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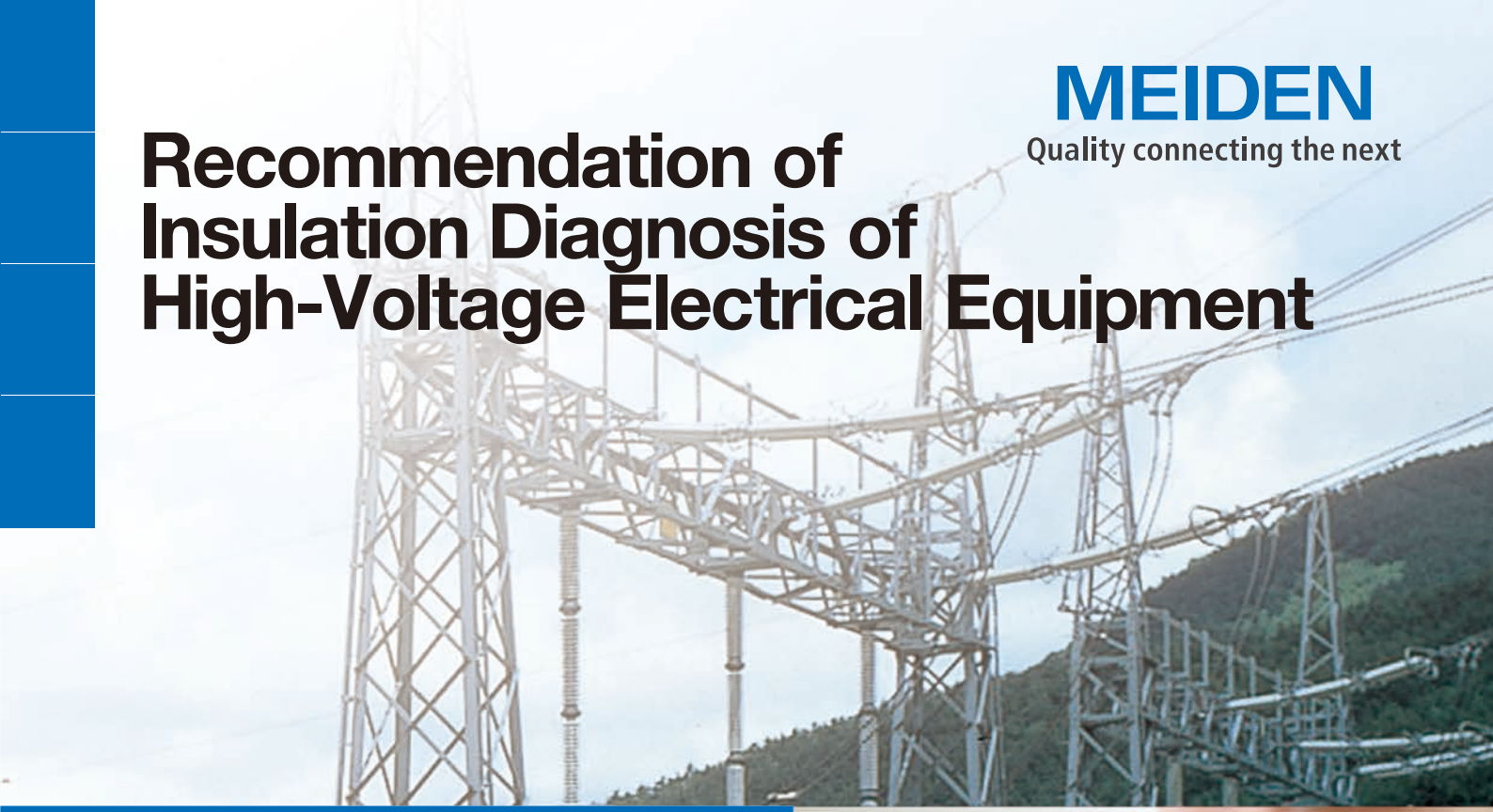
Quality connecting the next

Recommendation of Insulation Diagnosis of High-Voltage Electrical Equipment



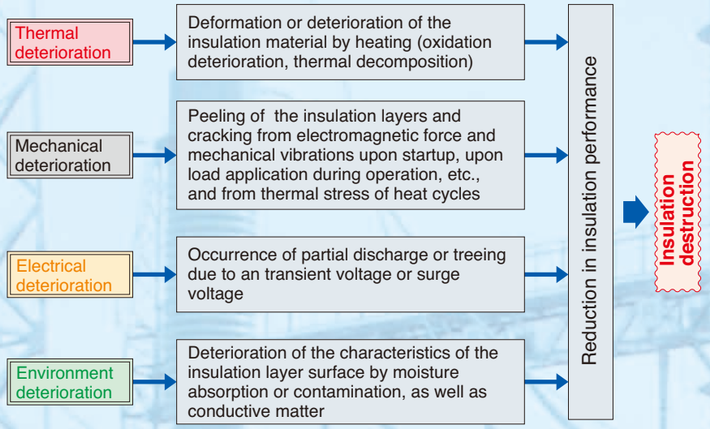
Periodic maintenance is also important for high-voltage electrical equipment

How healthy is the high-voltage electrical equipment you are using?

Deterioration of insulation

For a stable supply of electric power, it is important to ensure that high-voltage electrical equipment provides reliable long-term operation. However, various stresses during operation eventually cause deterioration of the insulation, reducing its function over time. Insulation deterioration is generally caused by the interrelation of many factors. Cleaning, repair, and other periodic inspections are important for eliminating deterioration and extending the life of the equipment.

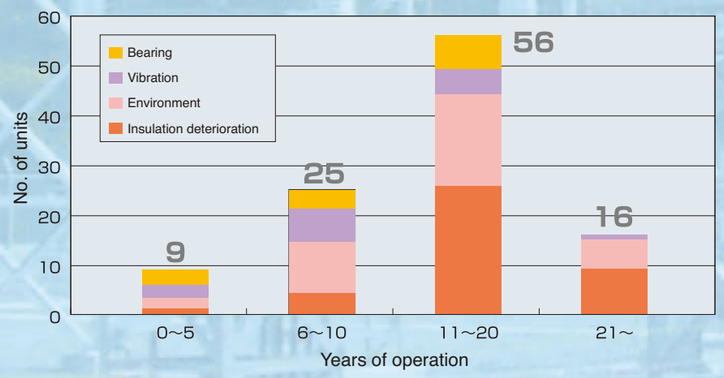
Process of insulation deterioration



Insulation breakdown accidents

Insulation deterioration is caused by overlapping multiple factors, i.e., thermal, mechanical, electrical, or environmental stresses, and progresses in a vicious circle. This shortens the life of the equipment, and in the worst case, may result in an insulation breakdown accident during operation. According to a technical report of the Institute of Electrical Engineers (Part II, Vol. 182), the occurrence of accidents mainly caused by insulation deterioration starts to increase ten years after the start of operation of high-voltage electric motors.
As deterioration inside the insulation cannot be detected by normal periodic inspections, insulation breakdown accidents occur unexpectedly and the repair time is long.

Years of operation and accident causes

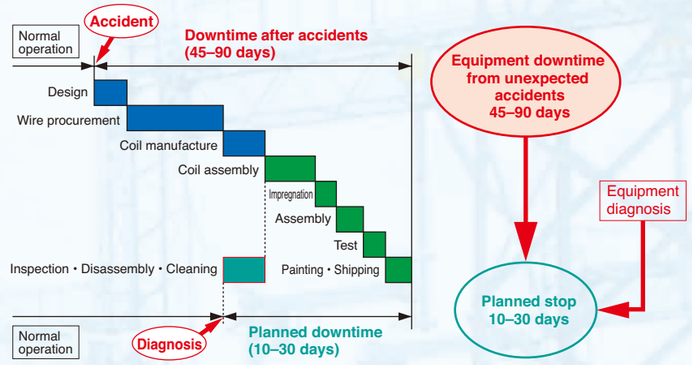


To prevent such insulation breakdown accidents, it is important to perform periodic insulation diagnosis using detailed test instruments in order to quantitatively determine the deterioration condition of the insulation over time.

Advantages of insulation diagnosis

1. Productivity increases due to reduced downtime losses

The deterioration of the components of electric equipment progresses with the number of years of operation. Particularly in the case of windings, etc., insulation deterioration is generally not visible from the outside, which can lead to unexpected insulation breakdown accidents. Periodic insulation diagnosis as preventive maintenance can improve productivity by considerably reducing downtime losses.



2. Quality diagnosis improves the reliability of the equipment.

By quantitatively and chronologically determining the contamination condition and degree of insulation deterioration and performing appropriate, timely maintenance, equipment damage and insulation accidents are decreased, and overall equipment reliability is improved. Furthermore, the servicing quality can be evaluated quantitatively by performing insulation diagnosis before and after the maintenance of transformers, rotating machines, etc.

Comparison data before and after maintenance of a dry transformer

			Before maintenance	After maintenance
Dielectric loss tangent test	tan δ0	(%)	0.89	0.87
	Δtan δ1 (E/√3)	(%)	0.13	0.01
	Δtan δ (1.25E/√3)	(%)	0.22	0.01
	Judgment		Good	Good
Partial discharge test	Qmax1 (E/√3)	(pC)	1100	60
	Qmax (1.25E/√3)	(pC)	1400	53
	Nq = [10 log (Qmax1/Qmax)]		1.05	0.54
	Judgment		Caution	Good

Before maintenance, the Δ tan δ in the dielectric loss tangent test was high, and the electric charge quantity of discharge in the partial discharge test frequently occurred with a load of 1400 pC. The measurement results after maintenance showed a decrease of Δ tan δ, and the electric charge quantity of discharge load was reduced to 53 pC. In the same way, the quality of the cleaning and drying conditions during the overhaul of rotating machines can also be evaluated from the transition of electrostatic capacity, resistance component current, etc., before and after maintenance.

3. Economical equipment improvement is possible.

The equipment life span is considered to be about 20 years, but it differs widely according to the operation conditions, environment conditions, etc. Rather than upgrading/improving the equipment based on its age, it is more economical to increase the estimation accuracy of the degree of deterioration by using insulation diagnosis for quantitative management over time and to implement effective measures at suitable times. For example, in the case of rotating machines, implementation periods for future insulation diagnosis, overhaul, coil rewinding, etc. can be selected according to the insulation diagnosis results.

Insulation breakdown examples

Insulation breakdown accidents occur more easily for electric equipment, cables, etc., that have been in operation for 10–15 years.

Examples of insulation breakdown accidents

Insulation breakdown of generator stator coils

Years in operation	20 years
Accident condition	Insulation breakdown at the coil end
Estimated cause	The fixing force of the coil deteriorated, and so the electromagnetic forces at the time of motor startup caused vibrations, resulting in wear and leading to insulation breakdown.

Insulation breakdown of electric motor stator coils

Years in operation	20 years
Accident condition	Insulation breakdown in the slot part
Estimated cause	The coil overheated due to the accumulation of dust, causing thermal deterioration and leading to insulation breakdown.

Insulation breakdown of electric motor stator coils

Years in operation	18 years
Accident condition	Insulation breakdown at the coil end
Estimated cause	Switching surges, etc., overlapped at locations where insulation deterioration from thermal and mechanical stress had progressed, leading to insulation breakdown.

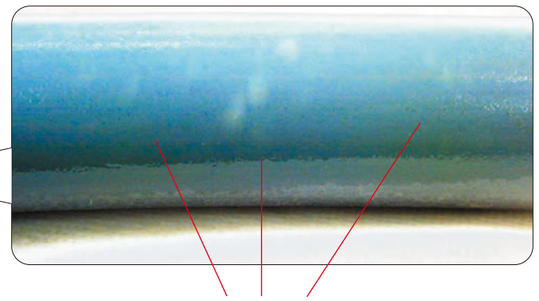
Transformer with insulation breakdown

Years in operation	19 years
Accident condition	Insulation breakdown on the side of the secondary winding
Estimated cause	Accumulation of dust on the winding surface, moisture absorption after stopping, and incursion of switching surges simultaneously occurred, leading to insulation breakdown.

High-voltage cable with insulation breakdown

Years of use	27 years
Estimated cause	Water tree deterioration progressed, leading to insulation breakdown.

The figure on the right shows a photo of the water tree phenomenon.



The white spots show the water tree phenomenon.

Electric equipment diagnosis vehicle

We recommend an electric equipment diagnosis vehicle equipped with various precision test devices for insulation diagnosis.

Features of an electric equipment diagnosis vehicle

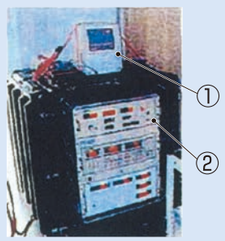
(1) Diagnosis of the object equipment is possible if it is within 50 m of the diagnosis vehicle. Measurement is possible even at locations that cannot be reached by the diagnosis vehicle because the diagnosis equipment is portable and can be unloaded from the diagnosis vehicle.
(2) As the transformer for testing is an auto-compensation type, the power supply capacity for testing is small: within 15 A for AC 100 V as well as for 200 V.
(3) As the previous data can be displayed as a graph at the time of measuring, the existence of abnormalities can be judged at the site by comparing the present and previous graphs.
(4) Acquisition and processing of the measurement data is performed by personal computer, so that various detailed characteristics data, trend management graphs, etc., can be submitted in a short time as preliminary reports.
(5) Partial discharge measurement, which is effective for detecting local insulation deterioration, requires countermeasures for noise because minute discharge load quantities are measured (OK judgment for cables, etc., is 100 pC or less). Sufficient countermeasures are implemented for hardware and software by means of a noise cut transformer, noise reduction measuring methods, etc., thus ensuring high-quality analysis.

Electric equipment diagnosis vehicle

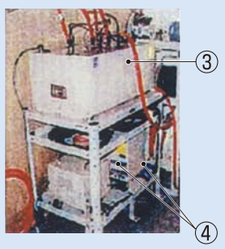
Measuring in the diagnosis vehicle

Measuring outside the diagnosis vehicle

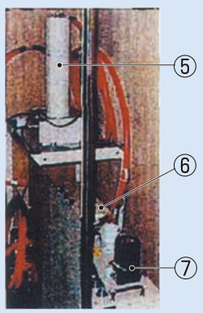
Main equipment loaded in the electric equipment diagnosis vehicle



① Oscilloscope
② Various measuring instruments



③ Switch
④ Noise cut transformer



⑤ Partial discharge detector
⑥ tan δ meter
⑦ Transformer for testing

⑧ Power supply operation section

Diagnosis items for insulation diagnosis

Diagnosis item / Object equipment	DC absorption test (leakage current test)	AC current test	Dielectric loss tangent test (tan δ test)	Partial discharge test
Rotating machine	●	●	●	●
Transformer (high voltage)	—	—	—	●
Power cable (high voltage)	●	—	—	—

Diagnosis flow

Object diagnosis equipment

Rotating machine

Cable

Transformer

Cable disconnection, terminal detachment, etc.

Insulation diagnosis

Electric equipment diagnosis vehicle

Measuring instruments, data processing

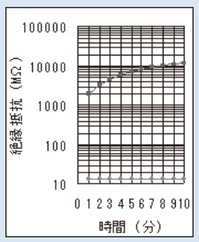
High-voltage megger

Partial discharge meter

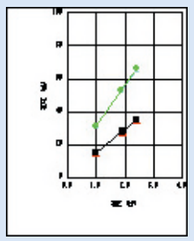
AC current
tan δ meter

Cable insulation treatment, terminal installation, etc.

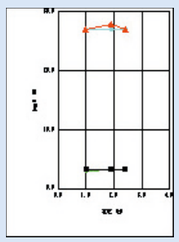
Report of insulation diagnosis test results



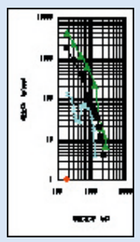
DC absorption test



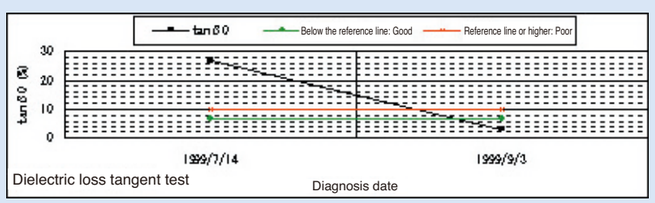
AC current test



Dielectric loss tangent test

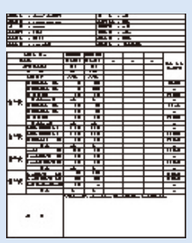


Partial discharge test



Dielectric loss tangent test

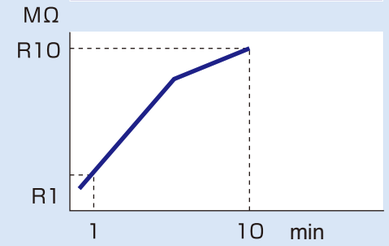
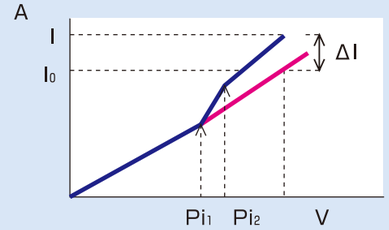
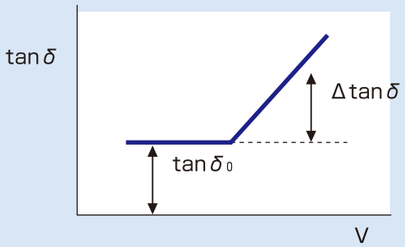
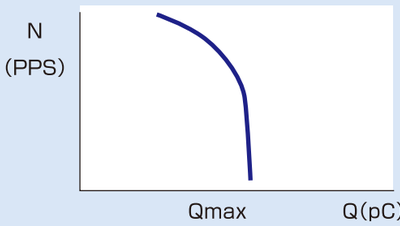
(Before maintenance) (After maintenance)



Insulation test results table

Note: Chronological management data (data for the last 10 years) exists for each item. (Moisture absorption, contamination / deterioration)

Insulation characteristics test and diagnosis contents

Test item	Judgment item	Definition	Diagnosis contents
DC absorption test	Insulation resistance R Polarization index PI	**Insulation resistance – time characteristics**  $PI = \frac{R10}{R1}$	**Moisture absorption, contamination** A state of moisture absorption or contamination exists when the insulation resistance value drops. Also, there is a greater degree of moisture absorption when PI approaches 1.0.
AC current test	Current increase rate ΔI Second current rapid increase point Pi_2	**AC current – voltage characteristics**  $\Delta I = \frac{I - I_0}{I_0} \times 100$	**Insulation drying, peeling off, voids** Increasing ΔI occurrence indicates more advanced deterioration. When the insulation is in a deteriorated condition, Pi_1 or Pi_2 appears.
Dielectric loss tangent test	tan δ_0 Δ tan δ	**tan δ – voltage characteristics**  	**Moisture absorption, contamination, insulation drying Peeling-off, voids** When tan δ_0 is large, a state of moisture absorption or contamination exists. Increasing Δ tan δ indicates more advanced deterioration.
Partial discharge test	Maximum quantity of discharge Qmax	**Peeling-off voids**  	**Local deterioration (Peel off, cracks)** Higher occurrence of discharge loads indicates a greater degree of deterioration.

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