica with capacity 2 x 6.2 MW. To prevent damage to occur again on hydropower generators, an analysis is carried out using Root Cause Failure Analysis RCFA is a systematic approach to identify the root cause of the main orbasic root cause of a problem or a condition that is not wanted. There are several aspects to concerned such as: loading pattern and operations, protection systems, generator insulation resistance, vibration, the cleanliness of the air and the ambient air. Insulation damage caused by gradual inhomogeneous cooling at the surface of winding may lead in to partial discharge. In homogeneous cooling may present due to lattice hampered by dust and oil deposits. To avoid repetitive defects and unwanted condition above, it is necessary to perform major maintenance overhaul every 5000-6000 hours of operation.

## 1. Background

Wonogiri Hydroelectric Power Plant is one of the renewable energy electric power plant managed by PT.Indonesia Power UBP Mrica with 2 x 6.2 MW. Damage in generator winding caused financial losses of Rp. for repair cost Rp. and loss of output Rp. Based on the above problems PT. Indonesia Power does not expect any disruption in operations generating repeated. Therefore the article with the title Root Cause Failure Analysis of Stator Winding Insulation failure on 6.2 MW hydropower generator can be in use as one way to find out the root problem of damage to the generator and found the failure defense task such damage, hence similar damage can be prevented early so that the continuity of power supply for the general population can be met.

RCFA (Root Cause Failure Analysis) is a systematic approach to identify the root cause of the main (basic root cause) of a problem or a condition that is not wanted. RCFA leads to knowledge on the factors contributing to the occurrence of potential failure [1]. By collecting technical data, operation, maintenance, and protection data then converted into a fault tree analysis diagram used to search for the root causes of stator winding insulation failure. Analysis begins loading pattern and operations, protection systems, generator insulation resistance, the cleanliness of the air and the ambient air temperature and vibration generator.



## 2. Methodology

Manual analysis method performed by fault tree Analysis with collecting parameters such as operating data and maintenance (generator operation, maintenance, system protection test result, winding insulation test and vibration test), then changing the analysis results in to fault tree analysis diagram to facilitate the analysis. Preceded by determining how the top event can be caused by individual event or combination several events that is under them [1]. Analysis is continued by looking into each failure code like electrical analyze include insulation resistance, protection systems, loading pattern, operation pattern, environment analyze includes air temperature and ambient air hygiene, mechanical vibration and cooling system.

## 3. Discussion

bservations on operating parameters:

From the data obtained that the generator operation is still in the safe operating limits of the maximum limit of 6.17 MW from 6.5 MW and 0.71 MVAR of a maximum limit of 3.7 MVAR and amounted to 6.21 MVA of a maximum limit of 7.75 MVA [4].

Protection system test :

Differential relay on normal condition, there is no interference, because the operating current for diferential relay is followed the Equation (1).

$$i_d = i_1 - i_2 \quad (1)$$

$$i_d = 3.389 - 3.389 = 0 \text{ Ampere,}$$

In the case, there is disruption of the generator phase to ground then it will get  $i_d \neq 0$  then the differential relay will work [3], how ever, differential relay is still in good condition and it is not trip.

Insulation test :

Using IEEE Standard Std. 43-2000, IEEE Recommended Practice for Testing Insulation Resistance of Rotating calculated by the formula of minimum insulation resistance  $(U_n + 1) \text{ M}\Omega$ ,  $U_n = \text{kV}$ [2]. Testing insulation resistance between the phases U-G is 2.196 G $\Omega$  and it is considered as normal, measurement between phases V-G is at 1.35 G $\Omega$  (normal) and between phases W-G is 10 K $\Omega$ . The last measurement is considered below the standard of 7 M $\Omega$ . From the test results, there is indication that the phase W-G has insulation damage.

Insulation polarity index test :

The test is performed by injecting 2500 V dc. The polarity index shows measuring insulation is 10 K $\Omega$  and the injection voltage in the test equipment does not come out. Those indications shows potential of short circuit [2], then concluded that the generator at phase-W experienced short circuit to ground.

Measurement of winding resistant (Rdc):

DC resistance measurement indicates in the range 1  $\mu\Omega$  - 5  $\mu\Omega$  values with uncertainty of 1%, in the range of 5  $\mu\Omega$  - 10  $\mu\Omega$  the value uncertainty is 0.5%, in the range 10  $\mu\Omega$  - 200  $\mu\Omega$  the value uncertainty is 0.2%, It is concluded there is no short inter turn on coil according standard NEN-EN-ISO / IEC 17025[3]

Dissipation factor :

To determine the insulation damage caused by the increase in the number of air pockets (voids) in the insulation or increasing resistance in the semiconductor layer, the measurement of dissipation phase U to G with a value of DF 2.83% is normal, phase U to V with a value of DF 6.72% is normal, phase V to G with a value of DF 2.81% is within tolerance, phase V to W with a value of DF 9.67% is beyond the tolerance limit. The phase W to G has an indication of short circuit because the test voltage result is zero. Phase W to the U with a value of DF cannot be tested and it is an indication of short circuit because the voltage test result is zero[2].

Impedance Test :

Impedance Test using AC Current Voltage Injection has the results that Impedance  $Z$  for phase U is  $1.26\Omega$ , phase – V is  $1.25\Omega$ , and phase W is  $1.27\Omega$ . From this test concluded that the function of the inductance for both three stator winding phase is in normal and reasonable to do with a reinsulation [2].

Clean air and ambient air Temperature:

Winding failure 5 in stator coil insulation caused by the indication of partial discharge on the winding end side or bottom of generator stator. Visually visible damage on the upper side of the coil and bottom coil side of the upper winding phase -W does not appear abnormal. At the bottom of the winding phase –W, dark and white colors indicate short at the stator body as shown in Figure 1.



**Figure 1.** Short circuit W-phase stator generator

Indications of oil and dust deposits on the coil accumulated for a long time in the area shows that the generator stator air quality at generator stator cooling system has poor quality. This evidence is shown by the photo after the pull-out rotor in Figure 2.



**Figure 2.** Grid dirty obstruct the flow of cooling air

Figure 2 shows the evidence that by the discharge air temperature over the limit of maximum standards of 55 degree Celsius. Cooling system in hydropower generator stator Wonogiri is not optimal due to the accumulation of dirt, grease, and dust. The accumulation of dirt impedes the flow of air so that surface temperature at different winding is inhomogeneous and it arises a local thermal stress and triggers partial discharge. suspected that the partial discharge already occurs for long duration and cumulates since the last maintenance in 1994 or 18 years ago.

#### Vibration:

Vibration testing is done with the results of high enough vibration occurs at a pickup point at 3A at 4.04 mm/s and it is relatively normal. From observations of all tests conducted, there is evidence that the root problem of generator stator insulation damage caused by the failure of the generator stator insulation, short circuit in phase W to the Ground, and partial discharge. All these event occurs in sequence and it makes generator stop to operate. inhomogeneous cooling and web condition inside generator which is caused by deposits of dust and grease.

#### 4. Conclusion

From the analysis and discussion of Root Cause Failure Analysis Failure Isolation Generator Stator Winding described above, it can be concluded that:

1. The chosen method to find the root cause damage to the generator stator is Fault tree analysis.
2. Loading pattern and operation pattern generator capability curve is below safe limit 7.75 MVA.
3. Relay differential generator is still in good condition according to 30% settings of and test results.
4. The test results indicate resistance of insulation is breakdown at phase W-G phase with value of 10 K $\Omega$  and it is below the allowable minimum standard
5. Air Cooling system in hydropower generator stator Wonogiri does not work optimal due to deposit of oil, dirt and dust blocking the air passage to spread throughout the insulation layer of generator. The condition above causes the temperature of air is over maximum standard limit of 55°C.

#### 5. Suggestion

Generator maintenance is important to be applied for every 50000 to 60000 hours of operation or 5 years in order to anticipate the occurrence of insulation failure at generator stator winding.

#### References

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