# CONDITION MONITORING SYSTEM FOR GAS TURBINE GENERATOR IN KERAWALAPITIYA POWER PLANT

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## INTRODUCTION

In the case of electrical power generation. The generator cooling mechanism is a crucial factor which decides the reliability. Most of the available generators consist of air cooling systems and the condition of air is directly affected by the generator failures [1]. Most of the time ambient air quality is not satisfied due to carbon particles, salty mist, and moisture content. That low-quality air can cause damage to the rotor and stator windings directly. Therefore, it is essential to check the air condition continuously to ensure the required air quality standards within the generator compartment. Not only the air quality but also there are other few parameters which are neglected by commonly available condition monitoring systems that are still affecting the generator reliability. Kerawalapitiya power station is a combined cycle power plant, and it consists of two numbers of gas turbines and one steam turbine. All together three general electric brand generators are available. Each of the gas turbine generators have 100MW capacity and the steam turbine generator is 110MW. All three generators are industrial synchronous wound rotor brushless air-cooled generators.

The existing generator condition monitoring system consists of vibration monitoring, shaft displacement monitoring, generator bearing lube oil drain temperature monitoring, Generator lube oil pressure monitoring, generator partial discharge monitoring, magnetic flux monitoring and generator cooling air temperature monitoring. The partial discharge module monitors the partial discharge of generator stator winding. rotor flux monitoring helps to track generator rotor winding inner turns short circuits and location of the fault. Rotor shaft voltage detects the failures in the rotor winding insulation and the air temperature inside the generator is used to control the generator [2][3]. According to the overall situation, all those measuring parameters are essential to control the generator but the air quality related data and parameters that are taken through this system is not enough to detect the undesirable conditions in air inside the generator.

## PROBLEM STATEMENT

Gas turbine inside the generator gets cooled by taking fresh air from the surrounding. Sometimes the ambient air quality is not satisfied with the required standards due to carbon particles, salty mist and moisture level. [4] That low quality air causes damages to the rotor and stator windings. Usually the rotor & stator insulation is reduced to kΩ range when the generator is at the standby mode due to deposited particles, as a result of low-quality air inside the generator. Gas turbine takes 24 hours outage for turbine washing in every 250 hour operation cycle. So those days generator rotor winding should be heated using DC current injection system to keep the insulation resistance level at a recommended level. To prevent moist and salty air entering to the generator compartment, silica gel vessels were installed with air filters. However, it was not successful since the silica gel vessels were required to change frequently within a short time duration. After that instrument air system was installed to supply conditioned air to the generator. Although that attempt was successful, since there was not any air condition monitoring system, there could be low inside pressure situations and that may cause the lube oil entering from bearing to the generator inside. Hence it is important to maintain required air pressure levels at generator inside. Not only that but also the dust and moisture levels of inside air should be maintained to protect the windings. Shaft grounding brush AC-DC current & voltage monitoring is very important to identify the insulation defects of the rotor & the bearings as well as malfunctions of the grounding brushes. Also, it can help to prevent potential bearing damages with the continuous monitoring of shaft voltage and grounding current through the grounding brushes.

## METHODOLOGY

Once the proposed parameters are measured from the field that can be sent to the controller through the available analog input cards. Using the membership function which was built based on previous data it is possible to analyse the condition inside the generator. The output will be generated based on the created fuzzy logic rules. An alarm will be created if the conditions are not complied with the pre created conditions.

Operating data ranges of the parameters are used to develop the membership function of the fuzzy logic system. The values below the normal operating range will be considered as low values & the values above the normal region will be considered as higher values.

**Table 1:** Fuzzy logic input membership function data for load condition

| Input | low | | | | Normal | | | | High | | | | Function Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | 0 | 0 | 40 | 60 | 40 | 60 | 100 | 120 | 100 | 120 | 200 | 200 | Trapezoidal |
| b | 0 | 0 | 250 | 270 | 250 | 270 | 530 | 550 | 530 | 550 | 600 | 600 | Trapezoidal |
| c | 0 | 0 | 10 | 15 | 10 | 15 | 25 | 30 | 25 | 30 | 50 | 50 | Trapezoidal |
| d | 0 | 0 | 50 | 70 | 50 | 70 | 130 | 150 | 130 | 150 | 200 | 200 | Trapezoidal |
| e | 900 | 900 | 980 | 1000 | 980 | 1000 | 1010 | 1030 | 1010 | 1030 | 1200 | 1200 | Trapezoidal |
| f | 0 | 0 | 5 | 10 | - | - | - | - | 5 | 10 | 80 | 80 | Trapezoidal |
| g | 0 | 0 | 25 | 35 | 25 | 35 | 115 | 125 | 115 | 125 | 150 | 150 | Trapezoidal |

**Table 2:** Fuzzy logic input membership function data for no load condition

| Input | low | | | | Normal | | | | High | | | | Function Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | - | - | - | - | 0 | 0 | 8 | 10 | 8 | 10 | 50 | 50 | Trapezoidal |
| b | - | - | - | - | 0 | 0 | 12 | 15 | 12 | 15 | 50 | 50 | Trapezoidal |
| c | - | - | - | - | 0 | 0 | 4 | 5 | 4 | 5 | 20 | 20 | Trapezoidal |
| d | - | - | - | - | 0 | 0 | 12 | 15 | 12 | 15 | 50 | 50 | Trapezoidal |
| e | 900 | 900 | 980 | 1000 | 980 | 1000 | 1010 | 1030 | 1010 | 1030 | 1200 | 1200 | Trapezoidal |
| f | 0 | 0 | 5 | 10 | - | - | - | - | 5 | 10 | 80 | 80 | Trapezoidal |
| g | - | - | - | - | 0 | 0 | 35 | 40 | 35 | 40 | 100 | 100 | Trapezoidal |

## FUZZY LOGIC SYSTEM DESING

Proposed system consists of 7 inputs and 5 outputs which has been mentioned above.

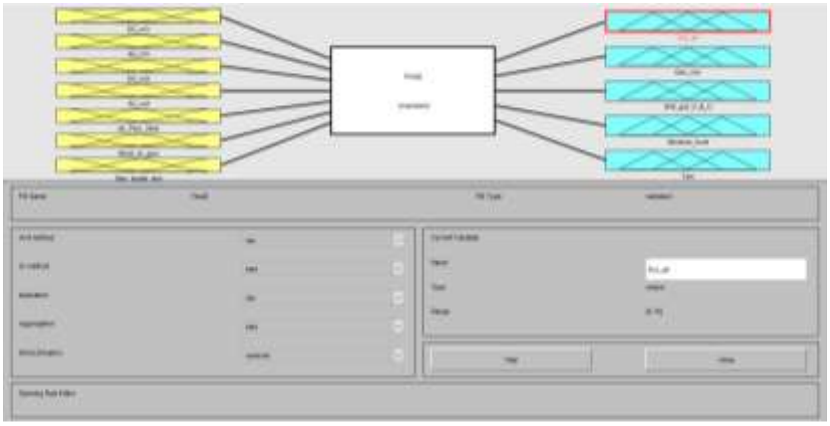

Figure 1 Fuzzy logic system

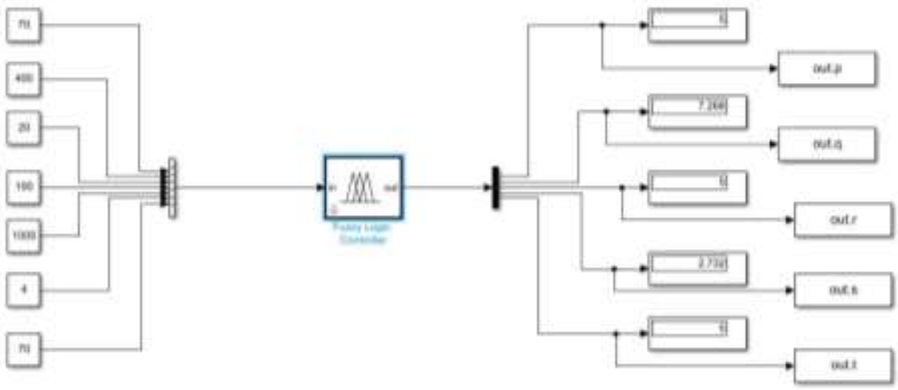


Figure 2: MATLAB Simulink interface

## RESULTS AND DISCUSSIONS

If a rotor failure is detected, the reason for that failure will also be identified by the system via analysing the different failure factors. Since no precise inputs are required for the process, the proposed system can be identified as a robust control system with effective results. If the readings taken from the sensors to the control system are different than the reference conditions, the system will provide warning alarms to prevent generator rotor failures which could occur in the future. Required data and storage capacities for the proposed system is comparatively lesser when compared with the other existing control systems.

To check the effectiveness of the proposed design, ten different input incident profiles were created based on the actual data of Shaft ground current & voltages, Moisture level, Generator inside air temperature & pressure taken from the plant database. Then the received simulation results were compared with the actual outputs of each incident and all the received system outputs were matched with the actual incident outputs and hence the effectiveness of the proposed system was validated. The test results are given in the table below.

**Table 1:** Test Results

| Input variable | Test 01 | Test 02 | Test 03 | Test 04 | Test 05 | Test 06 | Test 07 | Test 08 | Test 09 | Test 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| a | 70 | 5 | 70 | 70 | 70 | 70 | 70 | 10 | 120 | 120 |
| b | 400 | 400 | 40 | 400 | 400 | 400 | 400 | 400 | 400 | 400 |
| c | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| d | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| e | 1005 | 1005 | 1005 | 900 | 1005 | 1005 | 900 | 900 | 900 | 1005 |
| f | 4 | 4 | 4 | 4 | 15 | 4 | 15 | 15 | 15 | 4 |
| g | 70 | 70 | 70 | 70 | 70 | 125 | 125 | 125 | 125 | 80 |
| Output variable | | | | | | | | | | |
| p | 5 | 5 | 5 | 1.737 | 5 | 5 | 1.737 | 1.737 | 1.737 | 5 |
| q | 7.268 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| r | 5 | 3.73 | 3.73 | 5 | 5 | 5 | 5 | 3.73 | 6.27 | 6.27 |
| s | 2.732 | 2.732 | 2.732 | 2.732 | 7.268 | 2.732 | 7.268 | 7.268 | 7.268 | 2.732 |
| t | 5 | 5 | 5 | 5 | 5 | 8.263 | 8.263 | 8.263 | 8.263 | 5 |

| | |
|---|---|
| Alarm condition | (yellow) |
| Warning condition | (red) |
| Good Condition | (green) |

Apart from the proposed control system, it was proposed to modify the inside air system of the existing generator with a treated air system. Originally, it was designed with ambient air, and the high moisture content in the ambient air may weaken the insulation resistance of the generator. Hence, the generator insulation resistance was improved and then the inside conditions of the improved generator were used as reference conditions to the proposed fuzzy control system.

## CONCLUSION

The proposed Fuzzy logic system can be used to detect incidents related to rotor failures. The inputs to the fuzzy membership function are generator shaft ground DC voltage (mV), generator shaft ground AC voltage (mV), generator shaft ground DC current (mA), generator shaft ground AC current (mA), generator inside absolute pressure (mbar), generator inside moisture level (ppm) and generator inside air temperature (°C). The generator dry air condition, generator overall condition, shaft ground voltage & current condition, generator moisture level condition and inside temperature condition are the fuzzy logic system outputs. This system will generate warning alarms when the air condition is poor under both normal operating and turning gear conditions and it also has the ability to re-analyse the limits using the collected operational data. With the proposed model it is possible to analyse the air conditions and that will avoid air quality related failures of the gas turbine generator while enhancing the overall system reliability. Hence, the plant availability can be improved while maximizing profits.

## REFERENCES

Hee-Dong Kim†, Tae-Sik Kong, Kyeong-Yeol Kim, ‘Analysis of Insulation Diagnosis and Failure in Stator Windings of Air-Cooled Gas Turbine Generator’, KEPCO Journal on Electric Power and Energy, Vol. 2, No. 3, Korea Electric Power Corporation, September 2016.

Ronald J. Zawoysky, Karl C. Tornroos, ‘GE Generator Rotor Design, Operational Issues, and Refurbishment Options’. GE Power Systems _ GER-4212 _ (08/01)

G.C. Stone, M. Sasic, D. Dunn, I. Culbert. 'Recent Problems Experienced with Motor and Generator Windings'. IEEE Paper No. PCIC-2009-6.

Dr. Rudolf Brütsch, Dr. Tilman Weiers, Makoto Tari, Dr. Ruben Vogelsang, Prof. Dr. Klaus Fröhlich. 'Insulation Failure Mechanisms of Power Generators'. DEIS Future articles, July/August 2008 — Vol. 24, No.4

S. N. Sivanandam, S. Sumathi and S. N. Deepa, 'Introduction to Fuzzy Logic using MATLAB' ISBN-10 3-540-35780-7 Springer Berlin Heidelberg New York

Gary Griffith, Shelagh Tucker and Jason Milsom, Greg Stone. 'Problems with Modern Air-Cooled Generator Stator Winding Insulation' IEEE Electrical Insulation Magazine, November/December 2000 — Vol. 16, No. 6

Jangho Yun, Bin Lee, Greg C. Stone, 'Reliable Flux-Based Detection of Field Winding Failures for Salient Pole Synchronous Generators'. IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 34, NO. 3, SEPTEMBER 2019