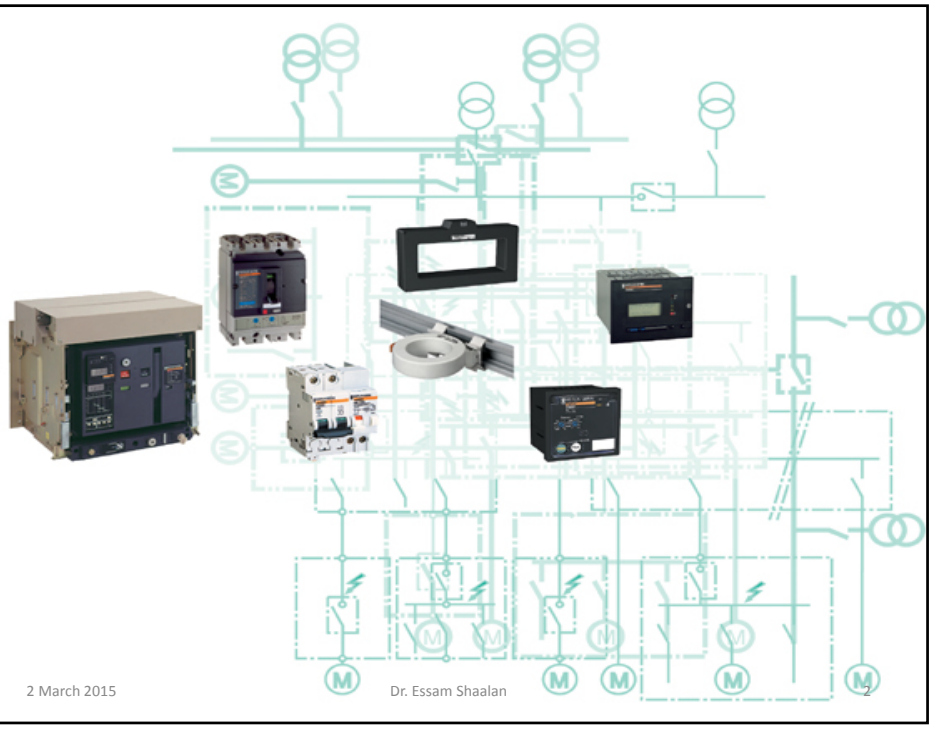
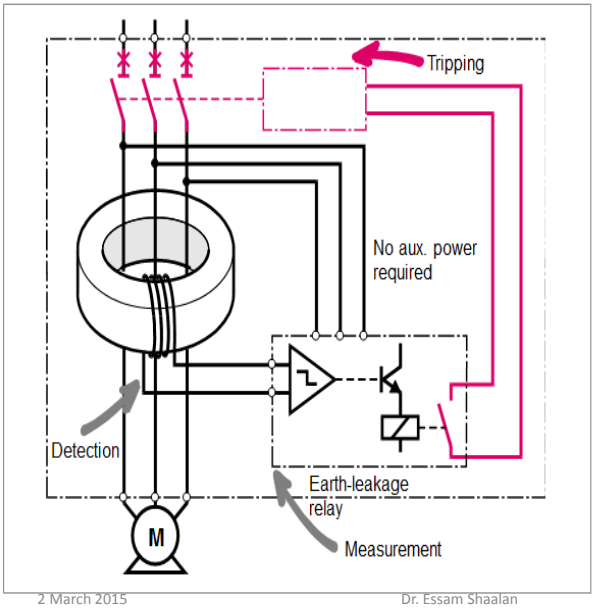
High Voltage and Current Measurement Techniques



Operating principle



Operating principle of residual current devices requiring no auxiliary supply (electronic)

Detection

Measurement

Tripping

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Difference between Tests and Measurements

Intensive development **tests**, routine tests and commissioning tests are the basics for a reliable design and proven product quality.

While it is essential to **measure** the voltages and currents accurately, ensuring perfect safety to the personnel and equipment.

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Difference between Tests and Measurements

HIGH VOLTAGE TESTING OF ELECTRICAL APPARATUS:

Testing of Insulators and bushings,

Testing of Isolators and circuit breakers,

Testing of cables,

Testing of Transformers,

Testing of Surge Arresters.

MEASUREMENT OF HIGH VOLTAGES AND CURRENTS:

Measurement of High Direct Current voltages, Measurement of High Voltages alternating and impulse,

Measurement of High Currents-direct, alternating and Impulse.

Type Tests

Type tests: are for the purpose of proving the characteristics of equipment, their operating devices and their auxiliary equipment.

Type Test is a destructive test and is carried **only one time.**

Table 8 – Example of grouping of type tests

Group	Type tests	Subclause
1	Dielectric tests on main, auxiliary and control circuits	6.2
	Radio interference voltage (r.i.v.) test	6.3
2	Measurement of resistance of the main current path	6.4
	Temperature rise tests	6.5
3	Short-time withstand current and peak withstand current tests	6.6
	Making and breaking tests	See relevant IEC standard
4	Tests to verify the degrees of protection of enclosures	6.7
	Tightness tests (where applicable)	6.8
	Mechanical tests	} See relevant IEC standard
	Environmental tests	

Routine Tests

Routine tests : are for the purpose of revealing faults in material or construction. They do not impair the properties and reliability of a test object.

Routine Test is not destructive test.

Routine tests

- By agreement, any routine test may be made on site.
- The routine tests given in this standard comprise:
  1. Design and Visual Inspection
  2. Dielectric test on the main circuit.
  3. Measurement of the resistance of the main circuit.

Tests and measurements at different life cycle periods of GIS

Life Cycle Period	Tests and Measurements	Information for …
Research & Development	Development tests Type tests	Design
Production	Routine tests	R & D Product Quality Commissioning
Installation & Commissioning	Tests after installation (on-site tests)	R & D Production Service
Service	Maintenance Tests after extension/repair Monitoring (continuous, periodic, spontanuous)	R & D Production Installation & Commissioning Asset management Further operation End of life-time
Disposal, Recycling	Inspection Material tests	R & D

Instrument transformers (CTs, VTs) in the system

Three main tasks of CTs and VTs

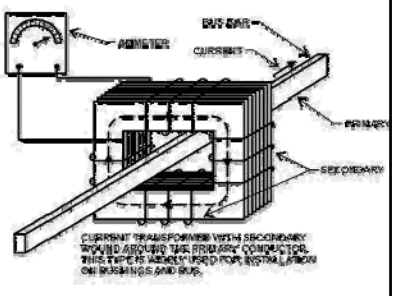
The three main tasks of instrument transformers are:

1. To transform currents or voltages from a usually high value to a value easy to handle for relays and instruments.
2. To insulate the metering circuit from the primary high voltage system.
3. To provide possibilities of standardizing the instruments and relays to a few rated currents and voltages.

Instrument transformers are special types of transformers intended to measure currents and voltages.

Current transformer

The primary of a **current transformer** typically has only one turn.
This is not really a turn but just a conductor or bus going through the "window."
The primary never has more than a very few turns,
While the secondary may have a great many turns, depending upon how much the current must be stepped down.
In most cases, the primary of a current transformer is a single wire or **busbar**, and the secondary is wound on a laminated magnetic core, placed around the conductor in which the current needs to be measured



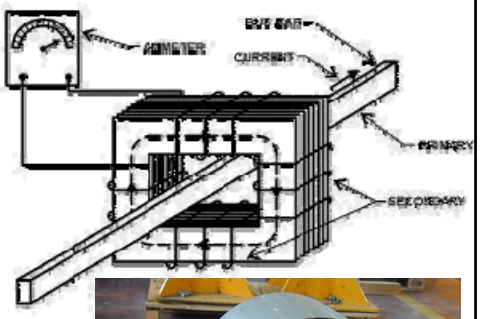

Current Transformer in Switchyard.


Lab Current Transformer.


Current Transformer in Switchyard.

Current transformer

If the secondary is opened with current in the primary, the primary magnetizing force builds up an extremely high voltage in the secondary, which is dangerous to personnel and can destroy the current transformer.



CAUTION:

For this reason, the secondary of a current transformer should always be shorted before removing a relay from its case or removing any other device that the CT operates. This protects the CT from **overvoltage**.

Current transformer

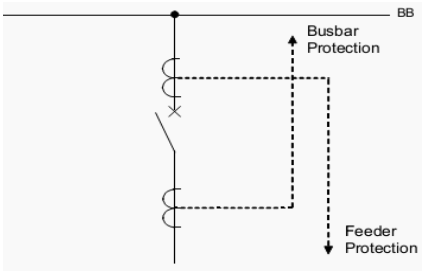
CTs are used for:

Protection,
Instrumentation,
M**etering and**
Control.

CTs are used with ammeters, wattmeters, powerfactor meters, watt-hour meters, compensators, protective and regulating relays, and trip coils of circuit breakers.

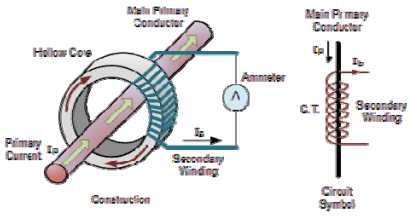
Ideally the current transformers should be **on the power source side of the circuit breaker** that is tripped by the protection so that the circuit breaker is included in the protective zone.

CT's on both sides of CB



Bushing current transformer installation

Current transformer



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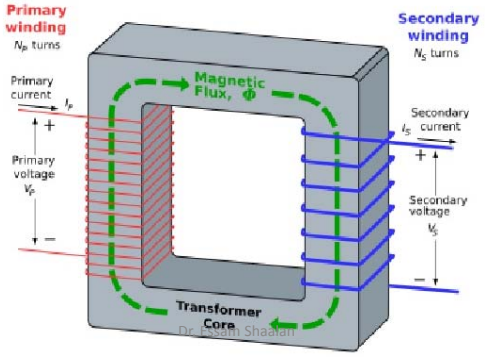
Potential transformer

PT is a device used to step down voltage from high value (primary voltage) to a low value (secondary voltage).

Low value voltage is easy to measure, no need to develop high voltage measuring equipment.

The secondary voltage is substantially proportional to the primary voltage.



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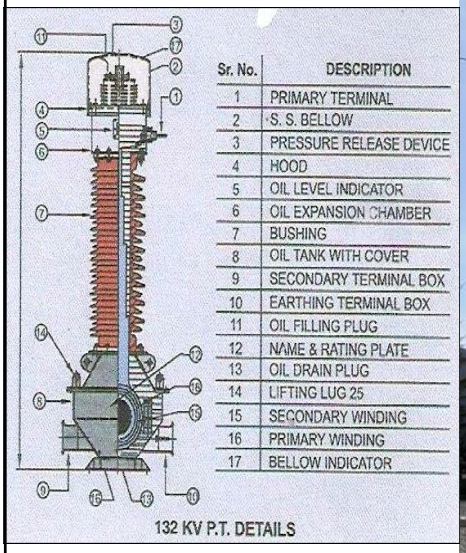
Potential transformer

PTs are used for:

1. **Protection**
   Voltage transformer connected to protection equipment (protection relay). The protection relay can be set to identify whether the input voltage indicate that fault occur in the system.
2. **Measurement**
   Voltage transformer connected to measurement equipment (voltmeter, energy meter).

Potential transformer



Sr. No.	DESCRIPTION
1	PRIMARY TERMINAL
2	S. S. BELLOW
3	PRESSURE RELEASE DEVICE
4	HOOD
5	OIL LEVEL INDICATOR
6	OIL EXPANSION CHAMBER
7	BUSHING
8	OIL TANK WITH COVER
9	SECONDARY TERMINAL BOX
10	EARTHING TERMINAL BOX
11	OIL FILLING PLUG
12	NAME & RATING PLATE
13	OIL DRAIN PLUG
14	LIFTING LUG 25
15	SECONDARY WINDING
16	PRIMARY WINDING
17	BELLOW INDICATOR

132 KV P.T. DETAILS

High Voltage and Current Measurement Techniques

Types of High voltage (HV)

High Voltage DC

- Used in HVDC Transmission lines.
- Used in laboratories for testing equipment (used in AC or DC Application).

High Voltage AC (Power Frequency)

- Used in power system (generation, transmission, distribution).
- Used to simulate interior overvoltage (Switching).

High Voltage Impulse

- Used to simulate external overvoltage (Lightning).

Measuring HV

Why measuring HV

- To measure the generated HV
- To test the HV equipment such as C.B, Transformer,…etc.
- For continuous monitoring the voltage level and to take action in case of over/under voltage to protect persons and equipment.
- For continuous monitoring the leakage current from HV insulators, that may affect persons.

High voltage Measurement Techniques

Type of voltage	Method or technique
(a) d.c. voltages	*(i)* Series resistance microammeter
	(ii) Resistance potential divider
	(iii) Generating voltmeters
	(iv) Sphere and other spark gaps
(b) a.c. voltages (power frequency)	*(i)* Series impedance ammeters
	(ii) Potential dividers (resistance or capacitance type)
	(iii) Potential transformers (electromagnetic or CVT)
	(iv) Electrostatic voltmeters
	(v) Sphere gaps
(c) a.c. high frequency voltages, impulse voltages, and other rapidly changing voltages	*(i)* Potential dividers with a cathode ray oscillograph (resistive or capacitive dividers)
	(ii) Peak voltmeters
	(iii) Sphere gaps

High Current Measurement Techniques

Type of current	Device or technique
(*a*) Direct currents	(*i*) Resistive shunts with milliammeter
	(*ii*) Hall effect generators
	(*iii*) Magnetic links
(*b*) Alternating currents (Power frequency)	(*i*) Resistive shunts
	(*ii*) Electromagnetic current transformers
(*c*) High frequency a.c., impulse and rapidly changing currents	(*i*) Resistive shunts
	(*ii*) Magnetic potentiometers or Rogowski coils
	(*iii*) Magnetic links
	(*iv*) Hall effect generators

1- High Ohmic Series Resistance with Micro-ammeter (HV DC Measure)

Construction

1- Very high series resistance: (few hundreds of mega ohms): to take a very high voltage drop across it.

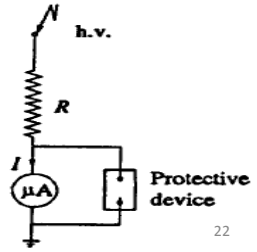
2- **Micro-ammeter:** to measure a few current in R.

Only the current (I) flowing through the large resistance R is measured by the moving coil micro-ammeter.

3- **Protective device:** like a paper gap, a neon glow tube, or a zener diode with a suitable series resistance is connected across the meter as a protection against high voltages in case the series resistance *R* fails or flashes over.

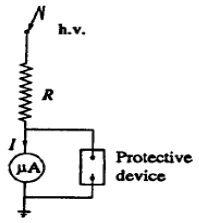
The voltage of the source is given by: **V=IR**

The voltage drop in the meter is **negligible**, as the impedance of the meter is only few ohms compared to few hundred mega-ohms of the series resistance *R*.



1- High Ohmic Series Resistance with Micro-ammeter (HV DC Measure)

The value of the series resistance *R* is chosen such that a current of one to ten micro-amperes is allowed for full-scale deflection.

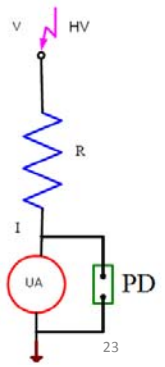


$$V=IR$$

Advantage: simple circuit design

The limitations in the series resistance design are:

(i) High power dissipation,
(ii) temperature effects and long time stability,
(iii) voltage dependence of resistive elements, and
(iv) sensitivity to mechanical stresses.



Series resistance meters are built for **500 kV d.c.** with an accuracy better than 0.2%.

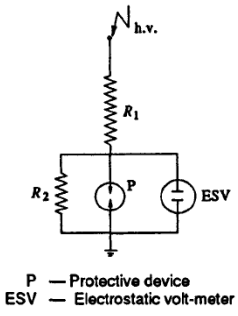
2- Resistance Potential Dividers Method (HV DC Measure)

Construction

1- Potential divider resistances (R_1, R_2): to divide the voltage across them.

2- Protective device: is connected across the voltmeter as a protection against high voltages in case the series resistance R_1 fails or flashes over.

3- Electrostatic or high impedance voltmeter: to measure DC voltage across R_2.



The high voltage magnitude of source measured is given by:

$$V=(V_2/R_2)*(R_1+R_2)$$

Where V_2 is the d.c. voltage across the low voltage arm R_2.

Potential dividers are made with **0.05% accuracy up to 100 kV**, with **0.1% accuracy up to 300 kV**, and with **better than 0.5% accuracy for 500 kV**.

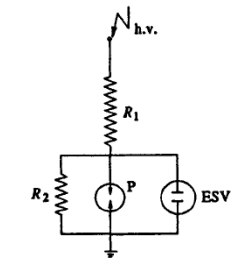
2- Resistance Potential Dividers Method (HV DC Measure)

Advantages

1- More precession than series R method

2- Simple Circuit design

3- The influence of temperature and voltage dependence on the elements is eliminated

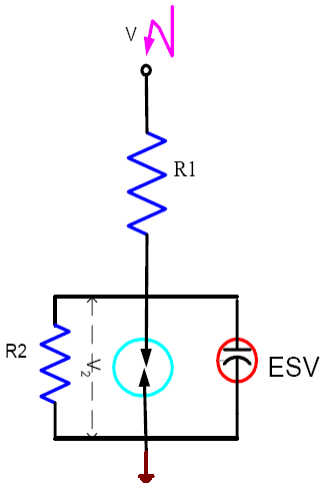


P — Protective device
ESV — Electrostatic volt-meter

Disadvantages

(i) High power dissipation,
(ii) Leakage current.
(iii) Sudden changes in voltage, such as switching operations, flashover of the test objects, or source short circuits, flashover or damage may occur to the divider elements.

2- Resistance Potential Dividers Method (HV DC Measure)



Methods of Measuring High voltage (HV)

Method of measurement	DC		AC			Impulse	
	Mean	Peak	rms	Peak	Waveform	Peak	Waveform
Sphere gaps		x		x		x	
Peak voltmeter				x			
Electrostatic voltmeter	x (rms)		x				
Voltage transformer			x	x	x		
Resistor in series with milliammeter	x		x				
Resistive divider	x	x	x	x	x	x	x
Capacitive divider			x		x		x