

Health Index & Life Expectancy of Generators

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Abstract— Rotating machines are very vital parts of the industries. Reliability of machine depends on its health and condition. Life of rotating machines is critical in view of availability. Every machine has its own calculated life. Designed life can estimate by considering various factors such as insulation material used, operating condition of machine, environmental conditions etc. During life span if any severe fault occurs then remaining life will reduce or machine life ends. Fault withstand capacity depends on the machine present strength. If we can get information of machine present strength then we can estimate its life in view of certain stress due to fault of critical operating conditions. Strength of machine is strength of its insulation system. Mica is base material used in high voltage Rotating Machines. Here insulation related machine life will be discussed. Insulation aging behavior is depends on various factors such as Temperature, Moisture, Electrical stress etc. Strength of insulation become weaker as the age is elapsing. Stress to insulation is varying based on various condition of Load, Voltage quality, surges, sudden changes, mechanical stresses and chemical expose. To understand the life of machine, insulation system need to understand first, right from design, manufacturing and operation. Life curve of machine will be discussed and algorithm for life will be established. Further health index will be calculated based on various test of machine and health index will be correlate with life expectancy.

Key words: Health Index, Life Expectancy, HV Machine, Generator, Insulation Aging

I. INTRODUCTION

When stresses act on the insulation of the stator windings, there is a progressive deterioration of the strength of the insulation. In other words, ageing is exhibited by a progressive deterioration of the physical properties of the insulation. Not all physical properties can give an indication of the progression of ageing, except perhaps those directly related to failure, e.g. electrical breakdown strength and mechanical strength. If stresses unable to produce a failure are considered such as temperature or chemical exposure, other failure criteria are selected that are related to electrical or mechanical breakdown strengths. In any case, failure essentially occurs when the selected property drops down to a limiting value, so that a unique definition can be adopted for remaining life – the time for the selected property to reach that point. This point is generally related to the stresses that are developed in the stator insulation during machine operation. In other words, when the strength of the insulation deteriorates to a point where it equals the developed stresses in the insulation, the insulation will fail.

II. INSULATION OF HV MACHINES

The base material of all HV machines insulation system is Mica. It is a mineral silicate. It used with various materials

such as potassium mica, sodium mica, lithium mica, magnesium mica, and iron mica based on their compositions. Its voltage withstand capacity is very high. Also it can withstand high temperature also normal Class B, F and H above 130°C. It also supported by resin rich system, resin poor system and epoxy resin system. Additionally epoxy bonded glass tape and epoxy bonded mica composite tape are used for more mechanical strength. It also consist of Corona grading system at the end of the slot portion and semiconducting coating throughout the slot area.

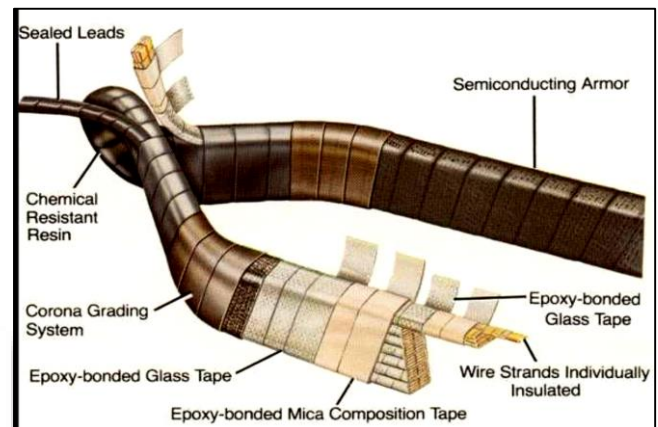


Fig. 1: Winding Insulation System

III. FACTOR AFFECTING LIFE OF INSULATION SYSTEM

Any insulation is subjected to aging there for insulation characteristics are degrading day by day. Normally aging is a chemical phenomenon which accelerates with stresses applied to it. The most important types of stresses to which the insulation is subjected are electrical, thermal and mechanical. Considering the conductor insulation in a HV rotating machine, this insulating structure encounters the three stresses at the same point in time. In order to understand the processes leading to insulation degradation, it is necessary to develop a physical model which connects the nature and magnitude of the various stresses and the time at which a failure ensues. One of the simpler methods of building the model is to assume that the stresses are applied in sequence and arrive at the distribution pattern of times to failure of nominally identical specimens. This type of testing is called the sequential testing and was applied to insulation failure degradation acquisition some time ago. This model is defective in the sense that the existence is ignored of interaction of failure modes due to the simultaneity of application of stresses, which gives rise to secondary degradation processes of significant magnitudes. Degradation of insulation cause to change various characteristic and nature of the insulation. Also creates some symptom of aging, such as delamination of layers, contamination over surface, pits on surface etc. When stress is become more than its strength the machine insulation fails hence life of machine ends.

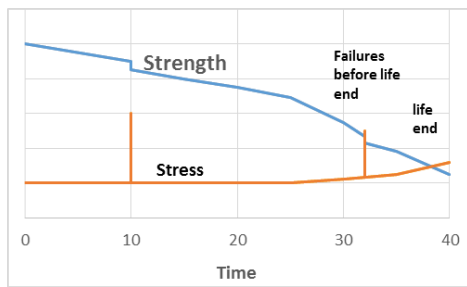


Fig. 2: Life phenomenon of machine

As per the figure 2 the intersection point of the stress and strength line is the actual span of the life there for that point is end of life point for the machine. Here stress line is shown straight however in real condition stress can be higher and lower with respect to various operating condition of the machine applied load and voltage. Strength of insulation can be measured by various state of art techniques. Basically these are condition monitoring tools to determine the condition and health of the machines.

IV. TESTS FOR LIFE EXPECTANCY

Strength of insulation or machine can be measured by various state of art techniques. Basically these are condition monitoring tools to determine the condition and health of the machines. Various test are related to various part of the machine. Some are insulation related and some are related to operation and malfunctioning. Some test give information about insulation aging or insulation condition. Which are

- 1) Tan-delta & Tan-delta Tip up test
- 2) Partial Discharge Measurement
- 3) Insulation resistance test &
- 4) Polarization index
- 5) Dielectric Discharge
- 6) ELCID (Electromagnetic Core Imperfection Detection)

These set of test will be used in the life estimation of the machine and life analysis will be done on basis of data obtained.

V. HEALTH INDEX AND LIFE EXPECTANCY METHODOLOGY

Health index will be a number but have four stage indicator which will be as follow

- 1) Excellent category
- 2) Good category
- 3) Moderate category
- 4) Critical Category

These four category will derived from various tests conducted on machines. Each test have their own limits and index in a scale of 1 to 10. 1 will be poor and 10 will be excellent condition. This will be based on previous results, case studies, various standards limits, and various OEM Guideline based on their database. Each test will have their own weightage factor. Weightage factor decided on the basis of nature and criticality of that test.

Health Index will be average of weighted sum of individual test indices. Based on these Health Index we will try to evaluate life expectancy of machine. As Health index is not directly related to life expectancy of but it can give idea of the life by considering some parameter in constant

A machine design life is around 30-45 years if no unexpected fault of stress occurred during its operative life.

It can be lower or higher based on the stress applied during its life cycle. Manly thermal, Electrical (voltage) & mechanical (vibration) stress are applied during operation. If we consider these as constant stress then life can be estimated based on present condition (Strength) of machine.

Tests	Excellent (10-8)	Good (7-6)	Moderate (5-4)	Critical (3-1)
Tan-delta	0.02 – 0.035	0.036 – 0.05	0.051 - 0.07	0.07 - 0.15
Tan-delta Tip-up	0.001 – 0.003	0.0031 - 0.005	0.0051- 0.0065	0.0065 - 0.010
Partial Discharge (pC)	2000 - 5000	5001 - 10000	10001 - 15000	15001 - 20000
IR (GΩ)	>100 - 50	49 - 10	9 - 1 + kV(k Ω)	< 1 + kV(k Ω)
PI	> 2	2 - 1.5	1.51 - 1	< 1
DD	1-3	4-5	6-7	8-10
ELCID (mA)	30-70	71-110	111-200	201-400

Table 1: Recommended Valued of Various Tests For Health Index

Tests	Weightages
Tan-delta	2
Tan-delta Tip-up	2
Partial Discharge (pC)	3
Insulation Resistance (GΩ)	1
Polarization Index	1
Dielectric Discharge	1
ELCID (mA)	1

Table 2: Weightage Factors for Different Technique

Weightage factor is decided based on the current practice of utilities, OEM and based on IEEE & IEC standards.

VI. CASE STUDY

A. A 210 MW Generator case study

A 210 MW Generator taken for study of Health index and life expectancy having following specifications.

Rating: 210 MW

Voltage: 15.75 kV

Phases: 3, Turbo Synchronous Generator

Frequency: 50 Hz,

Rated Speed: 3000 RPM,

Insulation Class: B

Cooling: Hydrogen

B. Health Index

Tests as mentioned in above section ware conducted. Values are given in table 3. Severe value among all three phase is considered for Health index calculation. Tests are conducted at ambient condition not in any controlled environment.

	Values	Index
Tan-delta	0.0114	10
Tan-delta tip-up	0.00036	10
Partial Discharge (pC)	6870	7
Dielectric discharge	0.66	10
Insulation Resistance (GΩ)	22.5	7
Polarization Index	3.30	7
ELCID (mA)	355	2

Table 3: Various Test Data and Respective Index

	Index	Weight	Weighted index
Tan-delta	10	2	20
Tan-delta tip-up	10	2	20
Partial Discharge (pC)	7	3	21
Dielectric discharge	10	1	10
Insulation Resistance (GΩ)	7	1	7
Polarization Index	7	1	7
ELCID (mA)	2	1	2
Overall Index			7.9

Table 4: Various Test Data and Respective Index

C. Life Expectancy

Health index	Condition	Description	Expected life
85-100	Very Good	Some aging or minor deterioration of a limited number of components	More than 15 years
70-85	Good	Significant deterioration of some components	More than 10 years
50-70	Fair	Widespread significant deterioration or serious deterioration of specific Components	Up to 10 years
30-50	Poor	Widespread serious deterioration	Less than 3 year
0-30	Very Poor	Extensive serious deterioration	At end of life

Table 5: Expected Life Based On Health Index

Here Obtained Health Index is 7.9 (79) hence expectancy will be more than 10 year as per above table. There are main concern is core area where laminations are short which may increase local temperature of core hence hot spot in winding may occur.

VII. CONCLUSION

Health index is one step ahead process of Condition monitoring which tell about healthiness of generator in terms of numbers on the scale of 0 to 10 or 1 to 4. Subsequently Life expectancy can also be calculated based on the health index. So it can be further step to condition monitoring and health monitoring of the machines. Various test can be used for the health index and approximate life can be predicted. Here confidence level will be around 60%. To increase confidence level more test and more factors need to include in this process. It may use finite element analysis also for more confidence. Even though the calculating remaining life of machine is only estimation and exact calculation is not practicable.

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