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Substation comprehensive preventive diagnosis system element technology reference material

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1. Transformer bushing leakage current measurement system

☐ System development purpose

○ 33kVCapacitance calculated by measuring the leakage current of a condenser-type bushing mainly used in high-level transformers,PF, tanδThe purpose is to diagnose insulation deterioration through

☐ Summary of related theories

○ Mainly used by KEPCOOIPBushings are manufactured by wrapping several layers of insulating paper and impregnating them with oil. In this process, the bushing manufactured by stacking thin metal layers on the inside is called a condenser cone bushing.33kVApplies to above-grade transformers

○ The multiple metal layers inserted inside the bushing each form capacitance to distribute the voltage stress applied between the bushing conductor and ground, thereby reducing the electric current generated between the conductor and ground.

○ inner insulating layer

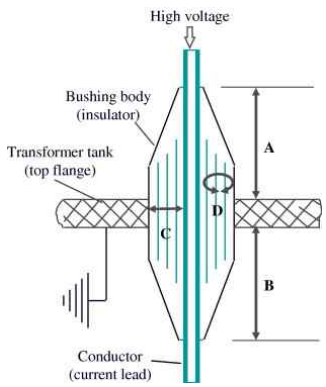
It gets worse

due to destruction

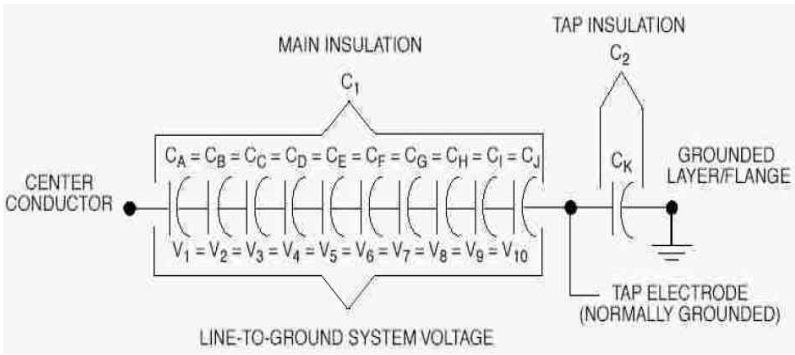
○ section of the insulating layer

As it increases

efficient through



Condenser cone bushing structure



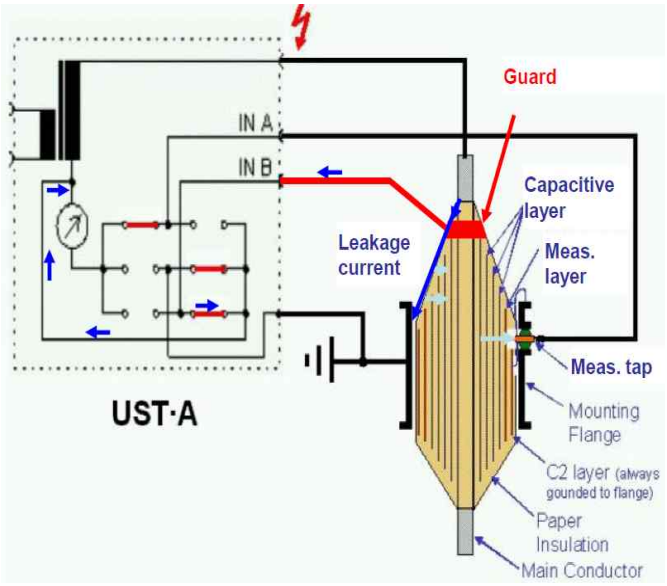
Bushing internal structure equivalent circuit

Transformer bushing damage due to internal insulation layer damage

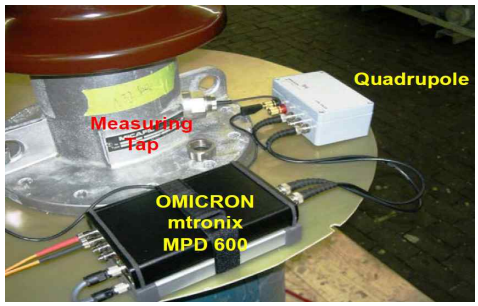
☐ Gas in oil measurement and analysis method

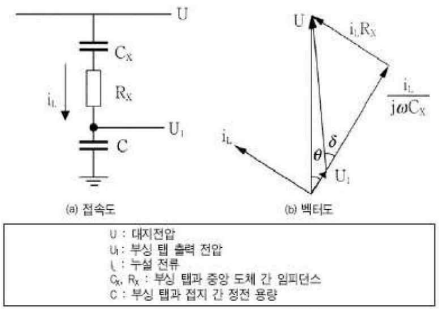
○ Internal outermost conductive layer (Meas. layer)Bushing tab connected with (Meas. tap)with the sensorN-type

step



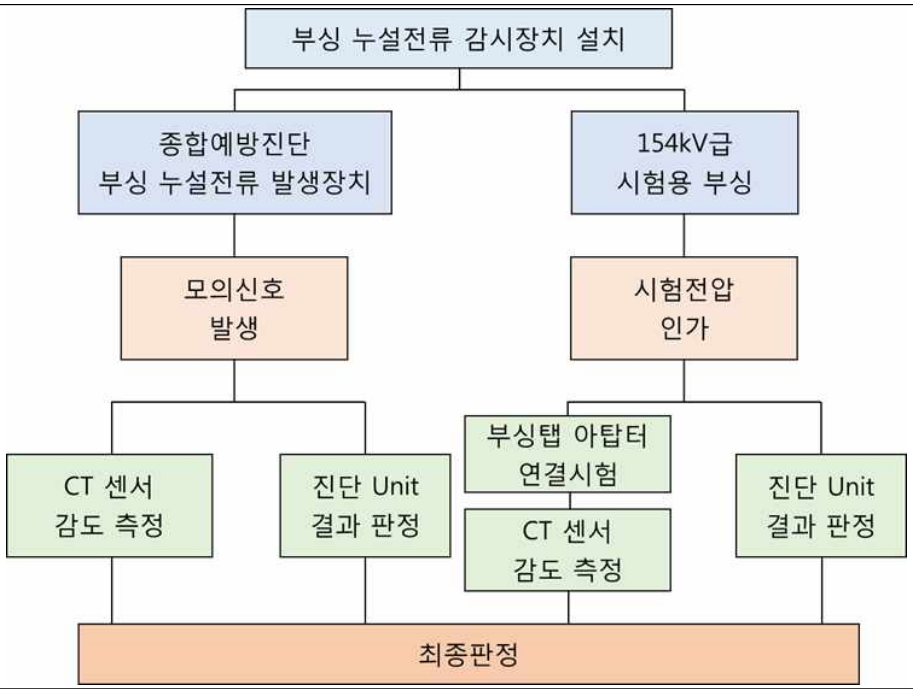
Bushing leakage current measuring device configuration diagram





Calculate diagnostic factors using leakage current values

☐ Certification test procedure



Bushing leakage current monitoring device certification test process

2. Transformer oil-in-gas analysis device

☐ Purpose of oil-in-gas analysis

○ The purpose is to diagnose the presence of internal abnormalities by measuring hydrocarbon-based gases that are formed due to thermal stress applied to the insulator when an abnormal phenomenon occurs inside the transformer.

☐ Related theory

○ Transformer orOLTCIf an abnormal phenomenon (insulation breakdown, local heating, etc.) occurs inside the device, heat is generated, and insulating materials such as insulating oil, insulating paper, and pressboard in contact with the heat source decompose.CO2, CO, H2, CH4, C2H2It dissolves by generating hydrocarbon gas such as

○ By collecting the insulating oil from the inlet device, extracting and analyzing the gas, it is possible to estimate the presence and extent of internal abnormalities depending on the amount and composition of the gas.

○ H2Detection: Diagnosis of abnormalities due to partial discharge and arc discharge

- When phenomena such as short circuit between coil layers, coil melting, arc short circuit between tap changer contacts, and arc generation due to circulating current occur.H2Series of gases are mainly formed
- This is a gas generated throughout transformer abnormalities,H2Diagnosis is possible through analysis alone.

○ CO, CO2Detection: Occurs when solid insulating material in insulating oil overheats (70%hit rate)

-C.O.When detecting a large amount: There is a high possibility of damage to solid insulating materials (insulating paper, backlight, etc.)

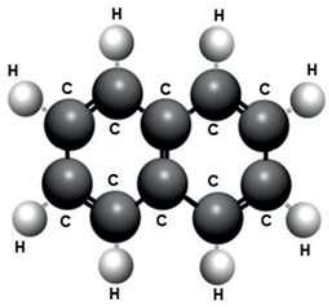
-C.O.When detecting a small amount: low possibility of damage to solid insulators

○ C2H2Detection: Generated in large quantities during high-temperature pyrolysis

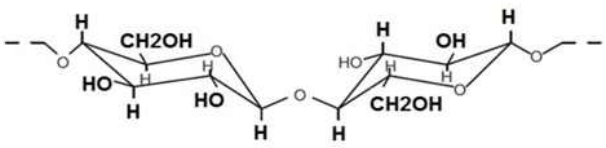
- When an arc occurs, the insulating oil decomposes at high temperature.C2H2is detected in large quantities and is classified as the most fatal transformer accident.
- Even if partial discharge occurs due to an internal defect in the transformer,C2H2Detected in large quantities
- Due to local overheating due to poor contact, etc.C2H2can be detected, but the amount generated is small

○ C3, C4System detection: Used as an aid when diagnosing abnormalities

- Compared to other combustible gases, the molecular weight is heavier, so the amount of diffusion into the air is small.
- Used as an auxiliary diagnostic item to check combustible gas generation trends.
- To date, there has been no clear analysis of the cause, and there have been no cases of it being the main ingredient even in the event of a serious accident such as a short circuit or flashover inside a transformer.

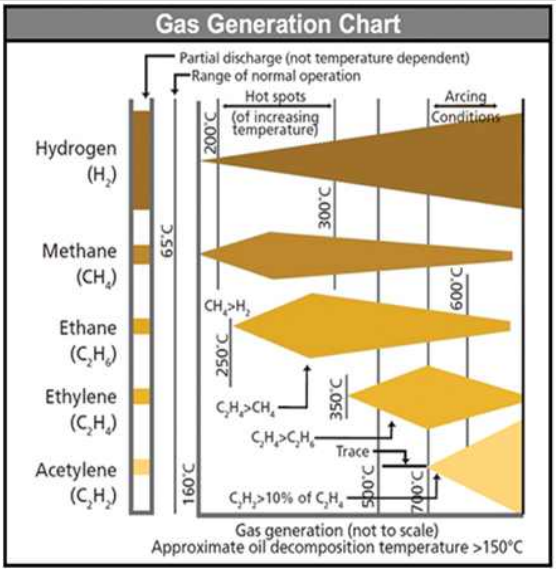


[절연유(Mineral Oil) 결합구조]

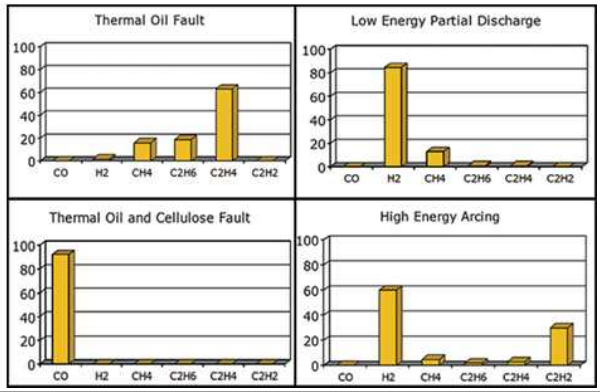


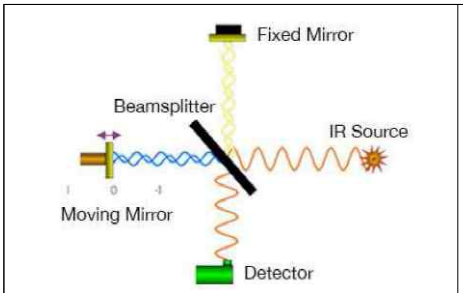
[절연지(Cellulose) 결합 구조]

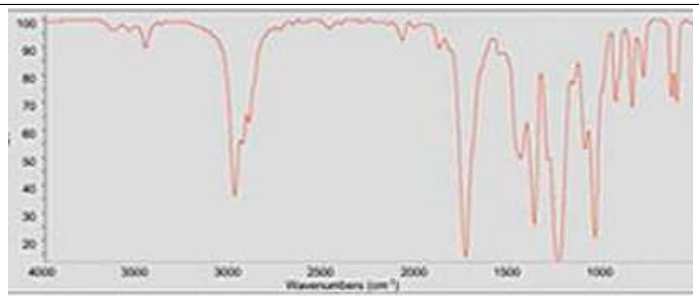
Combination structure of insulating oil and insulating paper



Key Gas Method (IEEE Std. C57.104-2008)		
Key Gas	Fault Type	Typical Proportions of Generated Combustible Gases
C_2H_4	Thermal oil	Mainly C_2H_4; Smaller proportions of C_2H_6, CH_4, and H_2; Traces of C_2H_2 at very high fault temperatures
CO	Thermal oil and cellulose	Mainly CO; Much smaller quantities of hydrocarbon; Gases in same proportions as thermal faults in oil alone
H_2	Electrical Low Energy Partial Discharge	Mainly H_2; Small quantities of CH_4; Traces of C_2H_4 and C_2H_6
H_2 & C_2H_2	Electrical High Energy (arcing)	Mainly H_2 and C_2H_2; Minor traces of CH_4, C_2H_4, and C_2H_6; Also CO if cellulose is involved







FTIRmethod

○ Infrared photoacoustic spectroscopy (In

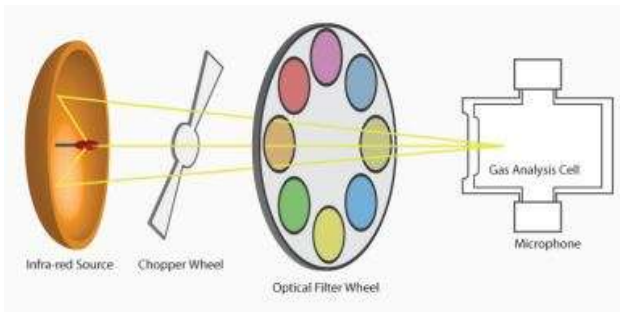
- A pulse-shaped light source

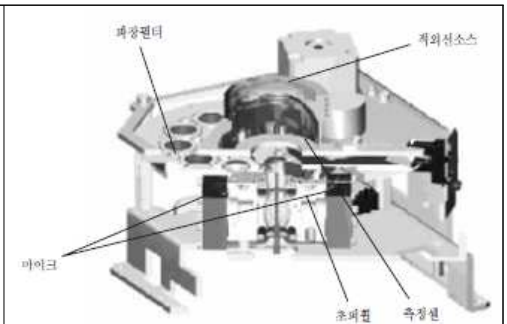
  Vibration due to increased pressure

- High sensitivity when vibrating

- Each gas has its own

  Appears and uses it



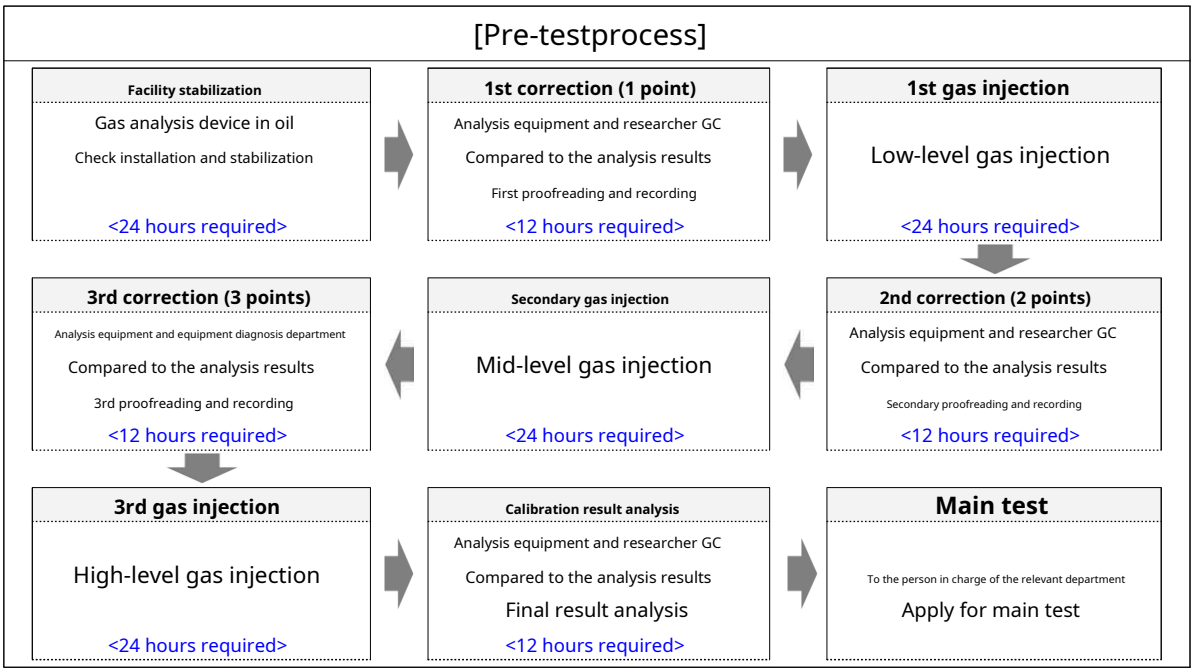


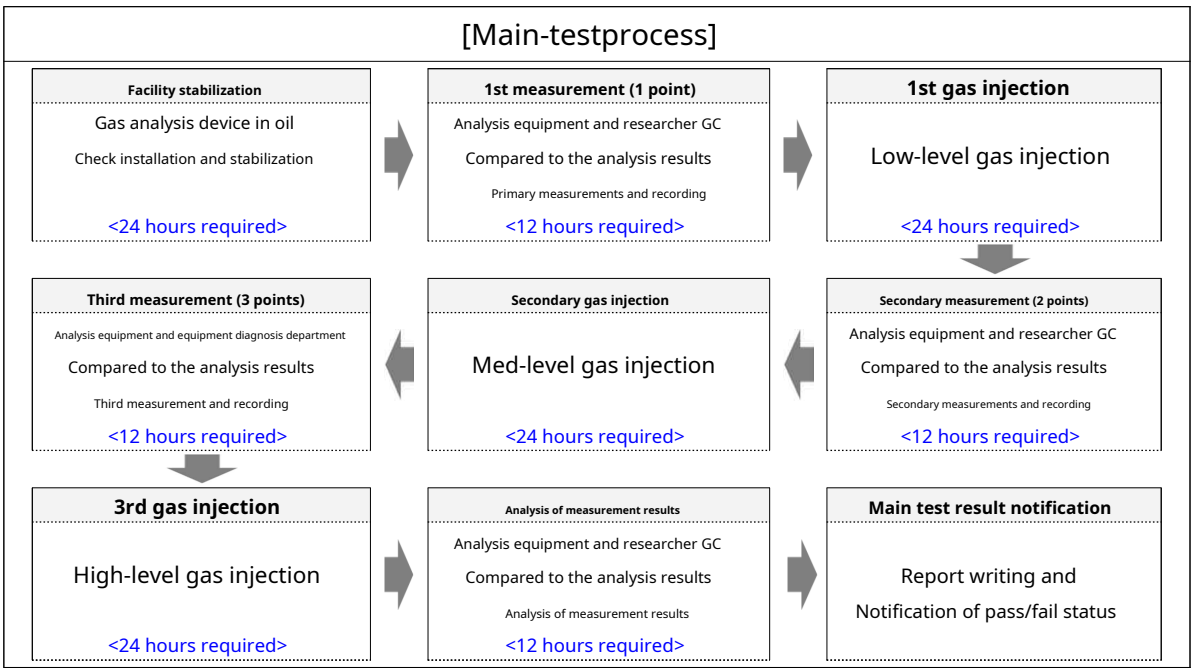
PASMeasurement principle

PASMeasuring unit structure

☐ Certification test procedures and criteria

○ for equipment calibrationPre-testandMain-testIt is divided into Korea Electric Power Research InstituteGCVerify whether the judgment criteria are satisfied by comparing the analysis results





○ Analytical gas types and judgment criteria

No.	analyst type	Detection range	Criteria
One	H2	5 to 5,000 ppm	baseline10%Within
2	C.O.	10 to 5,000 ppm	
3	C2H2	5 to 5,000 ppm	
4	H20	Relative humidity or “0”ppmmore	

3. GIS/Transformer/OLTC partial discharge diagnosis system

☐ Partial discharge measurement purpose

○ GIS/Transformers/OLTCThe purpose is to diagnose the condition of the device by acquiring partial discharge signals that occur when a defect occurs internally.

☐ Summary of related theories

○ Partial discharge is a localized electric discharge phenomenon that occurs in the insulation system and occurs in a portion of the dielectric without completely bridging the electrodes.

○ Partial discharge occurs at the discharge start voltage (PDIV, Partial Discharge Inception Voltage)It refers to a localized insulation breakdown phenomenon that occurs when a voltage exceeding the voltage is applied to a defect. It causes various types of chemical/physical transformations in the material and deteriorates the material due to energy collisions of high-energy electrons or accelerated ions.

○ Typical partial discharge defects

- Void discharge: When a void occurs inside a solid insulator, local electric field concentration occurs due to the difference in dielectric constant, which refers to the resulting internal discharge.
- Corona discharge: Appears due to local electric field concentration occurring in the protruding electrode structure.
- Creepage discharge: In a composite insulation structure made up of two or more insulators, the interface between the insulators exhibits the weakest electric field characteristics, and Occurs when leakage current flows
- Floating discharge: Occurs when metal is floating between electrodes.
- Particle discharge: Occurs when very small metal particles move due to electrical energy applied when voltage is applied.
- Electric tree: Occurs when an electric tree occurs or progresses inside a solid insulator.

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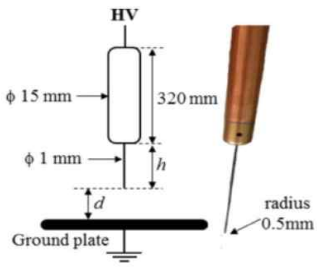
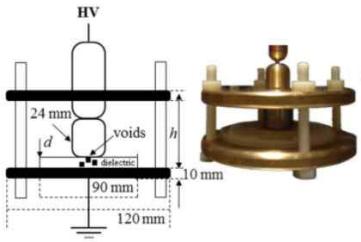
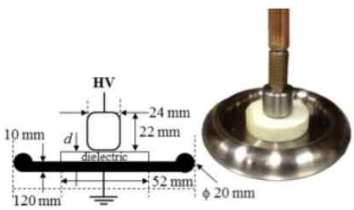
<tr><td> 
</td><td> 
</td><td> 
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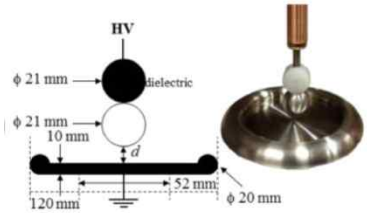
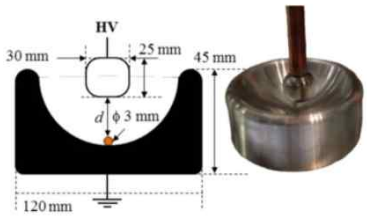
<tr><td>corona discharge</td><td>void discharge</td><td>creeping discharge</td></tr>
<tr><td> 
</td><td> 
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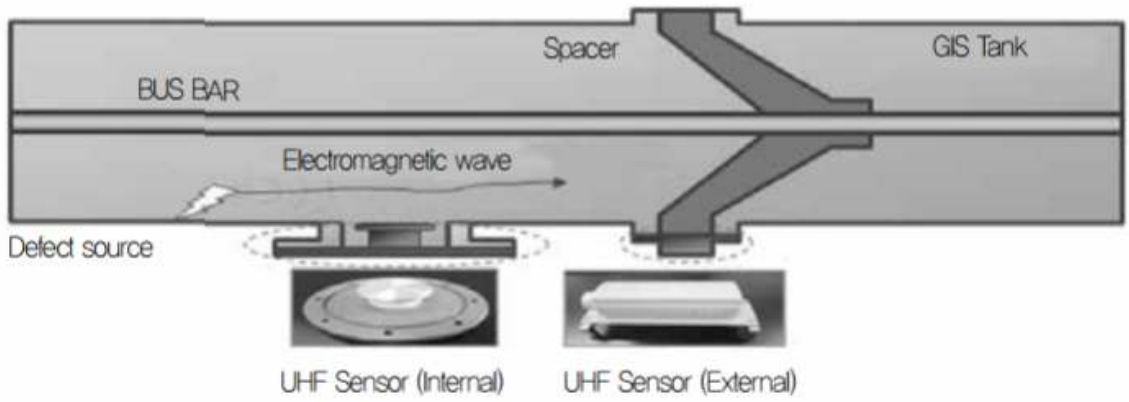
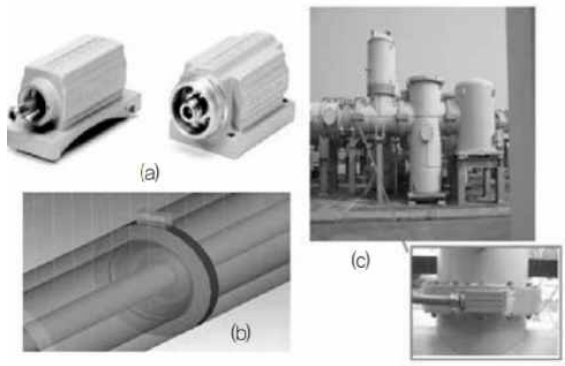
<tr><td>floating discharge</td><td>particle discharge</td><td>electric tree</td></tr>
<tr><td colspan="3">Typical partial discharge defect structure</td></tr>
</table>

Partial discharge detection method

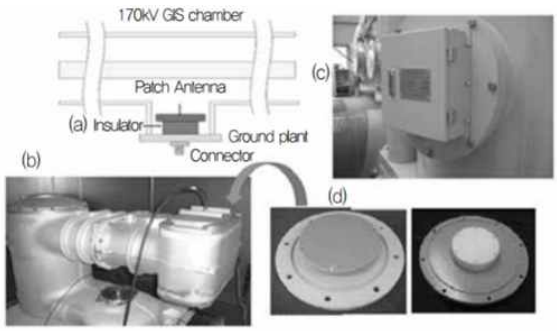
- Detection of partial discharge is based on the conversion of energy generated during discharge, and appears as electrical impulse current, electromagnetic radiation, sound, increase in gas pressure, chemical reaction, etc., so the method of measuring partial discharge is determined depending on the method of observing the phenomenon. .
- Currently, the most widely used detection method is the detection method that occurs during partial discharge.300 MHz to 2 GHz Measures electromagnetic waves in the band using a sensor.Ultra High Frequency (UHF)method, and the presence, cause, location, etc. of partial discharge can be diagnosed through the acquired signal.
- In the case of a transformer, since the steel enclosure is completely sealed and grounded, signal acquisition is possible only by installing a built-in sensor in the monitoring window.GISIn the case of this case, since radio waves can be propagated to the outside due to the spacer for supporting the conductor, it is possible to apply not only a built-in sensor through a surveillance window, but also an external sensor attached to the spacer.



Acquisition of partial discharge radio signal by installing internal/external sensors

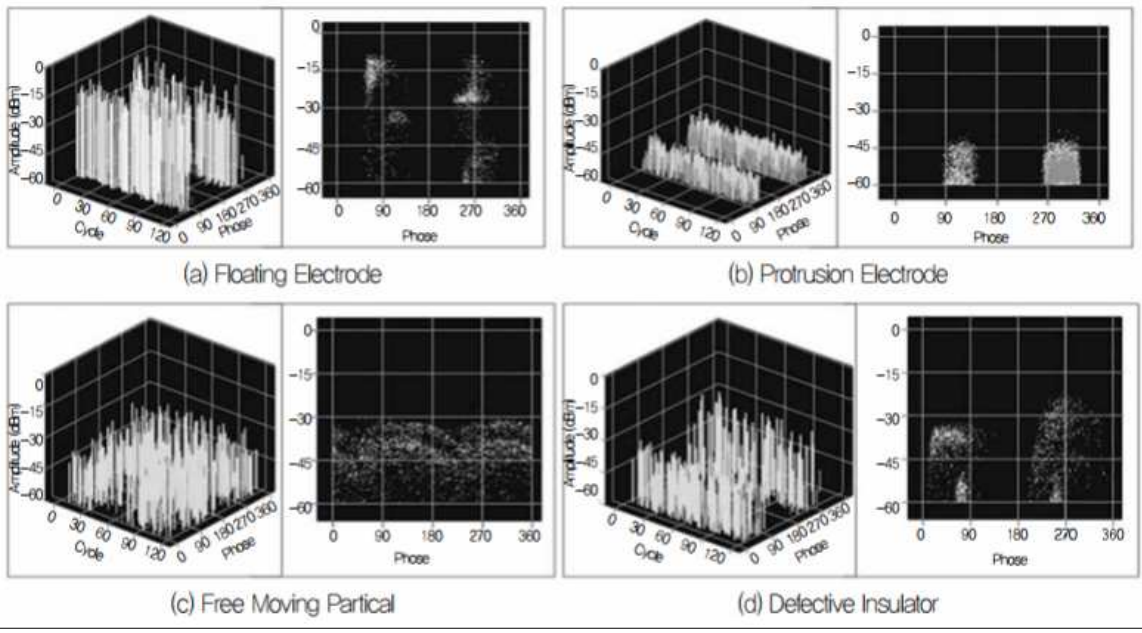


external typeUHFSensors and Installation



Built-inUHFSensors and Installation

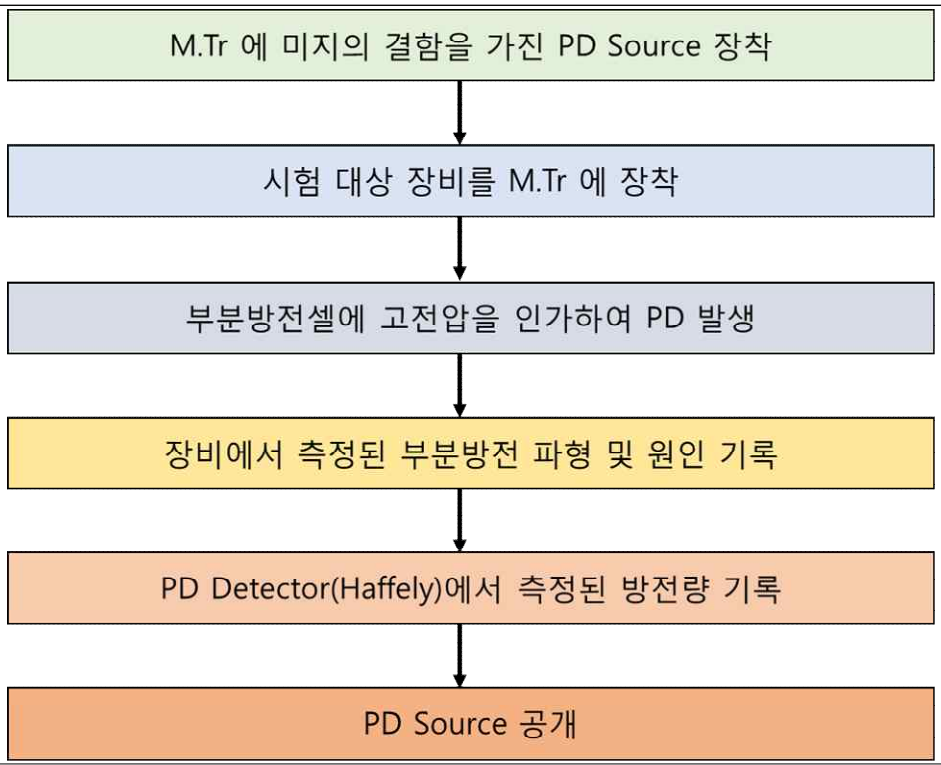
- Currently, the most widely used partial discharge waveform analysis method isPRPD(Phase Resolved Partial Discharge)/PRPS(Phase Resolved Pulse Sequence)As a method, Φ- is analyzed using the pulse phase, size, and frequency of the discharge signal.qnBased on analytics
- PRPDIf the signal acquired through this method is represented as a graph with the axis of the phase-signal period, it shows a unique pattern depending on the discharge type, so this can be used to determine whether a partial discharge has occurred and its type.



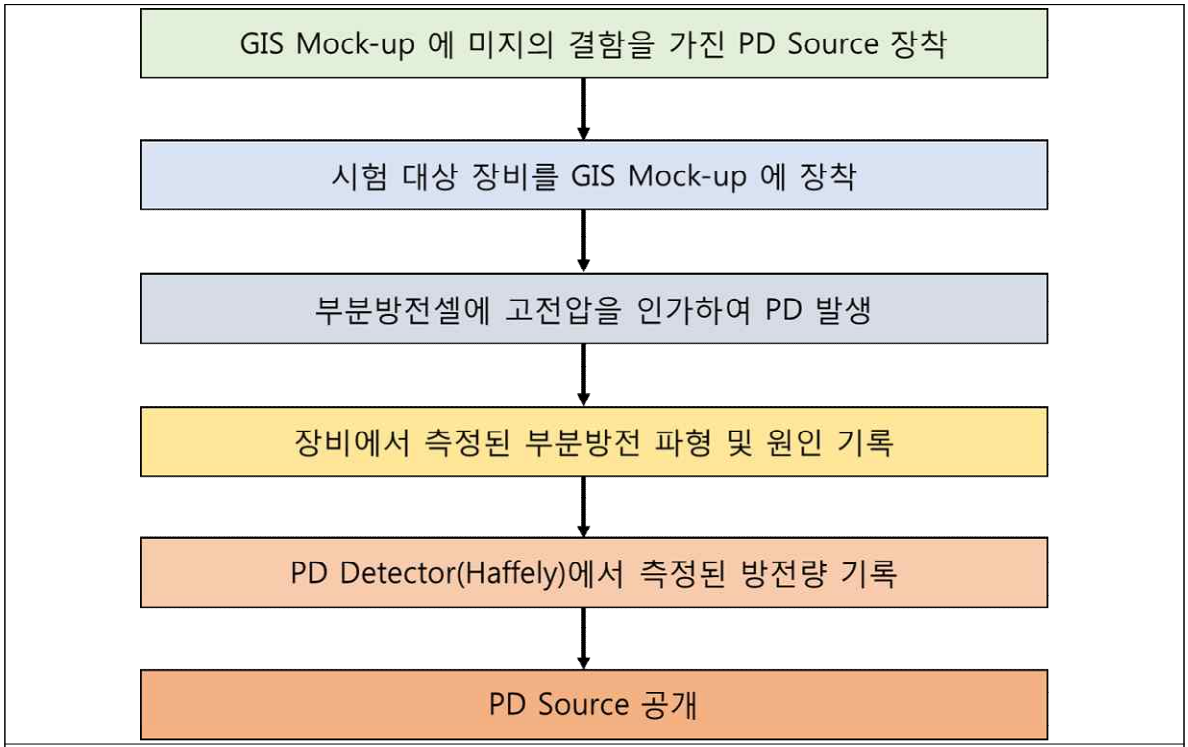
Pattern classification according to partial discharge type

☐ Certification test procedures and criteria

○ Certification test procedure



Transformer partial discharge diagnosis system certification test procedure



GISPartial discharge diagnosis system certification test procedure

○ Criteria

Test Items	Test contents	Criteria	note
Diagnostic performance test	DischargeCell,ExperimentData each20more than oneBlind test	By device type Discharge signal classification Whether	
interspecies Compatibility test	LU-DiagnosisUnit,DiagnosisUnit-HMIVerification of compatible diagnostic performance between heterogeneous systems		

4. OLTC operating characteristics analysis device

☐ System development purpose

- ○ OLTCThe purpose is to diagnose the contact status of each tap by measuring the tap position, operation time, and motor driving current during operation.

☐ Summary of related theories

- ○ OLTCThis is a device that allows tap switching even during normal operation of the transformer. It can adjust the transformation ratio of the transformer without affecting the active or reactive power while the load current is flowing, so it can be used from the distribution level.765kVWidely used in transformers
- ○ Currently at KEPCO765kVon transformerOLTC On-LineCondition monitoring system is being applied
- ○ OLTCAction sequence

  Transformers2Voltage fluctuations on the vehicle side occur→Detected by voltage regulation relay→OLTCDriving motor operation→OnePrimary winding tap selector moves to transfer target tap→Electrical connection through transfer switch operation
- ○ When the changeover switch operates, a circular current due to the tap voltage flows while temporarily short-circuiting one stage of the tap, causing an arc to occur when the tap is switched, resulting in contact cutting, etc.OLTCMay cause poor contact contact

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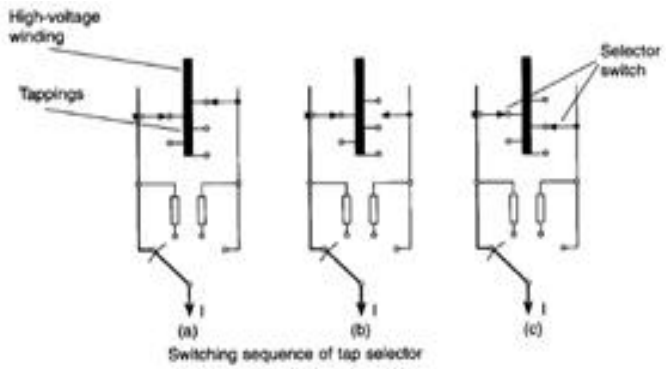
<tr><td> </td><td> 
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<tr><td></td><td>OLTCBasic operating procedure</td></tr>
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<tr><td>OLTC</td><td></td></tr>
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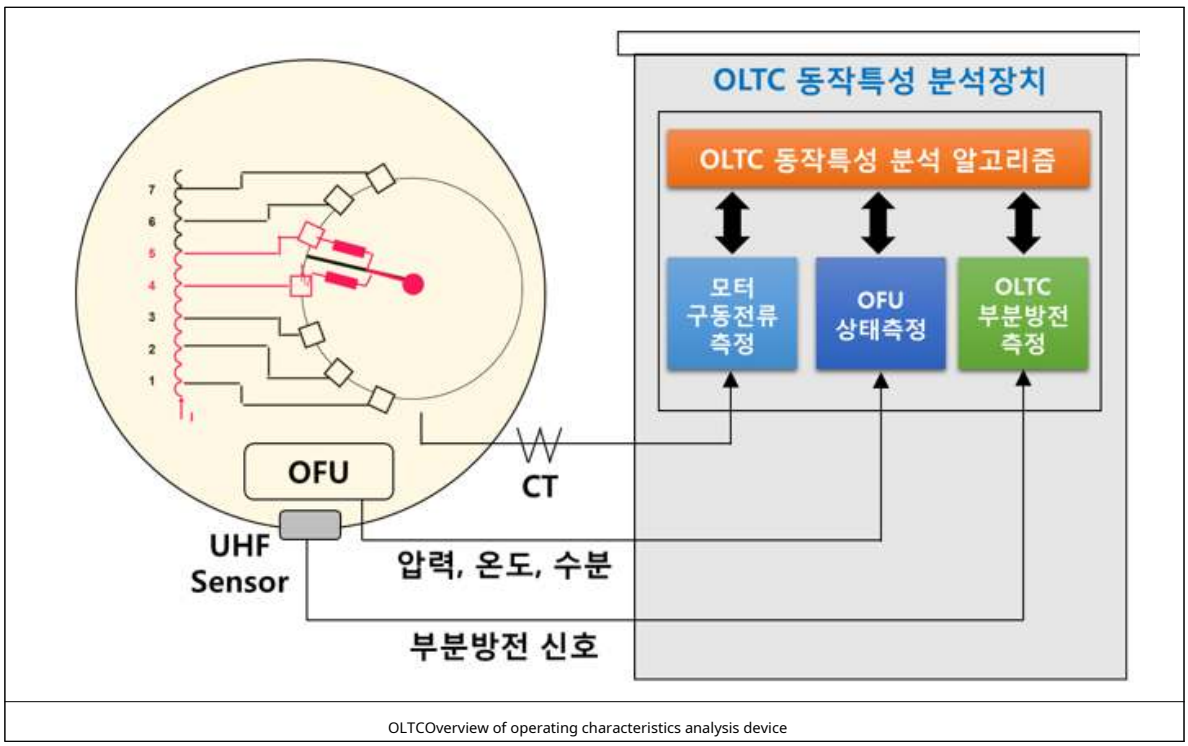
☐ OLTCOperating characteristics analysis method

○ A torque sensor is installed on the drive power transmission shaft to measure shaft torque.CTusing3Diagnosis is performed by measuring the current and load current of the phase motor

○ If contact resistance increases due to contact cutting,2It is possible to calculate contact wear by measuring the load current and number of operations by using the change in current on the load side of the car.

○ If the contact resistance increases, the motor driving torque increases when switching taps, and the motor torque is calculated using the change in the motor driving current to perform status diagnosis.

○ Besides that,UHFusing sensorsOLTCInternal partial discharge measurement andOFU(Oil Filter Unit)Perform comprehensive diagnosis by measuring pressure, oil temperature, and insulating oil contamination using



OLTCOverview of operating characteristics analysis device

☐ Certification test procedure

[TransformersOLTCDiagnostic system performance test process]

OLTC partial discharge detection sensor sensitivity test GTEM Cell and Network Testing with Analyzer Perform	**OLTC partial discharge diagnosis** Classification of discharge types into 5 types Check whether the decision is made	**OFU monitoring sensor sensitivity test** Temperature, pressure and moisture measurement
Actual signal operating characteristics test Diagnosis of OLTC abnormalities, Analysis of movement change trends and Is there any electrical or mechanical abnormality? judgment	**Simulated signal operating characteristics test** Diagnosis of OLTC abnormalities, Analysis of movement change trends and Is there any electrical or mechanical abnormality? judgment	**OLTC drive unit monitoring sensor sensitivity test** Motor inrush current peak value and Normal value and two values Pulse width detection?

5. Circuit breaker operation characteristics analysis device

☐ Purpose of analyzing circuit breaker operation characteristics

○ GISelectrical operation time andTripThe purpose is to measure signals and currents and use the measurement data to monitor the circuit breaker's operating status and diagnose any abnormalities.

☐ Related theory

○ GISMy circuit breaker control circuit consists of a control device made up of contact points depending on the equipment operation method, and sequence control is achieved by combining the contact points.

- 'a'Contact point: Normally, the contact point isOFFstate and in operation stateONcontact point
- 'b'Contact point: Normally, the contact point isONstate and during mechanical operation.OFFcontact point

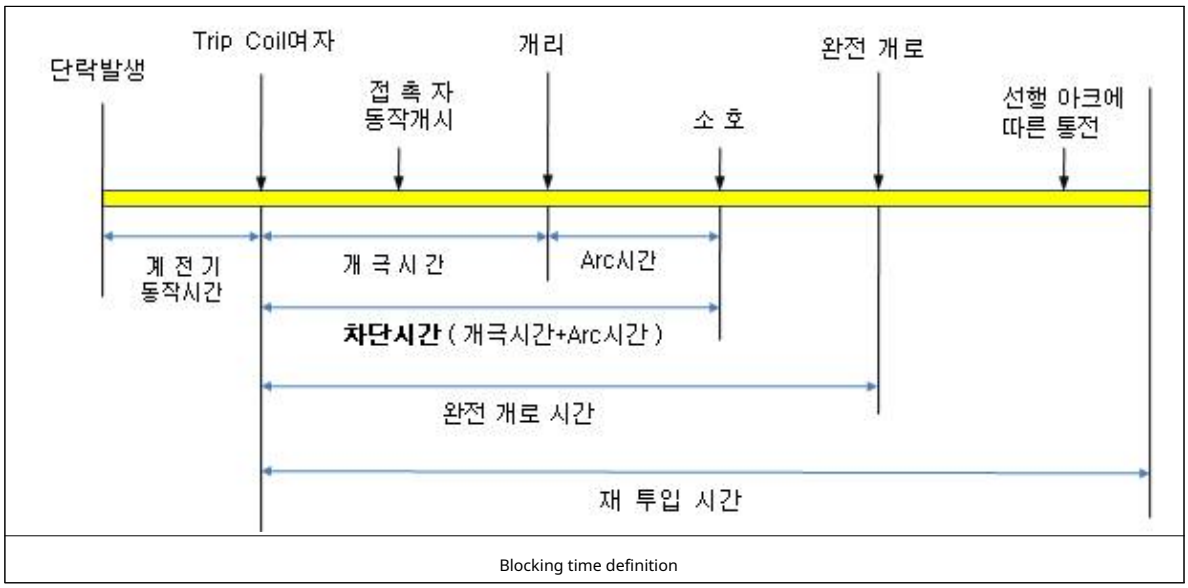
○ Breaker operation isTrip/CloseIt is divided into and the contact status during each operation is as follows.

-Trip:In protection relayTripWhen a signal is given and the compressed air or hydraulic pressure conditions for operating the breaker contact are met, the control circuit's 'a'contact pointON Changes to (circuit breaker on) stateTrip coilThis woman turns the breaker open

-Close:In protection relayCloseWhen a signal is given and the conditions for operating the breaker contact are met, the control circuitb'contact pointON((breaker open) state changes toTrip coilThis is energized and turns on the circuit breaker.

○ When the circuit breaker is closed/opened under load, a transient voltage is applied between the contacts. If the magnitude exceeds the dielectric strength, an arc is generated and continues until the current reaches zero, after which the arc is extinguished.

○ Trip CoilThe time from the point of excitation until the arc is extinguished is defined as the blocking time.



Blocking time definition

☐ How to measure circuit breaker operating current

○ Trip/CloseCoil current measurement

-Trip/Closeon the coilDC 10Awithin1.0(Error)±One%)with a precision of more than Open Clamp TypeofHallMeasure coil current using a sensor

○ ACload current

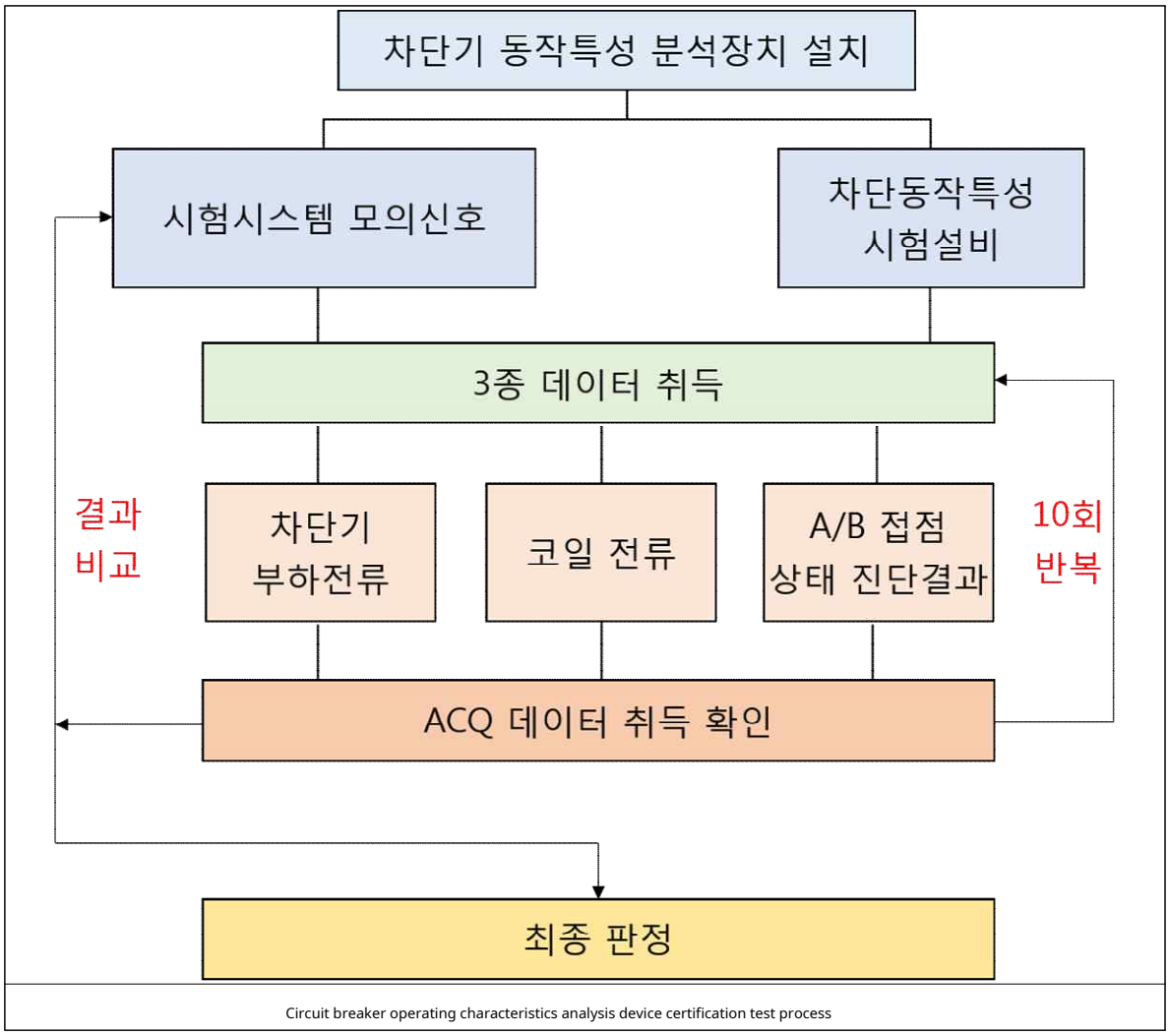
- For existing instrumentsCTof2Individually on the difference current sideCTBy attaching2Indirect analysis of the difference current

- AC 5Awithin0.5A sensor with a level of precision or higher must be used.

○ 'a', 'b'Contact configuration

- Configured to measure the opening and closing time of the breaker by combining each contact point

☐ Certification test procedure



Circuit breaker operating characteristics analysis device certification test process