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Review on Trend of Diagnostic factor as a Function of Thermal and Multi Ageing Time of 6.6 kV Rotating Machine Insulation System

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Motivation

- The performance of an insulation system of rotating machine gradually deteriorates depending on operating condition, and finally electrical breakdown occurs.

- It is necessary to determine maintenance schedule of the insulation system in advance by predicting residual lifetime.
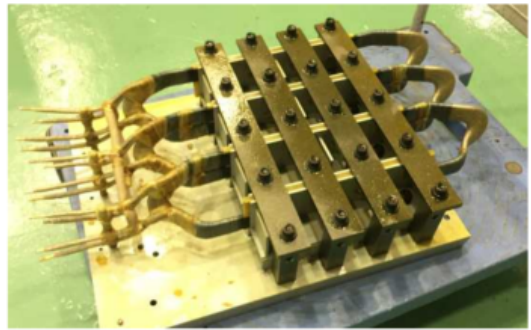

Fig. 1. A test specimen

Method/Approach

- Test specimen consists of strand/mainwall insulation tape, conductive/semi-conductive tape, shrink tape, and epoxy resin which are having a thermal index of F-class (155℃). → Fig. 1

- Thermal evaluation test and multifactor evaluation test were carried out based on IEC 60034-18-31:2012 and IEC 60034-18-33:2010. → Fig. 2

Objects of investigation

- Residual lifetime & reference values (Caution and Risk) of breakdown were proposed.

- The results of test of reference system will be utilized to improve lifetime and reliability of candidate systems.
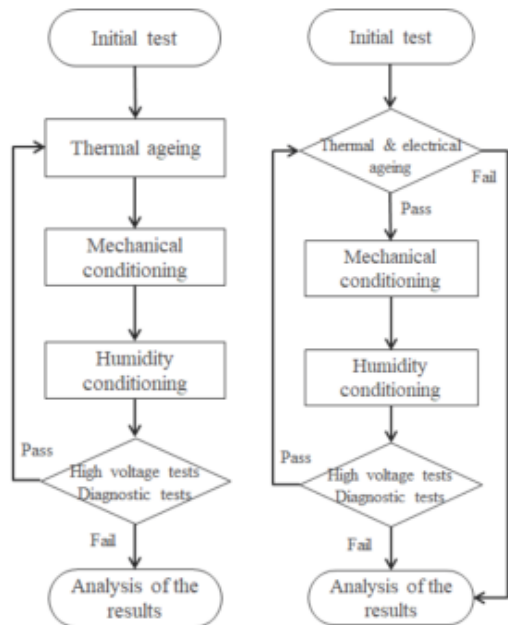
(a) Thermal evaluation test   (b) Multifactor evaluation test

Fig. 2. Flow charts of accelerated ageing test

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Test results/discussion (Accelerated life model)

- MTBF of thermal evaluation test was calculated as a, b, and c respectively.
  → Table 1, Fig. 3

- A temperature corresponding to the MTBF of 20,000 hours was 175℃.

- An estimated lifetime was 79 years (692,000 hours) in continuous operating condition at 120℃.

Table 1. Test results of thermal evaluation test

Section	Cumulative cycle [cycle]	Total number of specimens [each]	Number of specimen with electrical breakdown [each]	MTBF [hour]
Level 1 (180℃, 21-day/cycle)	24	9	0	a
Level 2 (210℃, 6-day/cycle)	25	9	4	b
Level 3 (230℃, 2-day/cycle)	16	6	6	c

- Note 1-1. Censoring of live specimens was carried out at the last cumulative cycle.
- Note 1-2. MTBF of each level was specified in Fig. 3.
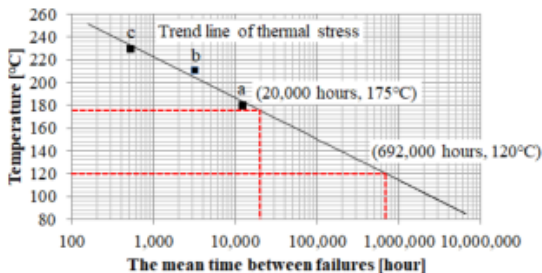

Fig. 3. Estimated lifetime curve of specimen through thermal evaluation test

- MTBF of multifactor evaluation test was calculated as d, e, and f respectively.
  → Table 2, Fig. 4

- An estimated lifetime was 81 years (710,000 hours) in continuous operating condition at 115°C and $1.1*U_N$ (7.26 kV).

Table 2. Test results of multifactor evaluation test

Section	Cumulative cycle [cycle]	Total number of specimens [each]	Number of specimen with electrical breakdown [each]	MTBF [hour]
Level 1 (145℃, 11.22 kV, 25-day/cycle)	11	5	3	d
Level 2 (155℃, 12.54 kV, 4-day/cycle)	8	5	3	e
Level 3 (165℃, 13.86 kV, 2-day/cycle)	11	6	2	f

- Note 2-1. Censoring of live specimens was carried out at the last cumulative cycle.
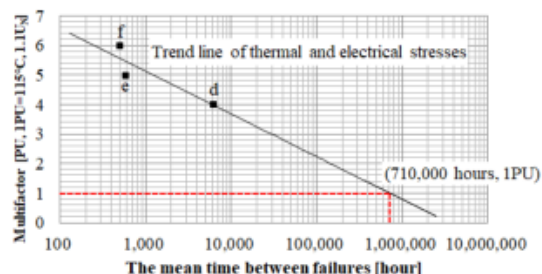- Note 2-2. MTBF of each level was specified in Fig. 4.

Fig. 4. Estimated lifetime curve of specimen through multifactor evaluation test

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Test results/discussion (Trend of diagnostic factor)

- The maximum values of delta-tan delta (U_N - $0.2U_N$) according to deterioration of inside defect of insulator with electrical breakdown (No. 3, No. 5, No. 7 and No. 8) were 6% or more or 6% close. → Table 3, Fig. 5

Table 3. Maximum value of loss tangent through thermal evaluation test at level 2 (210℃)

Division	Specimen	Maximum value [%]	Ageing time [hour]
Electrical breakdown	No. 3	6.07	1440
	No. 5	6.72	1296
	No. 7	6.14	1440
	No. 8	5.80	1728
Without electrical breakdown	No. 1	5.62	1872
	No. 2	5.58	1872
	No. 4	5.62	2016
	No. 6	5.65	1440
	No. 9	5.48	1008
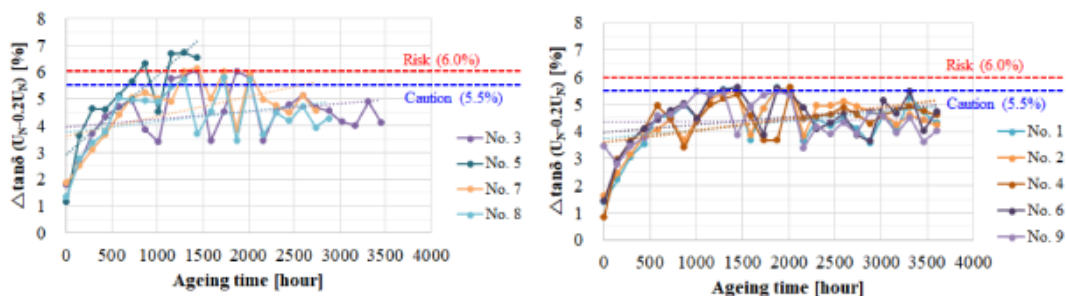
(a) Electrical breakdown specimens

(b) Live specimens without electrical breakdown

Fig. 5. Trend of loss tangent value through thermal evaluation test at level 2 (210℃)

Conclusion

- The estimated lifetime of this insulation system is about 79 years in continuous operating condition at 120℃ / about 81 years in continuous operating condition at 115℃ and $1.1*U_N$.

- Loss tangent was selected as trend of diagnostic factor, Caution (5.5%) and Risk (6.0%) were proposed for a value of delta-tan delta.