

Design Selection of CT and PT' Effective for Transmission Lines

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ABSTRACT

In this paper focused on design selection of CT and PT effective for substation in where must have different protective systems to avoid the failure of power system and to get the safety of employees and consumers. The current transformers and potential transformers perform both metering and protection and step down high voltages and currents to lower values which are safe and suitable for operation of relays and other instruments connected in secondary windings. Their design performance and characteristics are used at 230/33/11 kV substation. And then their principles, effectiveness, essential factors and ratio error of CT for 230 kV(Incoming Line), 230kV (Transformer 1) and 33kV(Bank-1), PT for 230kV(Incoming Line) and 33kV(Bank-1) are analyzed and calculation for requirement data.

Keywords: current transformer, potential transformer, protective device, voltage error, current error

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1. INTRODUCTION

A current transformer is used to step down the high ampere value to low ampere values that apply for application. Protective current transformer is used to trigger a relay to cut off the faulty part in an event of fault. Measuring current transformer is used to measure the electrical power being transmitted to transmission line. Therefore, current transformers used in conjunction with ammeters, watt meters, overcurrent relays, distance relays, etc.

Accuracy class of current transformer is the highest permissible percentage composite error at rated current. The accuracy class or simply class of measuring current transformer is 0.1, means the maximum permissible limit of error is 0.1%, more clearly, measuring 100A with a 0.1 class CT, the measured value may be either 100.1 or 99.9A or anything in between these range. In table (3) the standard accuracy class for the protection current transformer are 5P, 10P. In the protection current transformer, 5P means 5%, 10P means 10% error and 'P' stands for protection[2]. In table (4) expressed limits of error for protection CT accuracy class that shows current error at rated primary current, Phase displacement at rated current and composite error at rated accuracy limit current A potential transformer is also known as voltage transformer. The standard values of secondary voltages are 100V, 110V and 200V. For single phase PT, the secondary voltages are $100/\sqrt{3}$ V and $110/\sqrt{3}$ V. The secondary winding of a CT may have one or more according to its uses. Like step down power transformer, PTs have many turns in primary winding and fewer turns in secondary winding. They step down the voltage of high magnitude to a lower voltage which can be used with standard measuring and protection instruments. A potential transformer connected in parallel with the power system[2].

Table1. Suitable Application for Metering CT Accuracy Classes

Class	Suitable Application
0.1	For precision measurement
0.2	For precision measurement
0.5	For high grade unit meter for commercial
1	General industrial measurement
3	General industrial measurement
5	Approximate measurement

Table2. Limits of Error for Metering CT Accuracy Class (IEC 60044-1)

Class	Current error at rated primary current (percent)	Phase displacement at rated current (minutes)
0.1	± 0.1	± 5
0.2	± 0.2	± 10
0.5	± 0.5	± 30
1.0	± 1.0	± 60

Table3. Suitable Protective CT Application by Accuracy Class

Class	Suitable Application
5P	Zero sequence protection
5P	Differential protection
5P, 10P	Distance protection
5P, 10P	Overcurrent protection

Table4. Limits of Error for Protection CT Accuracy Class (IEC 60044-1)

Class	Current error at rated primary current	Phase displacement at rated current (minutes)	Composite error at rated accuracy limit current (percent)
5P	±1%	±60	5
10P	±3%	-	10

2. CT and PT Effectives

Their effective areas are considered in 230kV and 33kV transmission line with comparison with calculation of values. The current transformer must also withstand the rated primary current in continuous operations. Here, the average ambient temperature (30°C) must be taken into account, if there is a deviation from the standard. Current transformers are normally designed according to IEC and IEEE standards [1]. The primary rated current should be selected to be approximately 100% to 40% higher than the estimated operation current. Protective current transformers operate in the current range above rated currents with the accuracy limit factor that indicates the overcurrent as a multiple of the rated primary current up to which the rated accuracy is fulfilled with the rated burden connected refer to voltage Error or Ratio Error in Potential Transformer.

The Current transformer of 230kV (Incoming Line) incoming line has three secondary winding. The first winding is used for measuring (Multi meter or Unit meter). Second winding is for overcurrent and earth fault protection and third winding is for distance relay protection. The error with a transformer introduces into the measurement of a voltage and which arises from the fact that actual transformation ratio is not equal to the rated transformation ratio in equation [2].

2.1. Mathematical Design Consideration

In substation load varies with time derivation, thus the design factors are calculated for linearization for protective in operation. The equation [1] gives transformation ratio in proportion to the primary and secondary turns.

$$U_p \times N_s = U_s \times N_p \quad \text{Equation (1)}$$

where, N_p =Number of primary turns in PT (turns)

N_s =Number of secondary turns in PT (turns)

U_p =Rated primary voltage (V)

U_s =Rated secondary voltage (V)

Percentage voltage error is calculated by;

$$= \frac{k_n U_s - U_p}{U_p} \times 100\% \quad \text{Equation (2)}$$

where, k_n = Rated transformation ratio

U_p = Actual primary voltage (V)

U_s = Actual secondary voltage (V)

The actual burden (VA rating) is formed by the resistance of the pilot conductors and the protection relay (s).

$$S = I_s^2 R \quad \text{Equation (3)}$$

where, S = VA rating (VA)

I_s = Rated secondary current (A)

R = Resistance (ohm)

For four wire connection, a factor of 1.2 is typically used. Resistance of a conductor is calculate by

$$R = \frac{\rho L}{A}$$

Equation (4)

Where, L = Length of control cable

A = Control cable size,

ρ = Resistivity of copper ($\mu\Omega\text{m}$)

= 0.454 Ω

Rated secondary current, $I_s = 5A$

For first secondary winding,

Burden of multi meter = 1VA

Burden of unit meter = 3VA

Actual Burden of first winding,

$S_1 = \text{Meters Burden} + \text{Cable Burden}$

Equation (5)

For Second secondary winding,

Burden of Micon P122 relay = 0.3

Actual Burden of second winding,

$S_2 = \text{Relays Burden} + \text{Cable Burden}$

= 0.3 + 11.35

= 11.65VA

For Third secondary winding,

Burden of Micon P442 relay = 0.14VA

Actual Burden of Third winding,

$S_3 = \text{Relays Burden} + \text{Cable Burden}$

= 11.36VA

Total VA Rating = 15.35 + 11.65 + 11.36

= 38.36VA

$$\% \text{ VA Rating} = \frac{38.36}{40} \times 100\% = 95.9\%$$

According to the result, actual burden of all secondary windings are between 25% and 100% of rated burden. Therefore, it dominate fulfill of their accuracy class.

3. Results Data of Calculation

The insulation system for low voltage machines presents no particular difficulty, because insulation which is strong enough mechanically is sufficient for electrical purposes. However, the thickness of insulation required is quite large for high voltage alternators, in order to prevent the breakdown of insulation system[3].

Current transformer of 230kV (Incoming Line) incoming line has three secondary winding. The first winding is used for measuring (Multi meter or Unit meter). Second winding is for overcurrent and earth fault protection (P122 relay) and third winding is for distance relay protection (P442 relay)[5].

Current Transformer of 230kV (Transformer 1) has three secondary winding. The first winding is used for measuring (Multi meter or Unit meter). Second winding is for overcurrent and earth fault protection and Third winding is for transformer differential protection expressed in relay standard [5].

Current transformer of 33kV (Bank) has three secondary windings. The first secondary winding is used for measuring (Multi meter or Unit meter). Second winding is for overcurrent and earth fault protection (S20 relay) and third winding is not used[5].

Burden of all installed CT in Substation are between 25% and 100%, security factor and accuracy limit factor are between limitation (F_{Sa} between 1 and 50 and F_a between 1 and 100) and ratio error also between ± 1% for 5P class. And PTs installed in Substations fulfill their metering and protection accuracy class (0.5/3P) within these result values.

In substation, the measuring value of actual primary voltage is 225.4 kV and actual secondary voltage is 107.8V which data was calculated the percentage voltage error, satisfied data is .004% in table (2).The protection accuracy The

metering accuracy, burden and accuracy, turn ratio of 33kV (Bank) potential transformer selection of its ratio are calculated in table (2). In substation, the measuring value of actual primary current and actual secondary current. The measuring and calculating results of transmission lines is 89.5% according to these results, actual burden of all secondary windings are between 25% and 100% of rated burden, Therefore, they fullfill their accuracy class as shown in table 1 and figure 1. Actual Accuracy Limit Factor are metering primary and secondary that are comparison with calculation data are expressed. Figure 1 shown security factor is important calculation for protection in substation.

Ratio Error of PT for 230 kV (Incoming Line)the ratio error is expressed the measuring value of actual primary current and actual secondary current of 230kV transmission line and 33kV bank in where calculated as shown in figure 2.

Table5. Results of Current Transformer

ITEMS	Calculation Results		
	230 kV (Incoming line) CT	230 kV (Transformer CT)	33 kV (Bank-1) CT
% VA rating	95.5%	87.5%	89.5%
Actual Security Factor	25.932	26.176	24.053
Actual Accuracy Limit Factor	62.313	68.163	32.732
	63.692	69.295	-
Ratio error	0.4%	-0.08%	0.11%

Table6. Results of Potential Transformer

ITEMS	Calculation Results	
	230kV (Incoming Line) PT	33 kV (Bank-1) PT
For Metering Class Maximum Voltage Minimum Voltage	276,000 V 184,000 V	39,6000 V 26,4000 V
For Protection Class Maximum Voltage Minimum Voltage	345,000 V 11,500 V	62,700 V 1,650 V
Maximum Burden Minimu Burden	100 VA 25 VA	50 VA 12.5 VA
Ratio Error	0.004%	-0.06%

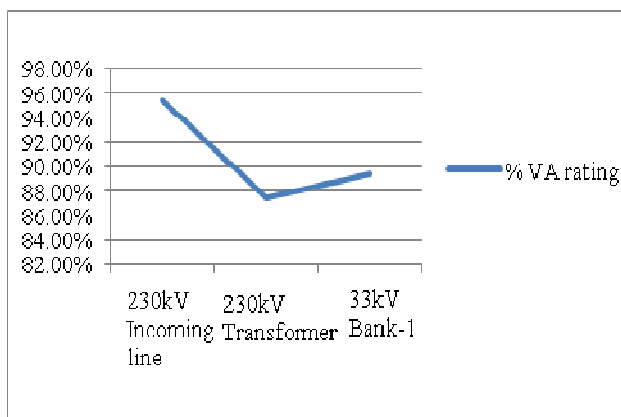


Figure1. The VA rating on Transmission Lines

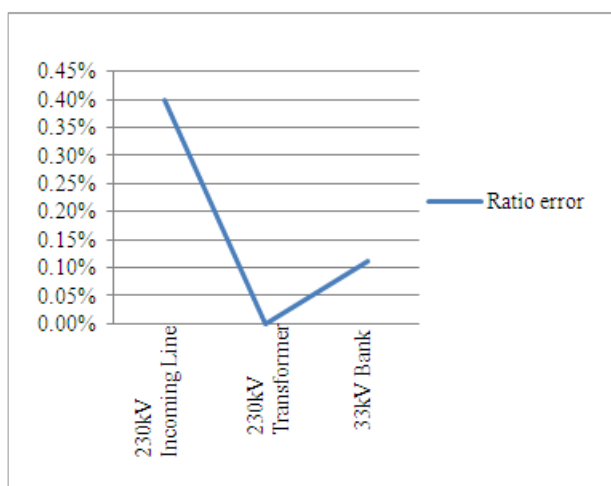


Figure2. The Ratio error on Transmission Lines

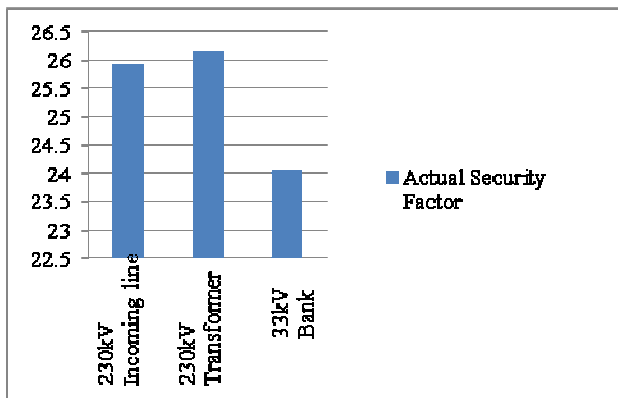


Figure3. Actual security factor on Transmission Line

4. Conclusions

In current transformer security factor and accuracy limit factor are very important. In metering core, security factor is determined and in protection core, accuracy limit factor is determined. Security factor is always less than accuracy limit factor as metering core are more important than protection core. The resistance of control cable is chosen according to specific resistance and secondary wire connection. In potential transformer, rated voltage factor is required to determine its maximum withstand voltage. Accuracy class of potential transformer is fulfilled within 5% of rated primary voltage (minimum) and F_v times of rated primary voltage (maximum) for combined class (both metering and protection).

The consideration errors that the current error of CTs for 230 kV (Incoming Line), 230 kV (Transformer 1) and 33 kV

(Bank 1) and voltage error of PTs for 230 kV (Incoming Line) and 33 kV (Bank 1) are calculate from actual measuring values of current and voltage. The measuring and calculation results are considered satisfied or not for selection; therefore the current error percentage values are satisfied for 0.5/5P class CTs and voltage error percentage values are also satisfied for 0.5/3P class PTs.

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