IECE 513 Energy Systems

Mini-Design Problem - Transformers

Name: Akhil Reddy Gujju

Section 1:

CURRENT TRANSFORMER:

Transformers are used in A.C systems for a wide application, the instrument transformers are used where the values of currents and voltages are very high. In those cases, direct measurement is not at all possible, the solution is to step down those currents and voltages with the use of instrument transformers so that they can be easier to measure.

Operation of Current Transformer:

The current transformer is a single-winding transformer, where its primary winding is connected in series with a line carrying the currents to be measured. The secondary winding has a larger number of turns of smaller wire and is usually rated 1A or 5A. The secondary turns can be determined by the turn ratio.

The below figure depicts the actual current transformer,

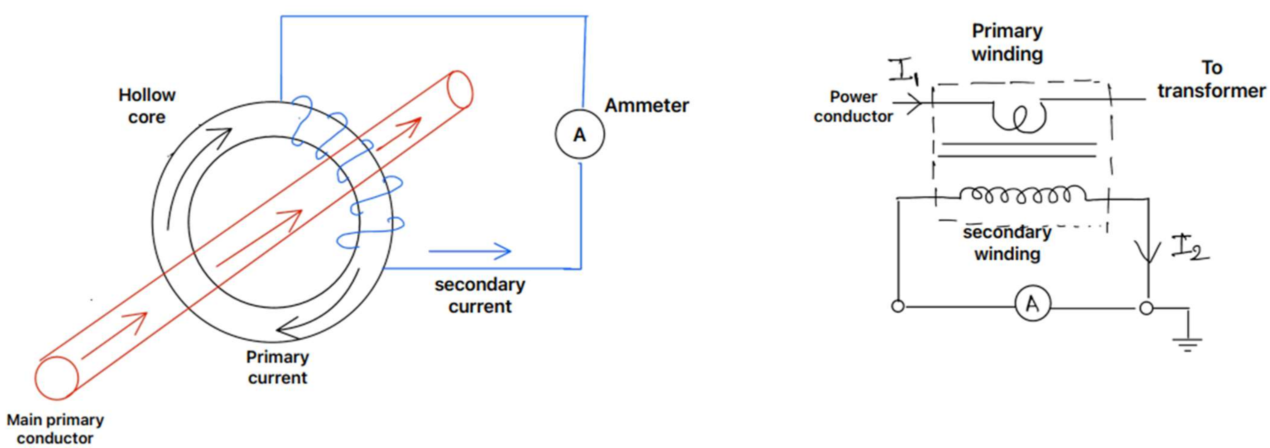


Fig.1 Working principle of Current Transformer

The Transformers are of two types, step-up and step-down transformers, let us take a step-up transformer, the voltage at the primary side is lower than the secondary side. Thus, the current in the primary is greater than the secondary. Let,

N1= Number of turns of the primary

N2= Number of turns of the secondary

I1= Primary current

I2= Secondary current

We know that the transformer turns ratio,

$$\frac{I1}{I2} = \frac{N2}{N1}$$

As N2 is high, the ratio I1 to I2 will also be high. This is how a CT ratio is defined.

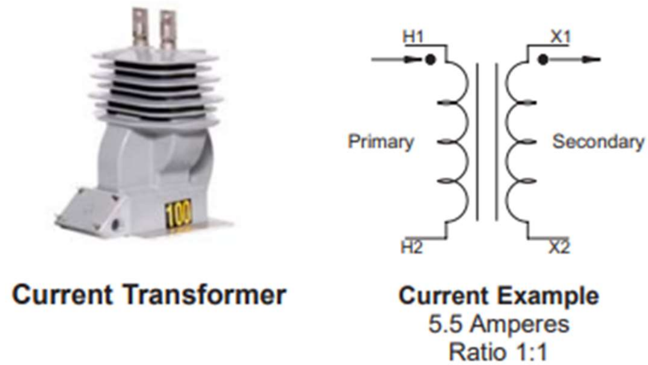


Fig 3. Current Transformer

Source: ABB

Construction of Current transformer:

There are three types of construction used for the current transformer:

1) Wound type
2) Bar type
3) Window type

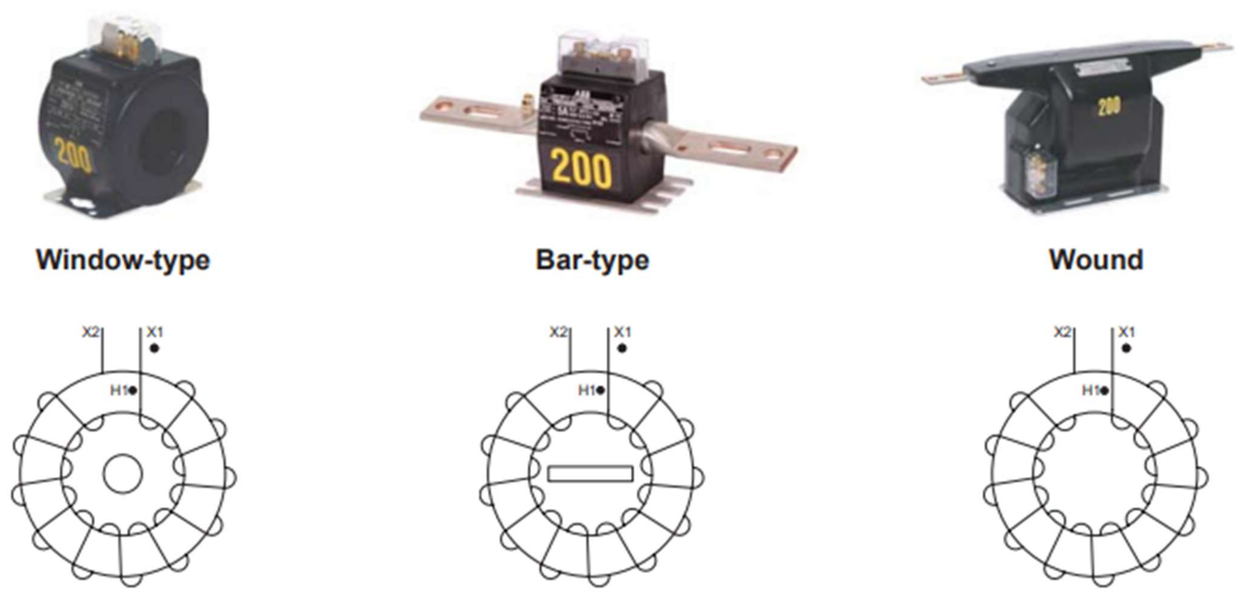


Fig 4. Different types of Construction of Current Transformer

Source: ABB

Note: The secondary of the CT must not be kept open. Either it should be shorted or must be connected in series with a low-resistant coil. If it is left open, then the current through the secondary becomes zero hence the ampere turns produced by the secondary which generally oppose the primary ampere turn becomes zero. As there is no counter m.m.f., unopposed primary m.m.f produces high flux in the core. This produces excessive core losses and heats the core beyond the limits. Due to heavy emf's the primary and the secondary induces more voltage, which will damage the insulation of the winding. Hence never open the secondary of the CT while its primary is energised.

POTENTIAL TRANSFORMER:

Operation principle:

The basic principle of these transformers is the same as current transformers. The high alternating voltage is reduced in a fixed proportion for measurement purposes with the help of potential transformers. The construction of these transformers is like the normal transformer. These are extremely accurate ratio step-down transformers. The windings are low-power rating windings. Primary winding consists of many turns while secondary has a smaller number of turns and is usually rated for 110V, irrespective of the primary voltage rating. The primary is connected across the high-voltage line while the secondary is connected to the low-range voltmeter coil. One end of the secondary is always grounded for safety purposes.

The below figure depicts the potential transformer:

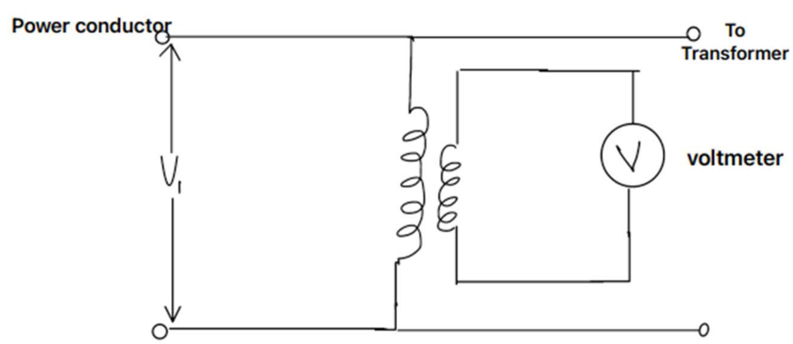


Fig 5. Working of Potential Transformer

So, if the voltage ratio of the P.T. is known and the voltmeter reading is known then the high voltage to be measured, can be determined.

Let, N1= Number of turns of the primary

N2= Number of turns of the secondary

I1= Primary Voltage

I2= Secondary Voltage

The transformation ratio of the potential transformer is given by:

$$\frac{V1}{V2} = \frac{N1}{N2}$$

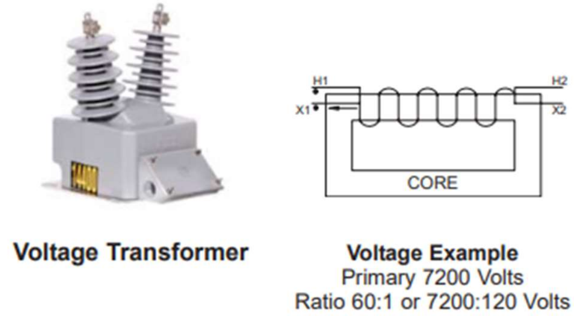


Fig 6. Voltage Transformer Source(ABB)

Construction of Potential Transformer:

The potential transformer uses larger core and conductor sizes compared to conventional power transformers. The shell type or core type construction is used. The shell type is used for low voltage while the core type is used for high voltage transformers.

Section 2:

Ratings of the Instrument transformers:

Given transformer is 10MVA in power, 66/13.8 kV Delta–star transformer.

We know that,

Three phase power, $S=\sqrt{3} * V_L * I_L$ (magnitude)

Primary side:

The primary side is Delta-connected winding, $V_L = V_{Ph}$ and $I_L = \sqrt{3}\, I_{Ph.}$

Line current, $I_{L\ primary} = \dfrac{S}{\sqrt{3}\ VL} = \dfrac{10*10^{\wedge}6}{\sqrt{3}\,(66*10^3)} = 87.4\ A$

A current transformer that I would choose is **100/5A C.T** on the primary side.

A potential transformer that I would choose is **66kV/115V P.T** on the primary side.

Secondary side:

The secondary side is Star-connected winding, $I_L = I_{Ph}$ and $V_L = \sqrt{3}\, V_{Ph.}$

Line current, $I_{L\ secondary} = \dfrac{S}{\sqrt{3}\ VL} = \dfrac{10*10^{\wedge}6}{\sqrt{3}\,(13.8*10^3)} = 418.3\ A$

Current transformer that I would choose is **500/5A C.T** on the secondary side.

Potential transformer that I would choose is **13.8kV/115V P.T** on the secondary side.

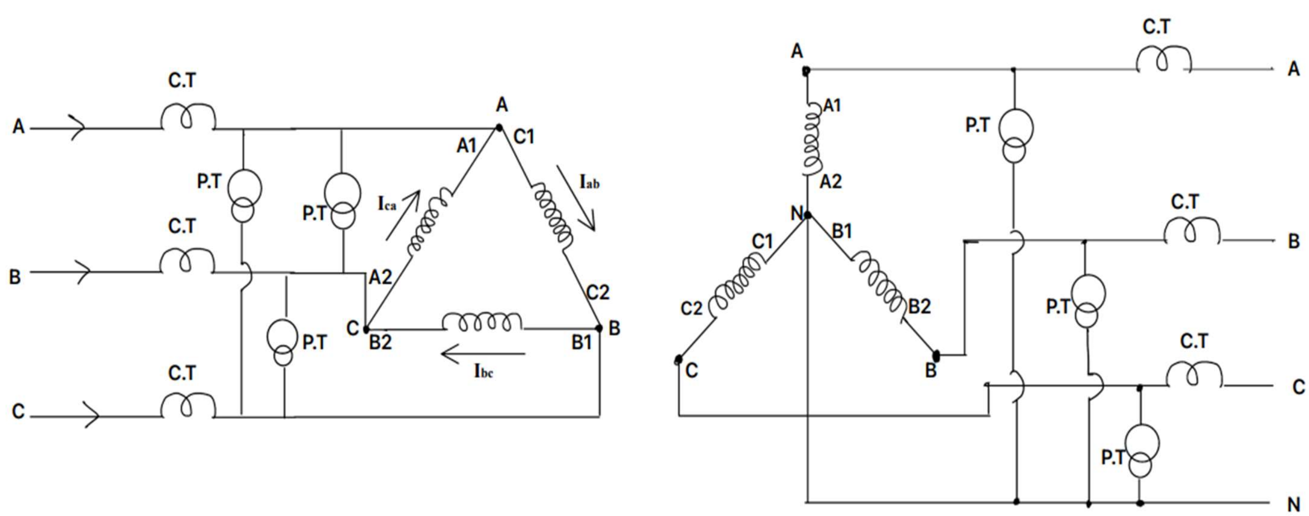


Fig 7. a diagram indicating the locations of the instrument transformers.

Section 3:

Passive components:

CT:

The passive components that are connected to the CT are burden resistors across the secondary of the CT, where we know we should not leave the secondary of the CT open-circuited.

The burden resistor here is placed in parallel to the secondary of the CT so that the current in the CT is converted into voltage reference. The obtained output voltage from the CT is given to the monitoring circuitry.

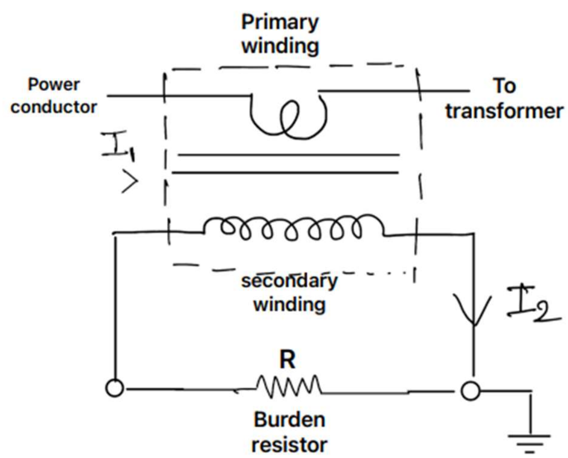


Fig 8. Diagram indicating the placement of Burden Resistor of Current Transformer.

Calculation of the burden resistor:

Primary side:

The selected CT for the primary side is 100/5A C.T,

The primary current, I_p= 100A

The secondary current, I_s= 5A

It is given that the monitoring/control circuitry operates at a voltage level of 15

Secondary side:

The selected CT for the secondary side is 500/5A C.T,

The primary current, I_p= 500A

The secondary current, I_s= 5A

It is given that the monitoring/control circuitry operates at a voltage level of 15V.

Burden Resistor, $R_b = \frac{V}{Is} = \frac{15}{5} = 3\Omega$

PT:

The passive component that are connected to the PT is the burden resistor, it is connected in series to the secondary winding of the transformer. Usually, the secondary of the PT is open-circuited.

The resistor produces an output voltage that is proportional to the resistor's value, based on the amount of current flowing through it. The rated burden of a potential transformer is the VA burden that must not be exceeded if the transformer is to operate with its rated accuracy. For low errors in PT, the burden value should be high.

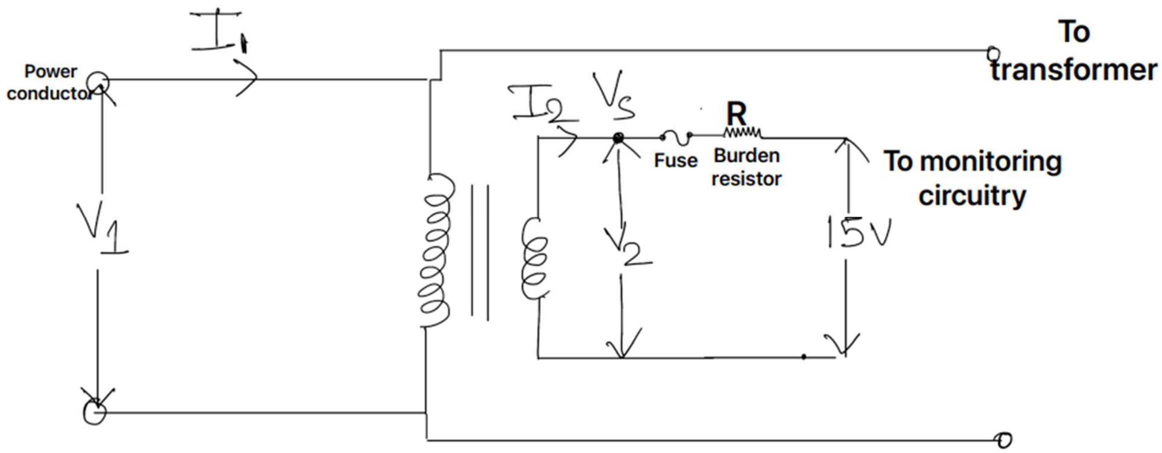


Fig 9 Diagram Indicating the placement of Fuse of Burden Resistor of Potential Transformer.

Calculation of the burden resistor:

Primary side:

The selected PT for the primary side is 66 kV/115 V P.T,

The primary Voltage, $V_p = 66kV$

The secondary Voltage, $V_s = 115V$

For the above Potential transformer the VA rating, S = 150 VA (from P.T designed by TE connectivity)

We know that power, $S = V_s * I_s$, where I_s = Secondary current of the P.T

From above, $I_s = \frac{S}{Vs} = \frac{150}{115} = 1.30$ A

It is given that the monitoring/control circuitry operates at a voltage level of 15V.

Now, the output of the P.T is 115 V it should be reduced to 15 V for monitoring purposes.

Burden Resistor, $R_b = \frac{Vs-V}{Is} = \frac{115-15}{1.30} = \frac{100}{1.30} = 73.52\Omega$

A fuse can be connected as a passive component, so that it will act as a protective element against fault currents. We know that the secondary current is 1.30 A, so a 5amps fuse is sufficient.

Secondary side:

The selected PT for the primary side is 13.8 kV/115 V P.T,

The primary Voltage, $V_p = 13.8kV$

The secondary Voltage, $V_s = 115V$

For the above Potential transformer the VA rating, S = 100 VA (from P.T designed by TE connectivity)

We know that power, $S = V_s * I_s$, where I_s = Secondary current of the P.T

From above, $I_s = \frac{S}{Vs} = \frac{100}{115} = 8.69$ A

It is given that the monitoring/control circuitry operates at a voltage level of 15V.

Now, the output of the P.T is 115 V it should be reduced to 15 V for monitoring purpose.

Burden Resistor, $R_b = \frac{Vs-V}{Is} = \frac{115-15}{8.69} = \frac{100}{8.69} = 11.50\Omega$

A fuse can be connected as a passive component, so that it will act as a protective element against fault currents. We know that the secondary current is 8.69 A, so a 15amps fuse is sufficient.

Section 4:

a) Current Measurement:

Current Transformer (CT): This transformer reduces the high current flowing in the main line to a safer and more manageable level for measurement purposes. The CT's secondary winding typically outputs a current proportional to the primary current.

Half Wave Rectifier: This component allows only the positive half of the AC current from the CT to pass through. It converts the AC signal to a pulsating DC voltage.

Capacitor: This component is used for filtering or smoothing out any fluctuations in the rectified voltage signal before feeding it to the Op-Amp.

Operational Amplifier (Op-Amp): This amplifier can further amplify the rectified voltage signal from the half wave rectifier. Depending on the circuit configuration, it can be used in inverting or non-inverting mode to scale or adjust the voltage level.

Analog-to-Digital Converter (ADC): This block converts the amplified voltage signal from the Op-Amp into a digital signal. The ADC translates the voltage amplitude into a digital code for processing by the microcontroller.

Microcontroller: This programmable device processes the digital data from the ADC. It likely calculates the actual current based on the CT's turn ratio and performs any necessary scaling or conversions.

Communication (LAN): This allows the microcontroller to potentially transmit the measured current data to other devices on a network.

Display: This block presents the processed and formatted current measurement data to the user in a readable format (e.g., amps).

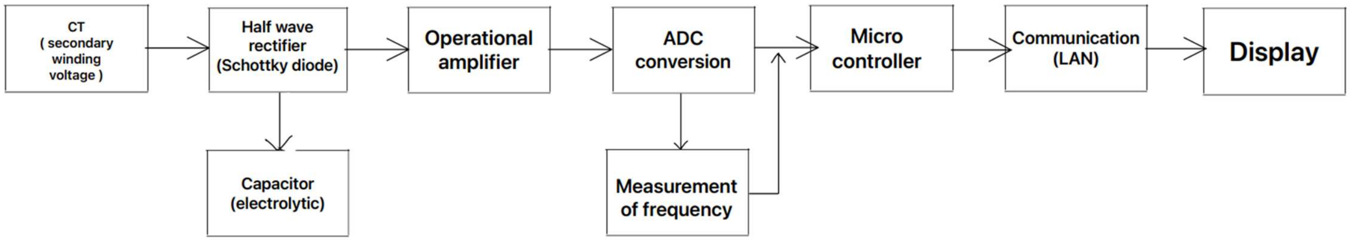


Fig 10. Block diagram of Current Measurement.

b) Voltage measurement:

PT (Potential Transformer): This transformer reduces the high voltage on the main line to a safer and measurable level. The PT's secondary winding typically outputs a voltage proportional to the primary voltage.

Half wave rectifier: This circuit component allows only the positive half of the AC voltage from the PT to pass through. It converts the AC signal to a pulsating DC voltage with positive peaks.

Capacitor: This passive electronic component stores electrical energy in an electric field. It might be used for filtering or smoothing out any fluctuations in the rectified voltage signal before feeding it to the Op-Amp.

Operational Amplifier (Op-Amp): This amplifier can further amplify the rectified voltage signal from the half wave rectifier. Depending on the circuit configuration, it can be used in inverting or non-inverting mode to scale or adjust the voltage level.

ADC (Analog-to-Digital Converter): This block converts the amplified voltage signal from the Op-Amp into a digital signal. The ADC translates the voltage amplitude into a digital code for processing by the microcontroller.

Microcontroller: This programmable device processes the digital data from the ADC. It likely calculates the actual voltage based on the PT's turn ratio and performs any necessary scaling or conversions.

Communication (LAN): This allows the microcontroller to potentially transmit the measured voltage data to other devices on a network.

Display: This block presents the processed and formatted voltage measurement data to the user in a readable format (e.g., volts).

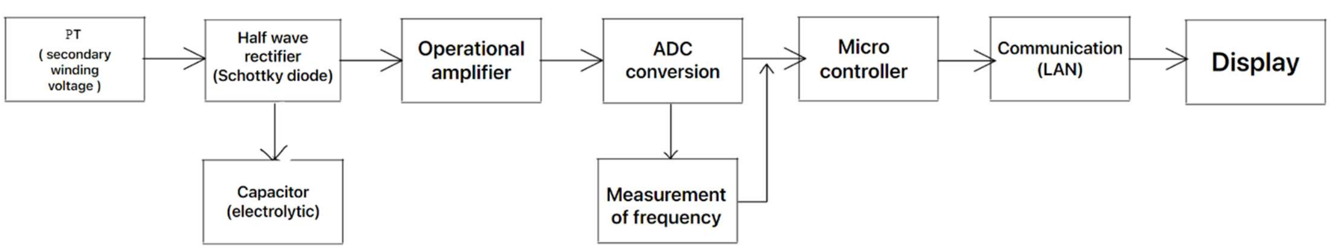


Fig 11. Block diagram of Voltage measurement

c) Measurement of Power:

The below diagram depicts the power measurement where the current, voltage analog signals are fed as inputs. Where the microcontroller takes care about the calculation. Where the obtained output from the microcontroller is the output power which is P= V * I * p.f, this is single phase power.

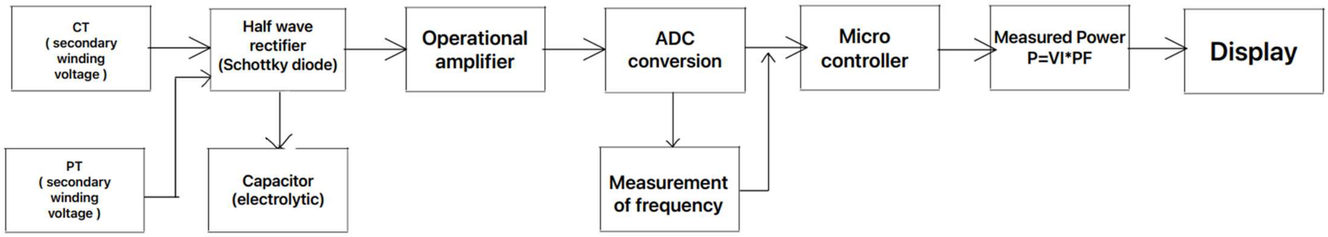


Fig 12. Block diagram of Measurement of Power

d) Frequency measurement

From fig12. We can see that the Analog to Digital converter gives the output in binary format which is in 0's and 1's where we get it in digital format.

So that in fig 13. The output of ADC where the time period T is the time taken for one cycle with respect to time.

Now the frequency can be calculated by, **f= 1/ T** hertz

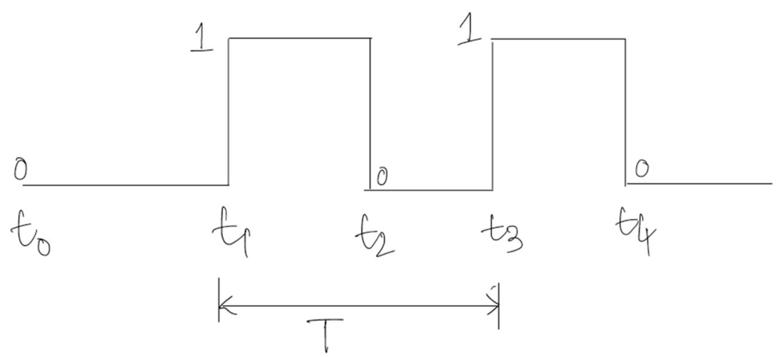


Fig 13. Output of Analog to Digital Converter.

Section 5:

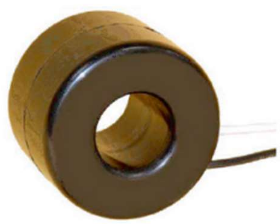
Part Numbers:

Current Transformer:

Primary side:

100/5A by GE Grid Solutions

Model 2DARL **Window: 1.00"**



APPLICATION
Sub-metering, load control , etc. Suitable for ammeters , wattmeters and cross current compensation.

REGULATORY AGENCY APPROVALS
UL Recognized File E93779
CSA Recognized File LR89403

WEIGHT (approximate) ....0.9 lbs

INSULATION LEVEL
600 Volts, 10 kV BIL full wave.

Flexible leads are UL 1015, 105oC, CSA approved, #16 AWG, 24" long. Non-standard, lead length can be specified.

FREQUENCY
50-400 Hz

2DARL DATA TABLE

Current Ratio (Amps) Pri : Sec	IEEE Accuracy Class 60 Hz Burden					VA ± 1% Class	Secondary Winding Resistnce (Ohms @ 75°C)	Continuous Thermal Current Rating Factor		Catalog Number
	B0.1	B0.2	B0.5	B0.9	B1.8			@ 30°C Amb.	@ 55°C Amb.	
50:5	4.8	--	--	--	--	2% 2.5	0.008	2.0	2.0	2DARL-500
60:5	1.2	4.8	--	--	--	2.5	0.011	2.0	2.0	2DARL-600
75:5	1.2	2.4	--	--	--	3.5	0.015	2.0	2.0	2DARL-750
80:5	1.2	2.4	4.8	--	--	4.0	0.016	2.0	2.0	2DARL-800
100:5	1.2	2.4	4.8	--	--	5.0	0.018	2.0	2.0	2DARL-101
120:5	1.2	2.4	2.4	4.8	--	5.0	0.022	2.0	2.0	2DARL-121
125:5	0.6	1.2	2.4	4.8	--	5.0	0.028	2.0	1.5	2DARL-1250
150:5	0.6	0.6	1.2	2.4	4.8	10.0	0.031	2.0	1.5	2DARL-151
200:5	0.3	0.6	1.2	1.2	2.4	12.5	0.047	1.5	1.33	2DARL-201
250:5	0.3	0.3	0.6	1.2	2.4	15.0	0.074	1.5	1.25	2DARL-251
300:5	0.3	0.3	0.6	0.6	1.2	20.0	0.089	1.5	1.0	2DARL-301

Part number: 2DARL-101 for 100/ 5A by GE grid.

<u>Secondary side:</u>

500 /5 A by GE

GE

Energy Connections

Model 500

Split Core Current Transformer
Window Sizes Available up to 10"x 30"

Application

Metering.

Frequency

50-400 Hz

Insulation Level

0.6 kV, BIL 10 kV full wave.

Continuous Thermal Current Rating Factor

1.33 at 30 °C. amb.
1.0 at 55 °C. amb.

Terminals are 8-32 brass studs with one flatwasher, lockwasher, and regular nut.

Flexible leads are UL 1015, 105°C , CSA approved, #16 AWG, 24" long are available.

Approximate Weight 8 to 18 lbs.

Model 500

REGULATORY AGENCY APPROVALS

E93779 LR89403

Manufactured to meet the requirements of ANSI/IEEE C57.13.
Classified by U.L. in accordance with IEC 44-1

Model 500

Ratio Number	Ratio	Accuracy Class with U.P.F Burden
301	300:5	5 % @ 1.5VA
401	400:5	3 % @ 2.5VA
501	500:5	2 % @ 2.5VA
601	600:5	1 % @ 4.0VA
751	750:5	1 % @ 5.0VA

Part number: Model 500

Potential Transformer:

Primary side:

66 kV/ 115v potential transformer by JDCF

Part number : JDCF-72.5W3

JDCF 系列 66 ~ 230kV串级式油浸电磁式电压互感器
JDCF Series 66 ~ 230kV oil immersed cascade inductive voltage transformer

Pollution level
Applying to high altitude
Rated voltage (kV)
Individual measuring and protective winding
Cascade structure
Single-phase
Voltage transformer

Scope

◆It is outdoor, single phase and oil immersed cascade inductive voltage transformer, which is used for metering and relay protection of 66~230kV, 50 or 60Hz system.

Standards

◆IEC 61869-1; IEC 61869-3
◆GB 20840.1; GB 20840.3

技术参数 Technical data

额定一次电压 Rated primary voltage, kV	66or69	110or115	132or138	150	220or230
设备最高电压 Highest voltage for equipment, kV	72.5	123or126	145	170	245or252
额定频率 Rated frequency, Hz	50 或 or 60				
额定工频耐受电压 Rated power frequency withstand voltage, kV	140/160	230	275	325	460
额定雷电冲击耐受电压 Rated lightning impulse voltage, kV	325/350	550	650	750	1050
弧闪距离 Flashover distance, mm	780	1050	1300	1300	2000
外绝缘爬电距离 External insulation creepage distance, mm	W_1:1450 W_2:1820 W_3:2250	W_1:2520 W_2:3150 W_3:3910	W_1:2900 W_2:3630 W_3:4500	W_1:3400 W_2:4250 W_3:5270	W_1:5040 W_2:6300 W_3:7820
机械载荷 Mechanical load, N	1250	1250	1250	1250	1250

额定二次电压 Rated secondary voltage, kV	$\frac{0.115}{\sqrt{3}}$ or $\frac{0.11}{\sqrt{3}}$ or $\frac{0.1}{\sqrt{3}}$ or 0.115 / 0.11 /0.1		
二次端子标志 Secondary terminal marking	1a-1n	2a-2n	da-dn
准确级 Accuracy class	0.2	0.5	3P
额定输出 Rated output, VA	100	250	300
	150	150	300
	150	-	300
热极限输出 Thermal limiting output, VA	2000		
额定电压因数 Rated voltage factor	1.2/连续continuous; 1.9/8h (66kV) 1.2/连续continuous; 1.5/30s(110~230kV)		
介质损耗因数tgδ，在10kV下 Dielectric dissipation factor tgδ, under 10kV	整体tgδ≤0.02；支架tgδ≤0.05 Product tgδ≤0.02; frame tgδ≤0.05		

Secondary side:

13.8kV / 110v potential transformer.

Part number: PTG5-1-110 by GE.

GE

Grid Solutions

Models PTG5-1-110 & PTG5-2-110

Indoor Voltage Transformers
Medium Voltage

Accuracy Class

0.3 WXMYZ 1.2 ZZ at 100% rated voltage with120V based ANSI burden.

0.3 WXMY, 1.2Z at 58% rated voltage with 69.3V based ANSI burden.

Frequency

60 Hz.

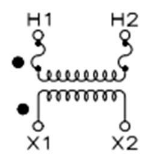
Maximum System Voltage

15.5 kV, BIL 110 kV.

Thermal Rating

1,500 VA 30 °C. amb.
1,000 VA 55 °C. amb.

Approximate weight 85 lbs. unfused.

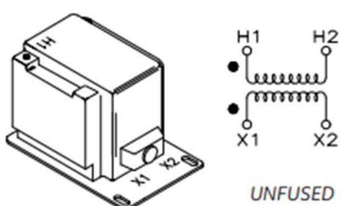


TWO FUSE
Two Bushing

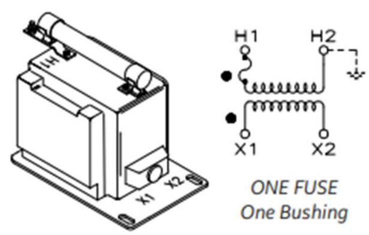
REGULATORY AGENCY APPROVALS

E145172 LR894

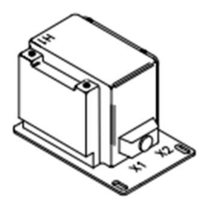
Manufactured to meet the requirements of ANSI/IEEE C57



UNFUSED
Two Bushing



ONE FUSE
One Bushing



SWITCHGEAR STYLE
Two Bushing

PTG5

Two Bushing (a)				Catalog Numbers			
Group	Primary Voltage	Ratio	Secondary Voltage	Unfused	Fuses	Fuse Clips Only	Switchgear Style
1	*7,200	60:1	120	PTG5-2-110-722	PTG5-2-110-722FF	PTG5-2-110-722CC	PTG5-2-110-722SS
1	*8,400	70:1	120	PTG5-2-110-842	PTG5-2-110-842FF	PTG5-2-110-842CC	PTG5-2-110-842SS
2	11,000	100:1	110-50 Hz	PTG5-2-110-113	PTG5-2-110-113FF	PTG5-2-110-113CC	PTG5-2-110-113SS
2	*12,000	100:1	120	PTG5-2-110-123	PTG5-2-110-123FF	PTG5-2-110-123CC	PTG5-2-110-123SS
2	13,200	110:1	120	PTG5-2-110-1322	PTG5-2-110-1322FF	PTG5-2-110-1322CC	PTG5-2-110-1322SS
2	*14,400	120:1	120	PTG5-2-110-1442	PTG5-2-110-1442FF	PTG5-2-110-1442CC	PTG5-2-110-1442SS

One Bushing (b)				Catalog Numbers			
Group	Primary Voltage	Ratio	Secondary Voltage	R FR (c)	Fuses	Fuse Clips Only (d)	Switchgear Style
4A	*7,200	60:1	120	65	PTG5-1-110-722F	PTG5-1-110-722C	PTG5-1-110-722S
4A	*8,400	70:1	120	65	PTG5-1-110-842F	PTG5-1-110-842C	PTG5-1-110-842S
4B	11,000	100:1	110-50 Hz	65	PTG5-1-110-113F	PTG5-1-110-113C	PTG5-1-110-113S
4B	*12,000	100:1	120	65	PTG5-1-110-123F	PTG5-1-110-123C	PTG5-1-110-123S
4B	13,200	110:1	120	65	PTG5-1-110-1322F	PTG5-1-110-1322C	PTG5-1-110-1322S
4B	*14,400	120:1	120	65	PTG5-1-110-1442F	PTG5-1-110-1442C	PTG5-1-110-1442S

NOTE: All Primary voltages marked with an asterisk (*) are approved for revenue metering in Canada by Industry Canada, Approval No. AE-0431 Rev. 01