Sometimes step-up transformer in a power station is built from three single phase units. This may “slightly complicate” differential protection scheme setup with RET670 or REG670 series of relays. The reason is that two sets of LV side CTs, which are actually connected in series and measure the same primary current, are present and shall be used for the differential protection. The previously used electro-mechanical differential protection relay was arranged for this application as shown in Figure 1:

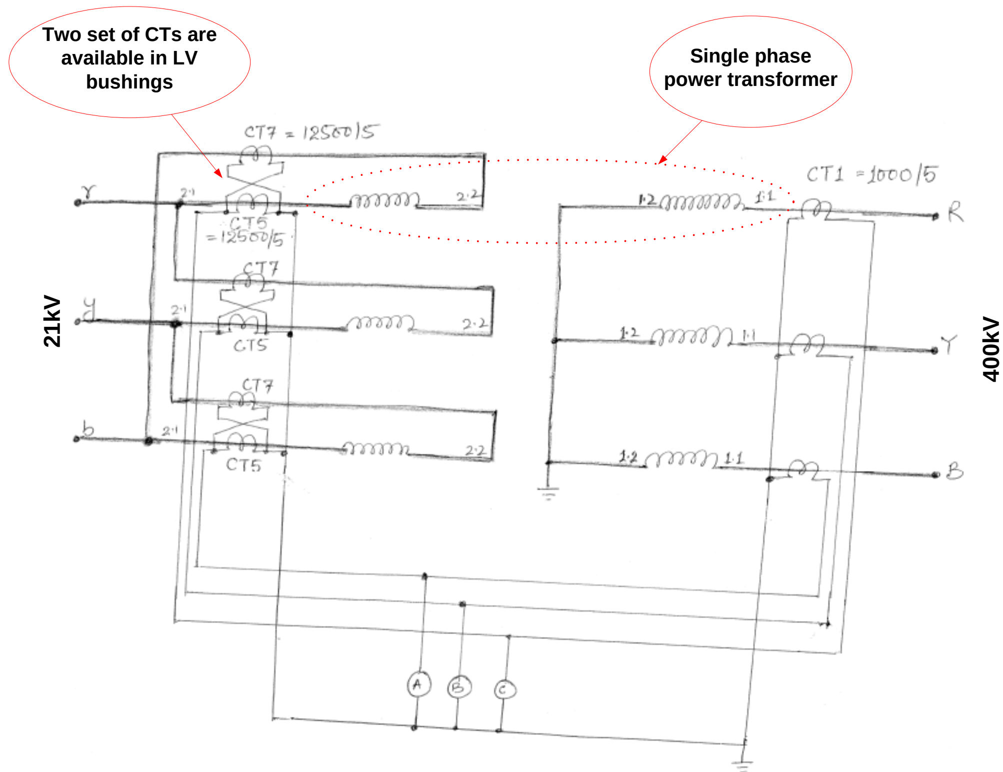

Figure 1: Original arrangement for differential protection of step-up transformer

The rating data for one single-phase transformer is given in Figure 2.

MVA		200
kV (NO LOAD)	HV	420/√3
kV (NO LOAD)	LV	21
AMPERES	HV	824.8
AMPERES	LV	9523.8
PHASES		1
FREQUENCY		50

Figure 2: Rating plate data for one single phase transformer

Two CT sets on 21kV and their special connection will effectively double the secondary current towards the differential protection on that side. How differential protection for such step-up transformer can be arranged by using 670 series of relays?

1 Applying REG670 or RET670 to such step-up transformer

First of all CT connections to the IED shall be properly done. In Figure 3 revised CT connections to the numerical differential protection are shown. Note that existing CT cabling can be re-used if it is still in a good shape. In this paper it will be assumed that:

- 400kV CTs are wired to IED CT channels 1, 2 and 3 on TRM1
- 21kV side CTs are wired to IED CT channels 4, 5 and 6 on TRM1

All of these six CT inputs into the IED shall have 5A rating (i.e. the same rating as used main CTs).

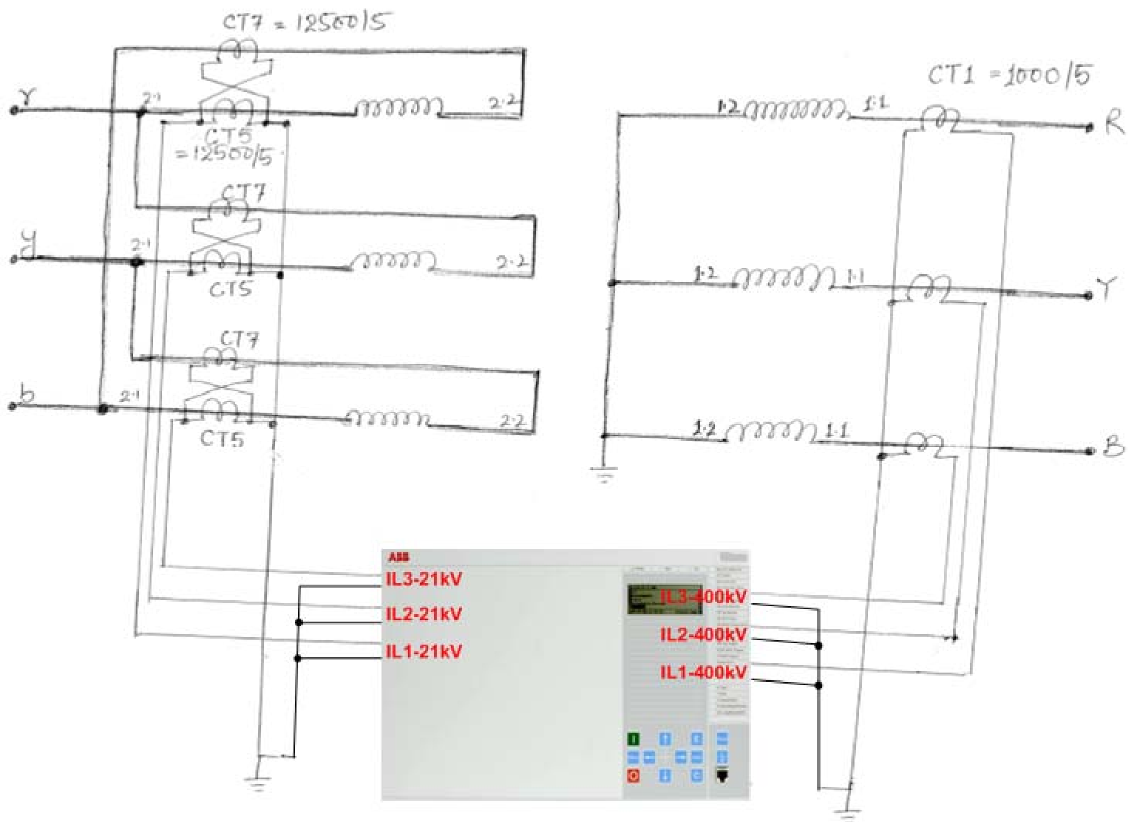

Figure 3: Revised CT connections for this application with 670 series IED

Note that 400kV and 21kV CT sets are not galvanically interconnected any more. Thus each CT set secondary circuit shall be separately grounded in one point as shown in Figure 3. Typically this grounding is performed as close as possible to the physical location of the main CTs (e.g. in the step-up transformer marshaling cubicle).

With such CT connections on 21kV side, the current into the IED on that side will be almost 10A when transformer is fully loaded. The exact secondary current value on 21kV side is calculated as follows:

$$2 * \frac{Ir\_21kV}{CTR\_21kV} = 2 * 9523,8 * \frac{5}{12500} = 7,619A$$

The CT inputs in 670 series IEDs are designed for continuous current of up to four times rated current (i.e. 20A in this case). Thus no any thermal problems!

For these six IED CT inputs the ratio and staring information shall be set as shown in Figure 4 and Figure 5. Note that actual staring of main CTs is shown in Figure 3.

CTStarPoint1	ToObject	
CTsec1	**5**	A
CTprim1	1000	A

Figure 4: IED input settings for 400kV CTs (channels 1, 2 & 3)

CTStarPoint4	ToObject	
CTsec4	**10**	A
CTprim4	**12500**	A

Figure 5: IED input settings for 21kV CTs (channels 4, 5 & 6)

Note that CT secondary rating for 21kV CT is intentionally set to 10A. By doing this one will compensate for two main CTs located on this side of the transformer. By doing this, the correct primary current value flowing through the transformer secondary winding will be measured by the IED. Note that all functions in 670 series do operate on the primary value of the measured current. Thus, such setting will allow not only differential function but as well other 21kV side functions like over-current or thermal overload protection function to be connected and set in the standard way by using these three CT inputs.

Now the differential function applied across this step-up transformer shall be balanced. This will be achieved when settings, as shown in Figure 6, are entered into the IED.

T2WPDIF(IdT): 1				
RatedVoltageW1	**420,00**	kV	0,05	2000,00
RatedVoltageW2	**36,35**	kV	0,05	2000,00
RatedCurrentW1	**825**	A	1	99999
RatedCurrentW2	**9524**	A	1	99999
ConnectTypeW1	WYE (Y)			
ConnectTypeW2	**WYE (Y)**			
ClockNumberW2	**0 [0 deg]**			
ZSCurrSubtrW1	**Off**			
ZSCurrSubtrW2	Off			
TconfigForW1	No			
CT1RatingW1	1000	A	1	99999
CT2RatingW1	**1000**	A	1	99999
TconfigForW2	No			
CT1RatingW2	**12500**	A	1	99999
CT2RatingW2	**12500**	A	1	99999
LocationOLTC1	Not Used			

Figure 6: Compensation settings for T2WPDIF function

Note the following special things regarding these T2WPDIF function settings:

1) Step-up transformer vector group is set as Yy0. This is done in order to compensate for CT location inside of the delta winding on the 21kV side.
2) Rated voltages on both sides are set as phase-to-phase values. This is the normal way to set the protected transformer rated voltages for T2WPDIF function in 670 series. From Figure 2 these voltages are obtained by multiplying the values given there by factor 1,732 (i.e. sqrt(3)).
3) Rated currents are just taken directly from the rating plate shown in Figure 2, because the transformer rated phase currents shall be entered here.
4) Zero sequence current reduction is disabled on both sides because the zero-sequence current can be measured in both windings.

Settings for the differential protection operating characteristic can be set in the following way. Because this power transformer does not have the on-load tap-changer the minimum pickup can be set to 20%. All other settings for the operating characteristic can be left to the default values.

Once all setting values are known the differential protection pickup can be calculated. Because the minimum pickup is set to 20% the 87T function will pickup when 20% of base secondary current is injected on any of the two sides. These three-phase pickup values in primary and secondary amperes can be calculated in the following way:

For 400kV side:

$$Pickup[PrimaryAmperes] = \frac{20}{100} * 825 = 165A$$

$$Pickup[SecondaryAmperes] = 165 * \frac{5}{1000} = 0,825A$$

For 21kV side:

$$Pickup[PrimaryAmperes] = \frac{20}{100} * 9524 = 1905A$$

$$Pickup[SecondaryAmperes] = 1905 * \frac{10}{12500} = 1,524A$$

Because the zero-sequence current reduction is disabled on both sides the single-phase pickup for both windings will be the same as the above calculated three-phase pickup values.

REVISION

Rev. ind.	Page (P) Chapt. (C)	Description	Date Dept./Init.
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