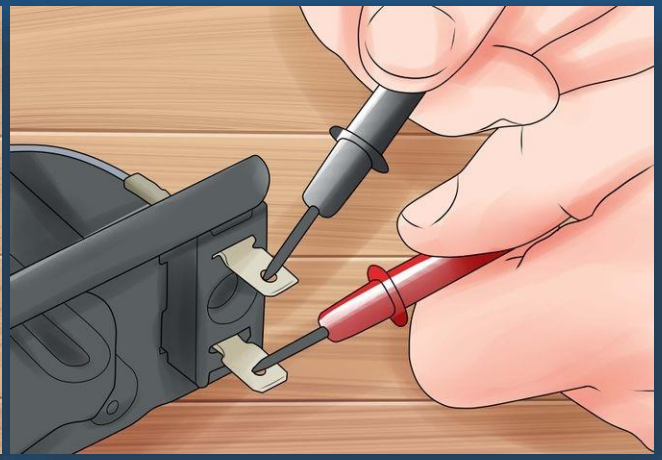
Testing of MV Electrical System



Ir. Hamzah Ismail
2021

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2.1 Factory Acceptance Test (FAT)

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3. Medium Voltage Cable

3.1 Factory Acceptance Test (FAT)

3.2 Site Testing

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
- Separate-source AC withstand voltage test (Applied voltage (AV) test)
- Induced AC withstand voltage test (Induced voltage withstand (IVW) test)
- Measurement of no-load loss and no-load current (excitation current)
- Measurement of winding resistance
- Measurement of short circuit impedance and load loss

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Measurement of voltage ratio and check of phase displacement (vector group)
- Partial Discharge Measurement (not applicable for oil-type transformers)
- Mesurement of insulation resistance (although this is a special test, the manufacturer will perform this test without cost)

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection

JKR ELEKTRIK	VISUAL INSPECTION REPORT 11 kV DRY-TYPE DISTRIBUTION TRANSFORMER	Form No.	: CKE.USPMA(P).003-2-8
		Rev. No.	: 01
		Rev. Date (m, y)	: August 2020
		Page No.	: 1/4

Report			
Report No.	:	.....	
Project Name	:	.....	
Applicant's Name	:	.....	
Inspected by (+ signature)	:	..... (name)	..... (signature)
Reviewed by (+ signature)	:	..... (name)	..... (signature)
Date of inspection	:	.....	
Inspection location	:	.....	
Address	:	.....	
		.....	
Inspection specification			
Approved Shop Drawing No.	:	1.	2. ..... 3. .....
Specification	:	L-S17	

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Neutral connection/bar

1. Transformer

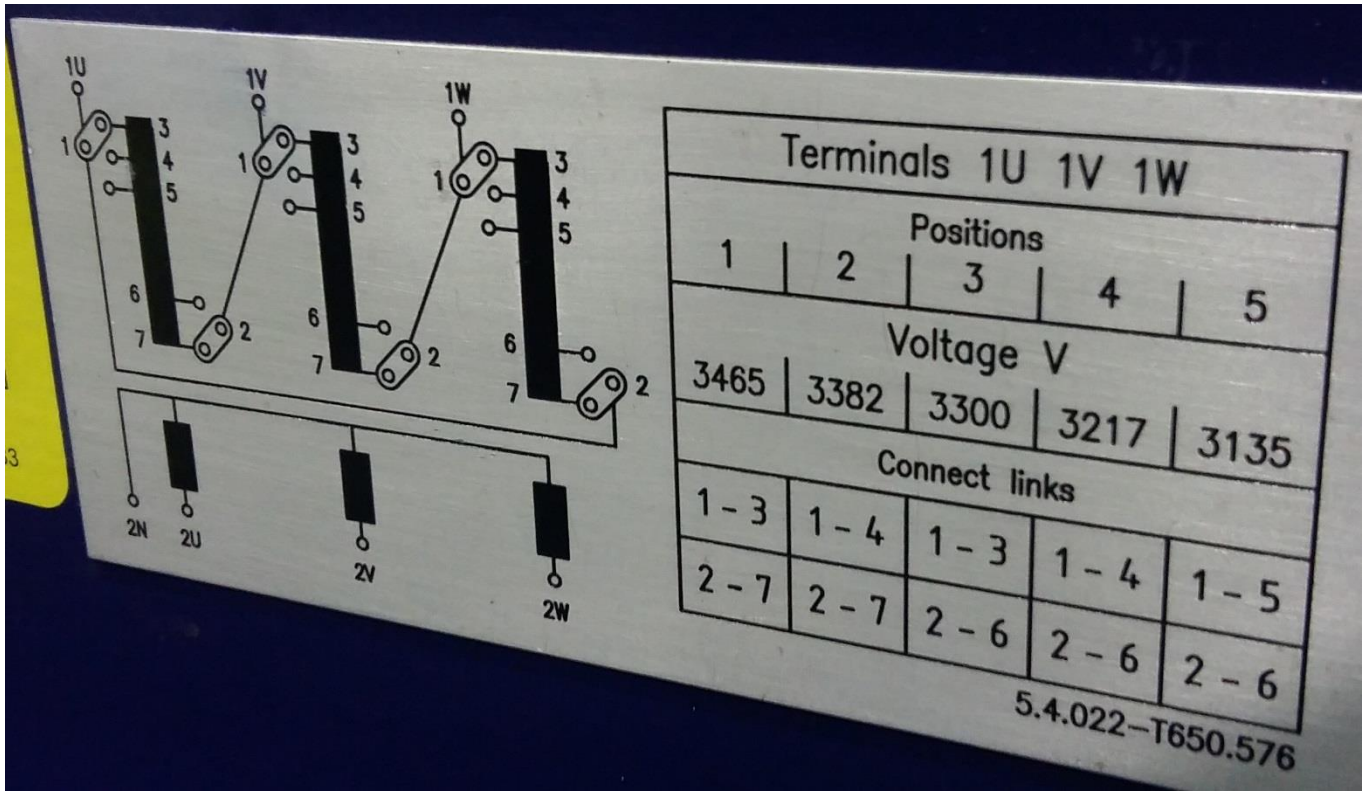
1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Off-load tap changer

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Tap changer diagram of connections



What's wrong?

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Lifting lugs

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Insulators

1. Transformer

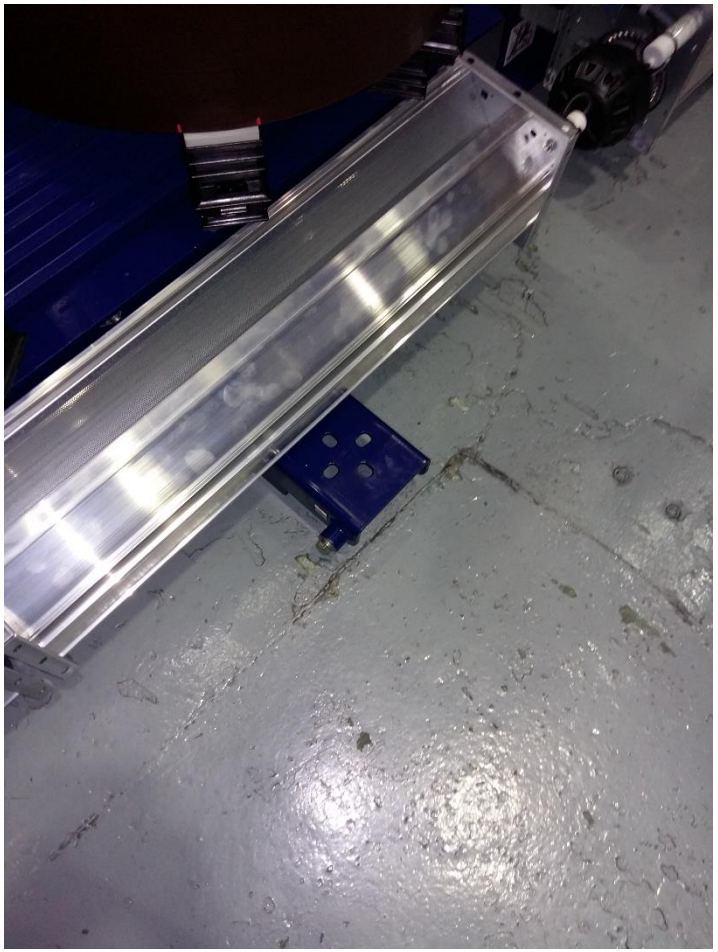
1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - LV terminals

1. Transformer

1.1 Factory Acceptance Test (FAT)

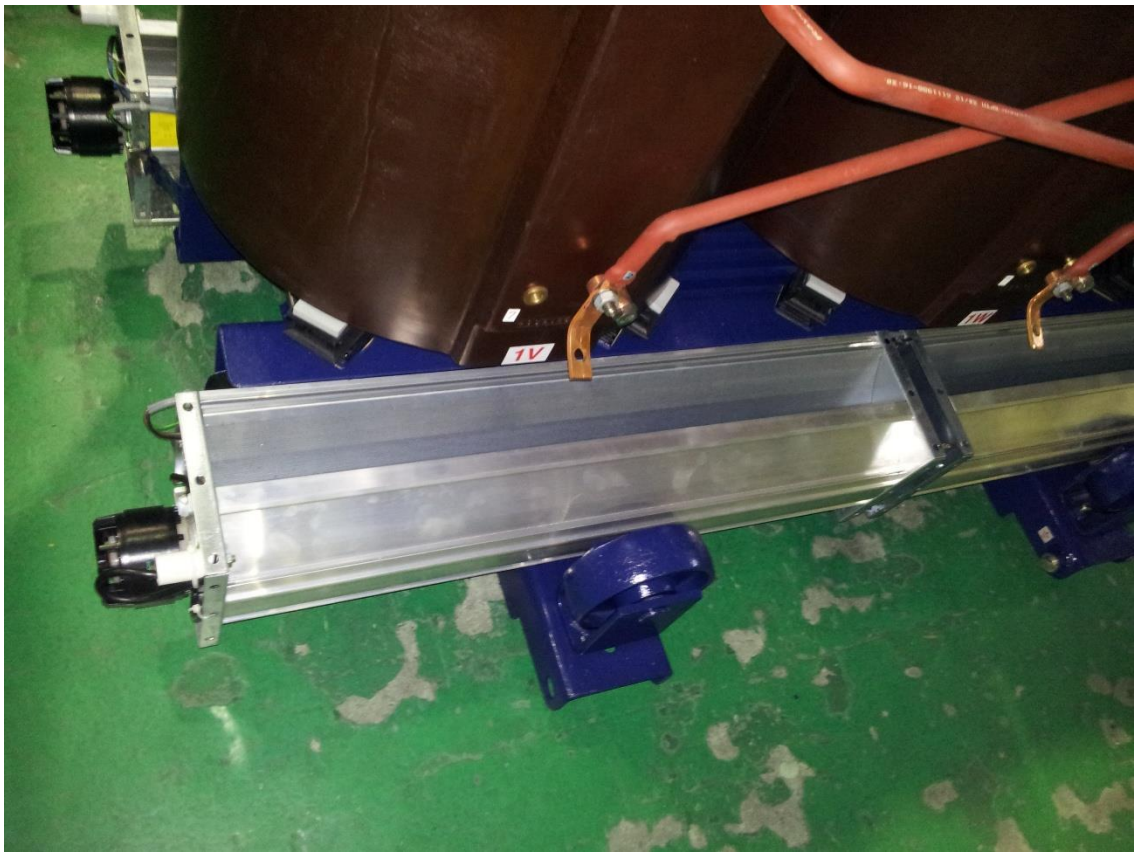
- Visual inspection
  - Earthing terminals



1. Transformer

1.1 Factory Acceptance Test (FAT)

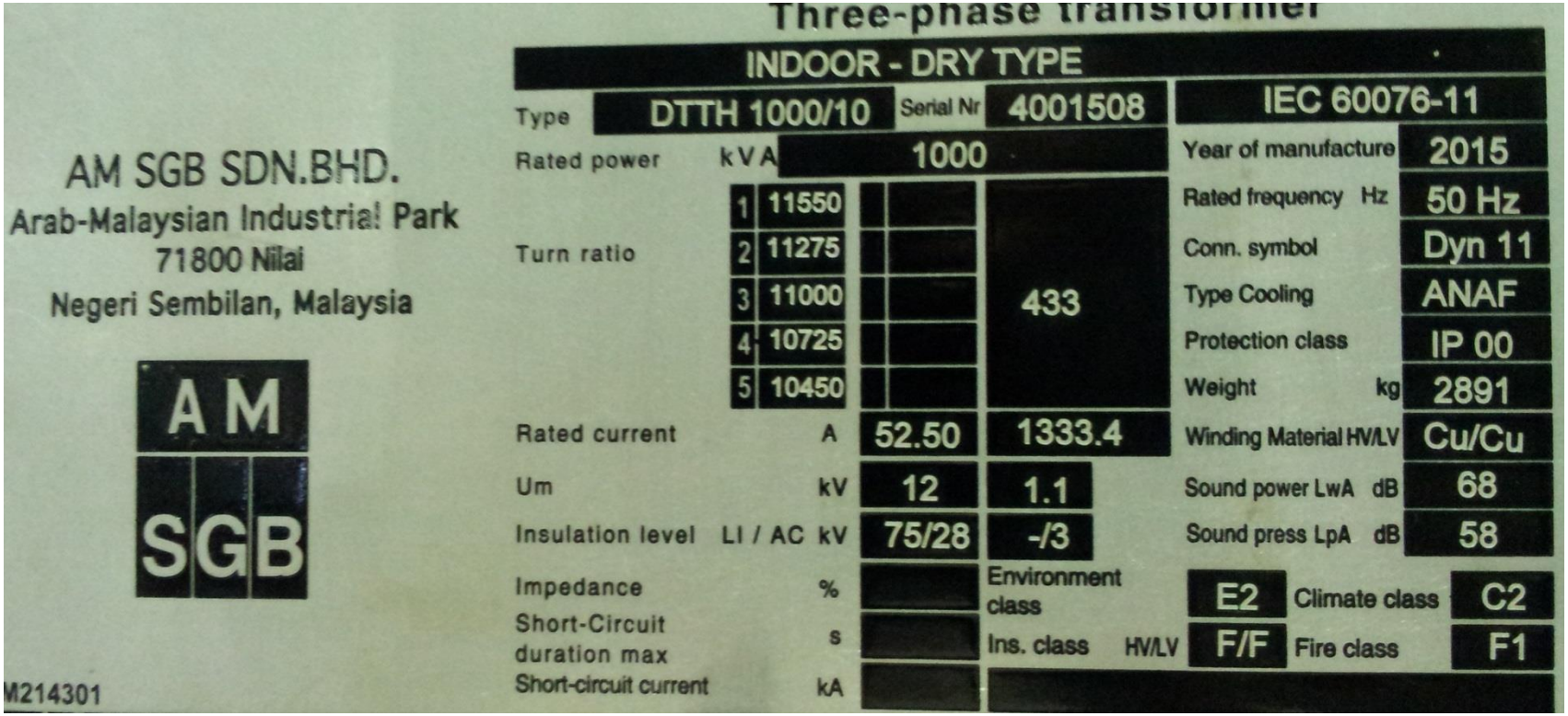
- Visual inspection
  - Wheels



1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Name plate



1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - PT100

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Controller

1. Transformer

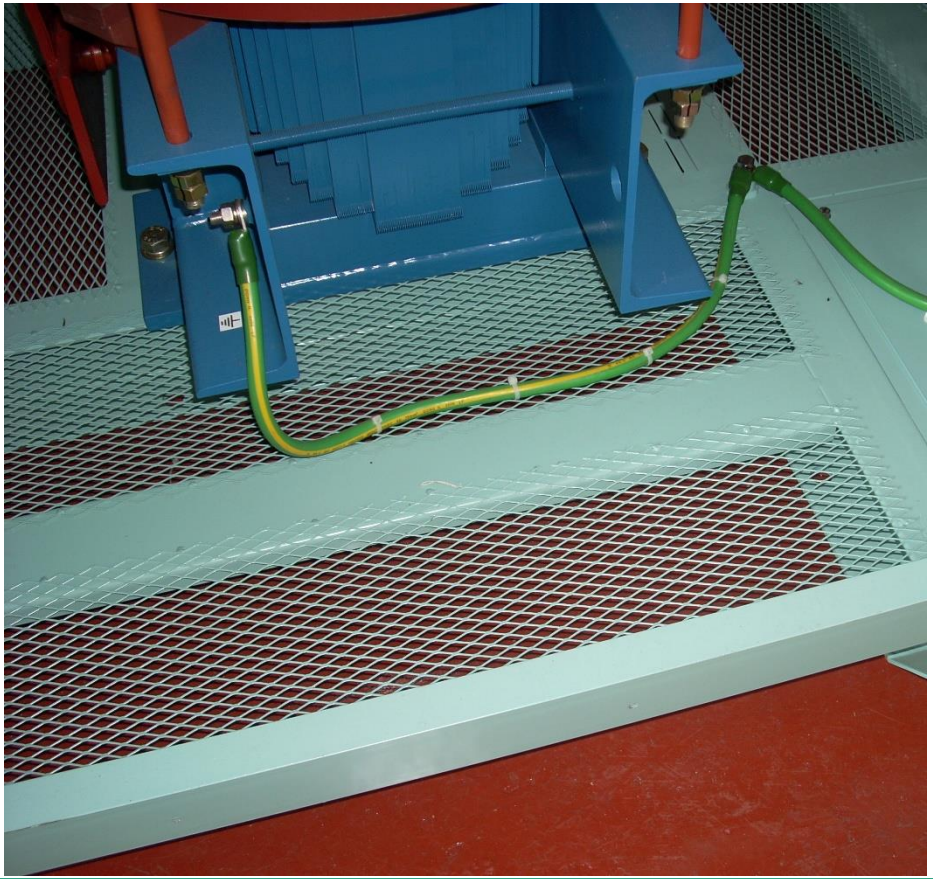
1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Enclosure

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Visual inspection
  - Protective conductors



1. Transformer

1.1 Factory Acceptance Test (FAT)

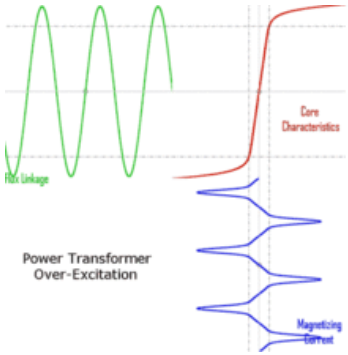
No	Test Item	Objective	Acceptance Criteria
Routine Test			
1	Separate source AC withstand voltage test (Applied voltage test – AV)	To check the insulation strength between the windings and core	No collapse of the test voltage occurs
2	Induced AC withstand voltage test (Induced voltage withstand test – IVW)	To check the insulation both between phases and between turns of the windings and also the insulation between the input terminals of the insulation windings and earth	No collapse of the test voltage occurs
3	Measurement of no-load loss and no-load current	To measure the no-load loss (core loss/iron loss) and the no-load current (excitation current). The excitation current is a composite of the energy which is lost due to eddy currents in the magnetic material (steel core) as well as hysteresis losses of the material. The value gives some indication to the quality of the core lamination.	Not exceed +15% of specification for no-load loss provided that the tolerance for total losses is not exceeded +10%. Not exceed +30% of the design value for no-load current.

1. Transformer

No	Test Item	Objective	Acceptance Criteria
Routine Test			
4	Measurement of winding resistance	To measure the resistance of HV and LV windings. Resistance values will be used for load loss calculation and as reference for future measurements.	Standard gives no acceptance criteria, however a deviation from average of 3 phases of 0.5% for HV and 5% for LV could serve as practical guideline.
5	Measurement of short curcuit impedance and load loss	To measure the load loss (copper loss) and the % of impedance voltage. The load loss and impedance shall be derived and corrected to reference temperature of 120^{o}C.	Not exceed +15% of specification for load loss provided that the tolerance for total losses is not exceeded +10%. Not exceed ±10% of specification for impedance.
6	Measurement of voltage ratio and check of phase displacement	To measure the voltage turn ratio and vector group of the transformer.	The voltage ratio error shall be within ± 0.5% for each tap.

1. Transformer

No	Test Item	Objective	Acceptance Criteria
Routine Test			
7	Partial discharge (corona) measurement	To measure the partial discharges which may occur in the transformer insulation structure. These discharges may occur in air bubbles left in the insulating media, gaps in the solid materials or at the surfaces of two different insulators. Although these discharges have small (weak) energy, the thermal energies due to these discharges can cause aging, deformation and tear of the insulating material.	The maximum level of partial discharge shall be of 10 pC



1. Transformer

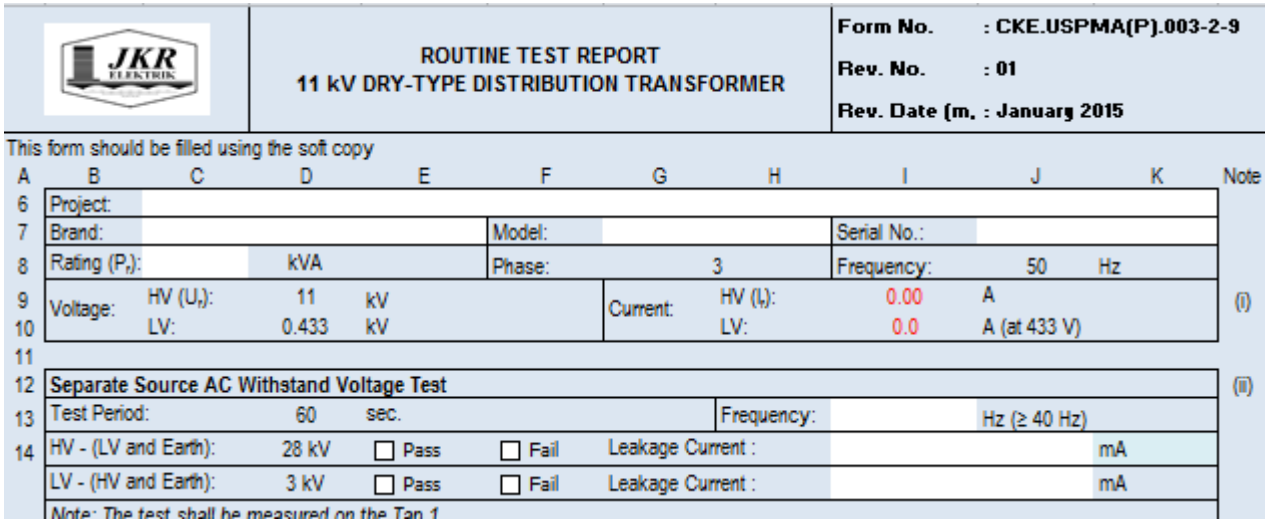
No	Test Item	Objective	Acceptance Criteria
Special Test			
1	Measurement of d.c. insulation resistance each winding to earth and between windings	To form a reference for future measurements. For comparison they have to be at the same temperature (e.g. 20 °C reference temperature). The test voltage is "direct voltage" and can be between 1000 Vd.c. and 5000 Vd.c	Minimum measured insulation resistance of 1 kΩ/V

1. Transformer

1.1 Factory Acceptance Test (FAT)

- Record of result
  - *Data-data pengujian dimasukkan ke dalam software yang telah dibangunkan oleh CKE bagi tujuan perbandingan dengan spesifikasi dan standard dan juga untuk mengelakkan data pengujian dimanipulasi oleh pihak pengilang.*

CLICK HERE



	JKR ELEKTRIK	ROUTINE TEST REPORT 11 kV DRY-TYPE DISTRIBUTION TRANSFORMER					Form No. : CKE.USPMA(P).003-2-9 Rev. No. : 01 Rev. Date (m. : Januarg 2015				
This form should be filled using the soft copy											
A	B	C	D	E	F	G	H	I	J	K	Note
6	Project:										
7	Brand:				Model:			Serial No.:			
8	Rating (P_r):		kVA		Phase:		3	Frequency:	50	Hz	
9	Voltage:	HV (U_r):	11	kV	Current:	HV (I_r):		0.00	A		(i)
10		LV:	0.433	kV		LV:		0.0	A (at 433 V)		
11											
12	Separate Source AC Withstand Voltage Test										(ii)
13	Test Period:		60	sec.				Frequency:		Hz (≥ 40 Hz)	
14	HV - (LV and Earth):		28 kV	☐ Pass	☐ Fail	Leakage Current :				mA	
	LV - (HV and Earth):		3 kV	☐ Pass	☐ Fail	Leakage Current :				mA	
	Note: The test shall be measured on the Tap 1										

1.2 Site Testing

- Separate-source AC withstand voltage test (pressure test / hipot test)
  - 24 kV_{ac} (85% of the factory test voltage) for 1 min.
  - LV to be connected to earth
  - No collapse of test voltage
- Measurement of winding resistance
  - To detect transportation/installation damage by comparison with FAT values and to be used for future diagnostic tests.
  - HV (at tap 3) and LV winding
  - Deviation from FAT results should not more than 2% (≤ 2%) (need to be corrected at the same temperature)

$$R_2 = R_1 \cdot \frac{235 + t_2}{235 + t_1}$$ (for copper)

1.2 Site Testing

- Measurement of voltage ratio
  - HV (at tap 3) and LV winding
  - Voltage ratio error shall be within ± 0.5%
- Measurement of insulation resistance
  - HV → LV
  - HV → E
  - LV → E
  - The results should not lower than 70% of FAT results (≥ 70%)

2. Metal-enclosed Switchgear

2.1 Factory Acceptance Test (FAT)

- Shall be carried out to determine whether the cable complies with the specification and standards
- To assure that cables are good quality before it leaves the factory
- Visual inspection

2. Metal-enclosed Switchgear

2.1 Factory Acceptance Test (FAT)

- Visual inspection
- 5 kV_{dc} insulation resistance test on the main circuit ($\geq$ 50MΩ) (before pressure test)
  - VCB Close
    - » A→BCE
    - » B→CAE
    - » C→ABE
  - VCB Open
    - » ABC→abcE

2. Metal-enclosed Switchgear

2.1 Factory Acceptance Test (FAT)

- Power frequency voltage test (pressure / hipot test)
  - Test voltage 28 kV_{ac} for 1 min. (for 11 kV switchgear)
  - Test voltage 70 kV_{ac} for 1 min. (for 33 kV switchgear)
  - To check the clearance with breaker racked in & closed
    - » A→BCE
    - » B→CAE
    - » C→ABE
  - To check the clearance with breaker racked in & open
    - » ABC→abcE
  - No flash over should occur

2. Metal-enclosed Switchgear

2.1 Factory Acceptance Test (FAT)

- 5 kV_{dc} insulation resistance test on the main circuit ($\geq$ 50MΩ) (<u>after</u> pressure test)
  - VCB Close
    - » A→BCE
    - » B→CAE
    - » C→ABE
  - VCB Open
    - » ABC→abcE

2. Metal-enclosed Switchgear

2.1 Factory Acceptance Test (FAT)

- Measurement of the resistance of the main circuit (contact resistance)
  - Measured with 100 A_{dc}
  - Each phase → breaker closed
  - Each phase → earth switch closed
  - Limit based on manufacturer's declaration value (μΩ) or based on type test report
- Secondary injection of protection relays
  - Timing test/operating time (low set, >)
  - Operating value (high set/instantaneous, >>)

2. Metal-enclosed Switchgear

2.1 Factory Acceptance Test (FAT)

- Potential transformer ratio test
  - 11000:110 (100:1)
- Heaters circuit test
  - Measure the resistance
- Circuit breaker mechanical and electrical functional test

2. Metal-enclosed Switchgear

2.2 Site Testing

- *Tujuan pengujian dilaksanakan adalah untuk memastikan* reliability of HT electrical system *selepas pemasangan di tapak dengan membandingkan nilai-nilai keputusan ujian dengan keputusan routine tests (FAT), spesifikasi,* standards dan best engineering practices*. Nilai-nilai bacaan keputusan ujian tersebut juga akan digunakan sebagai rujukan (*baseline*) bagi penyelenggaraan pada masa hadapan.*
- *Ujian-ujian perlu dilaksanakan/diselia oleh* Electrical Services Engineer

2.2 Site Testing

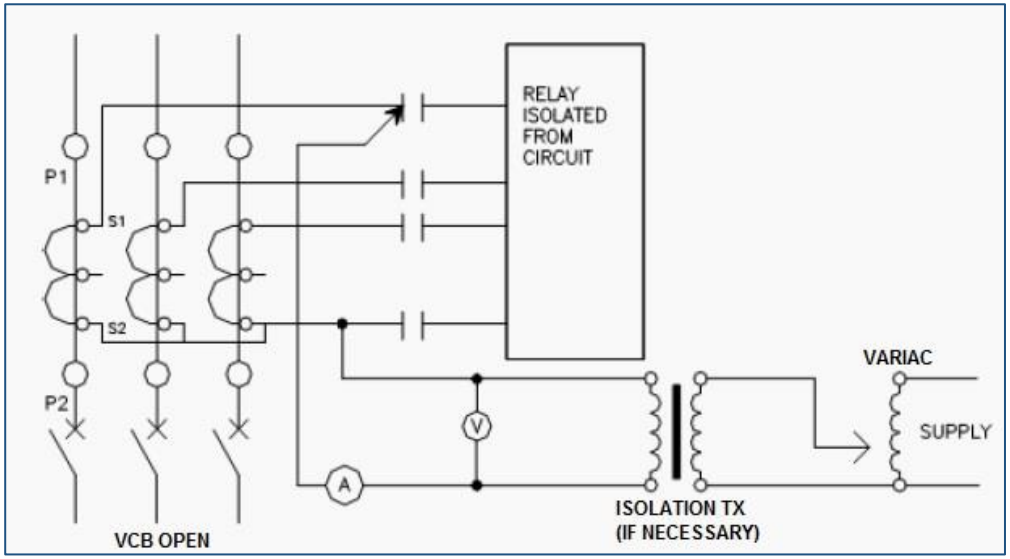
2.2.1 Current Transformer (CT)

*Objektif pengujian CT adalah untuk memastikan keadaan fizikal (*without shorted turns*), operasi dan sambungan kepada sistem adalah baik daripada semua aspek (*primary and secondary*). Standard yang digunapakai dalam pengujian ini adalah IEC 60044-1.*

2.2 Site Testing

2.2.1.1 CT Magnetization Curve Test

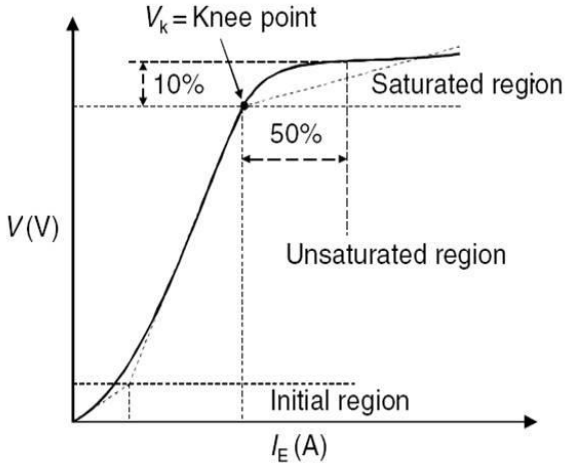
Magnetization curve test *adalah untuk memastikan* magnetization characteristics of CT *adalah seperti dengan spefifikasi* nameplate*. Sambungan* primary *hendaklah dibuka semasa pengujian. Sambungan litar adalah seperti yang ditunjukkan dalam Gambarajah.*



2.2 Site Testing

2.2.1.1 CT Magnetization Curve Test

Voltan ditingkatkan sehingga *excitation current* mencapai *saturation point*. Sekurang-kurangnya 8-10 poin diambil untuk memplot graf. *Knee-point* biasanya dicapai sebelum *magnetizing current* melebihi 20 % daripada kadaran CT (1 A). Graf tipikal IEC "*Knee-Point*" (10/50) adalah seperti yang ditunjukkan dalam Gambarajah. Bacaan voltan dan arus direkodkan di dalam *current transformer test set software*.



2. Metal-enclosed Switchgear

2.2 Site Testing

2.2.1.1 CT Magnetization Curve Test

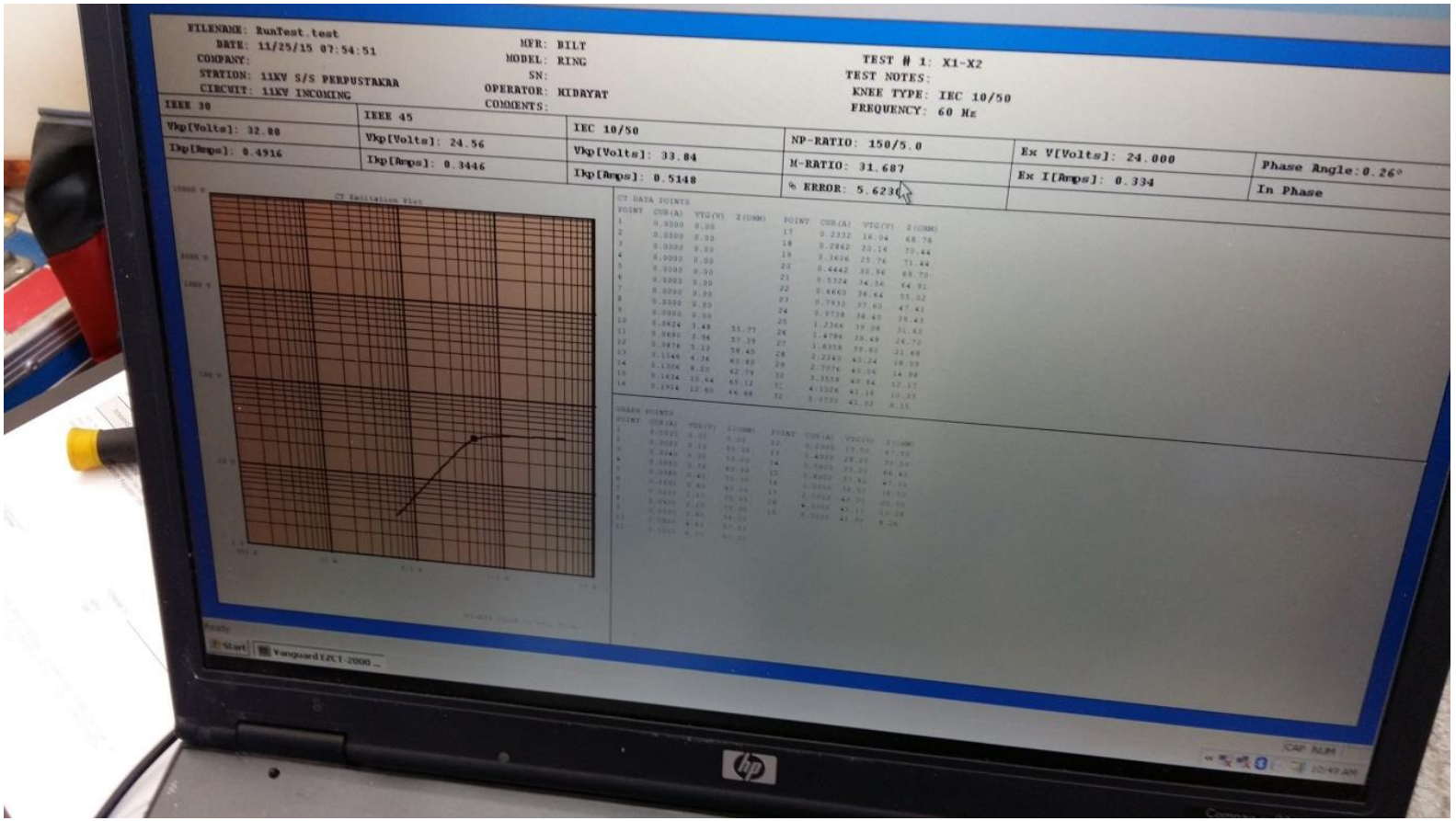
Contoh ringkasan keputusan ujian adalah seperti dalam Jadual.

OFFLINE TESTING						
Brand: BMAX		**Type:** Ring		**Class:** 5P10	**Burden:** 15 VA	**Ratio:** 150/5 A
Panel	**R**		**Y**		**B**	
	V_{kp}	**I_{kp}**	**V_{kp}**	**I_{kp}**	**V_{kp}**	**I_{kp}**
Incomer	33.84 V	0.5148 A	33.34 V	0.5198 A	33.32 V	0.5195 A
Note:	*V_{kp} – Knee point voltage*					
	I_{kp} – Magnetizing current					

2. Metal-enclosed Switchgear

2.2 Site Testing

2.2.1.1 CT Magnetization Curve Test



2.2 Site Testing

2.2.1.2 CT Ratio Test

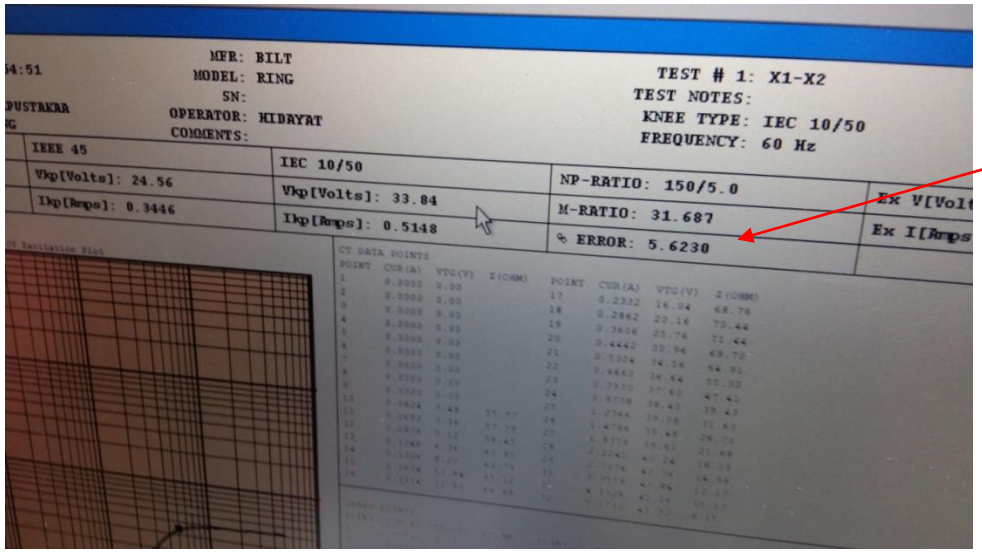
- Tujuan pengujian ratio adalah untuk memastikan CT *ratio transformation* berada di dalam *tolerance* yang dibenarkan iaitu tidak melebihi 10 % *current ratio error*. Keputusan ujian ratio adalah untuk verifikasi CT *ratio transformation* sahaja dan bukanlah untuk menguji pematuhan kepada *composite error designation* (5P).
- Bagi tujuan pengujian, arus disuntik pada *primary* CT melebihi 25 % daripada *rated primary current*.

2.2 Site Testing

2.2.1.2 CT Ratio Test

- Ringkasan keputusan ujian adalah seperti dalam Jadual.

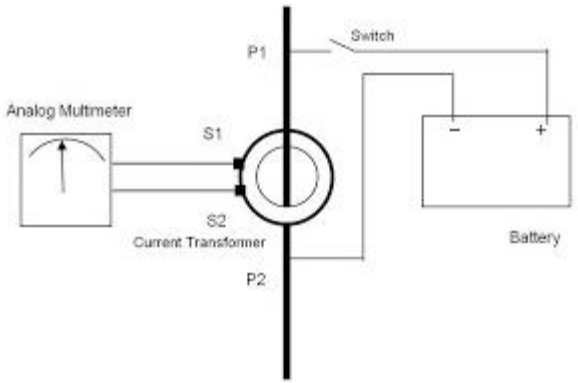
OFFLINE TESTING						
Brand: BMAX	**Type:** Ring	**Class:** 5P10	**Burden:** 15 VA		**Ratio:** 150/5 A	
Panel	**Primary Current**	**Calculated I_{PR}/I_{SC}**	**Measured**			**Result**
			R	**Y**	**B**	
Incomer	150 A	30	5.6230 %	4.9373 %	8.960 %	Pass



2.2 Site Testing

2.2.1.3 CT Polarity Test

- Tujuan pengujian ratio adalah untuk memastikan *polarity marking* dan pemasangan pada CT *primary* dan *secondary* adalah betul.
- Sambungan yang salah pada CT boleh menyebabkan *false operation of the protection relays.*
- Sekiranya CT *winding polarity* memaparkan '*in-phase'* pada *test set software*, maka keputusannya adalah memuaskan. Jika *test set software* memaparkan '*out-of-phase'* maka tindakan perlu diambil dengan membetulkan pemasangan tersebut.

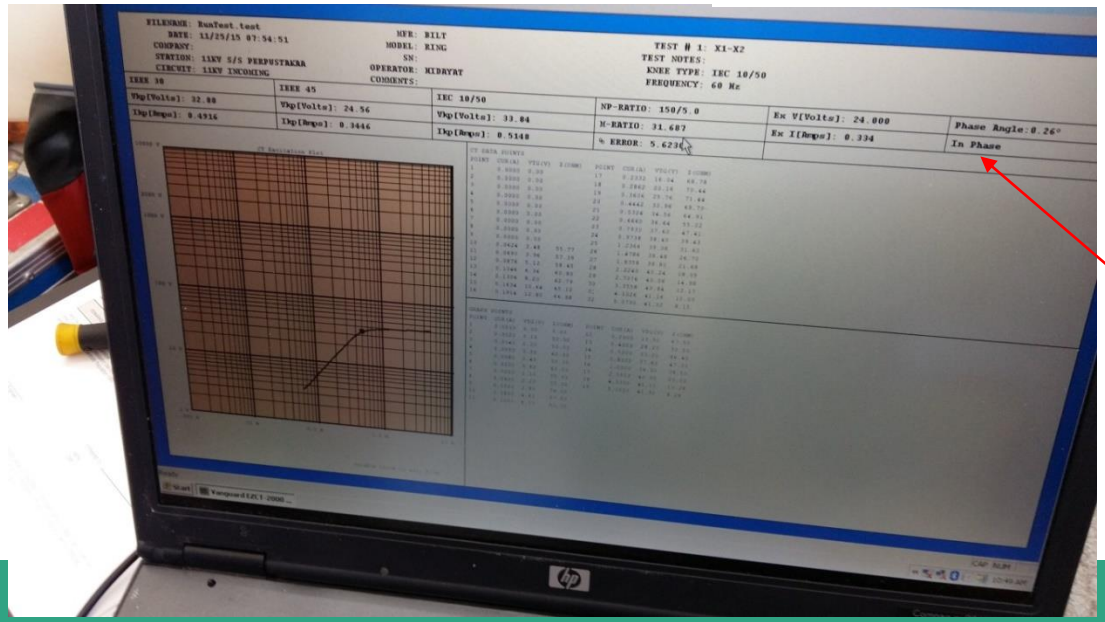


2.2 Site Testing

2.2.1.3 CT Polarity Test

- Ringkasan keputusan ujian adalah seperti dalam Jadual.

OFFLINE TESTING				
Brand: BMAX	**Type:** Ring	**Class:** 1	**Burden:** 15 VA	**Ratio:** 150/5 A
Phase	R	Y	B	
Polarity	In-phase	In-phase	In-phase	



2.2 Site Testing

2.2.2 *VT (PT) Ratio Test*

- The PT primary is excited by means of e.g. 110 V. The voltage supply will be connected to the primary and check the voltage at the secondary.

2.2 Site Testing

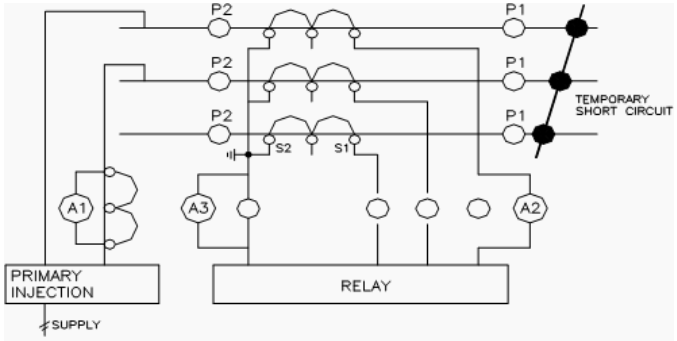
2.2.3 Relay Secondary Injection Test

- Before conducting the test, CT terminal connected to the relay has to be opened.
- Inject the current to the relay terminal using the secondary injection kit.
- Set the PSM (plug setting multiplier) to the half of the rated CT secondary (2.5 A) and TMS (time multiplier setting) at the relay. This setting should be Using the injection kit, inject about 130% (3.25A), 200% (5A), 300% (7.5A) of the PSM setting.
- Operating time of the relay is displayed in the kit timer. The result is compared with the manufacturer's data sheet.

2.2 Site Testing

2.2.4 Primary Injection Test (Stability Test)

- Primary injection tests on each relay to prove stability for external faults
- High current (≥ 20%) is injected to primary side of the CT.
- Primary injection tests must be carried out after secondary injection tests, to ensure that problems are limited to the CT's involved, plus associated wiring, all other equipment in the protection scheme having been proven satisfactory from the secondary injection tests.
- Leakage current < 1A



2.2 Site Testing

2.2.5 Measurement of the resistance of the main circuit (contact resistance)

- » Measured with 100 A_{dc}
- » Each phase → breaker closed
- » Each phase → earth switch closed
- » Measured resistance value will be compared with the FAT results

2.2.6 *Functional Test of Vacuum Circuit Breaker (VCB)*

2.2.7 *Heaters Operation Test*

3. Medium Voltage Cable

3.1 Factory Acceptance Test (FAT)

- IEC 60228, IEC 60502-2
- Sample tests – not more than 10% of the number of lengths in the contract
- Conductor – overall diameter
- Conductor screen thickness
- Insulation thickness
- Steel wire armouring – single wire diameter
- Outer sheath thickness
- Outer sheath overall diameter
- Embossing (marking)

3.1 Factory Acceptance Test (FAT)

- Partial discharge test
  - The test voltage shall be raised gradually to and held at $2U_o$ for 10s and then slowly reduced to $1.73U_o$
  - ≤ 10 pC
- High voltage test (pressure test)
  - 11 kV → Should be tested at 22.23 kV_{ac} for 5 min.
  - 33 kV → should be tested at 66.5 kV_{ac} for 5 min.
  - No breakdown of the insulation shall occur.
- Conductor resistance at 20^oC

Note: The IEC designation for cable voltage rating is: U_o/U (U_m),

where: Uo = max phase-to-ground voltage, U = max phase-to-phase voltage and Um = maximum system voltage.

3.2 Site Testing

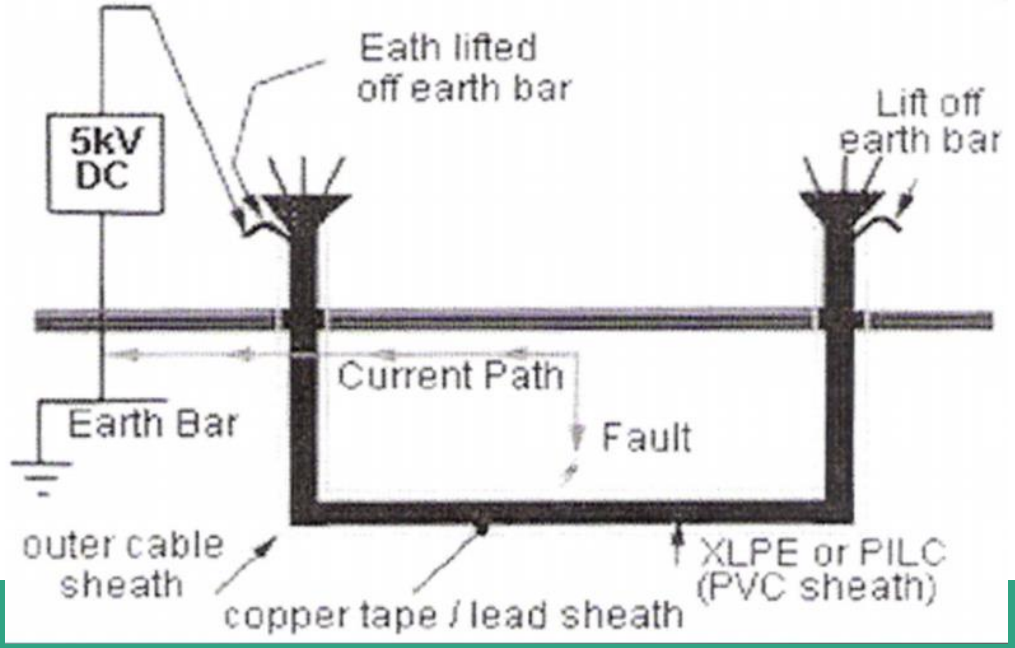
3.2.1 Insulation resistance test

- The test can indicate the contamination of insulation by moisture, dirt or carbonization.
- It is usually best to disconnect the cable at both ends in order to test only the cable, and to avoid error due to leakage across or through panel boards or circuit breakers.
- Should be tested at 5 kV_{dc}. R-E, Y-E, B-E, R-Y, Y-B, R-B.

3.2 Site Testing

3.2.2 Sheath integrity test

- HVDC Sheath Test
- To disconnect the SWA at both ends
- Should be tested at 5 kV_{dc}. SWA-E



3.2 Site Testing

3.2.3 Soaking test

- Kabel yang akan dimulatugas dihidupkan tanpa beban selama 48 jam sebelum bekalan mula disalurkan

3.2 Site Testing

3.2.4 High Voltage Test (Pressure test)

Very Low Frequency (VLF) test

- IEEE 400.2 standard
- Ujian mulatugas semula (selepas membaiki kerosakan):
  - The frequency applied is 0.01 to 1.00 Hz
  - The test duration is 30 minutes *bagi setiap fasa ke bumi.*
  - 11 kV → should be tested at $1.5U_o$ ($9.5\ kV_{ac}$)
  - 33 kV → should be tested at $1.5U_o$ ($28.6\ kV_{ac}$)

3.2 Site Testing

3.2.4 High Voltage Test (Pressure test)

Very Low Frequency (VLF) test

3.2 Site Testing

3.2.4 High Voltage Test (Pressure test)

Very Low Frequency (VLF) test

Thank You

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