PC-BUS01 • April, 2024
Published for the Basler Electric Power Systems Group

Application Note

Mixing Different Ratio CTs in High Impedance Bus Protection Schemes

Modern numeric relays have many thousands of settings, which makes it very difficult and time consuming to set them correctly. On occasion, different ratio CTs need to be mixed in a high impedance bus protection scheme. The common cause is a substation upgrade that installs a new breaker that has a much higher steady state current rating than existing older breakers. The CT ratios cannot be matched. Three methods that could be used to work with the mixed CT ratios are discussed below.

Use Partial Taps on CTs

The approach of using partial taps on multi-ratio CTs has two difficulties: CT overload and high voltage across the open terminals of the CT. Suppose one encounters a case of mixing 3000A and 1200A breakers on the same bus. As may be typical, assume that the 1200A breaker has only 1200:5MR CTs, so the approach one must consider is tapping the 3000:5 CTs at 1200:5. The first concern is CT overloads: If 3000A flows through the breaker, the 1200:5 CT tap will be carrying 12.5A current (2.5 times normal CT rating). The CT must have a thermal rating factor (TRF) of 3, or this will be an unadvisable current for the CT to carry.

The next issue is that, when a bus fault occurs, the voltage across the open winding tap will be higher than the relay setting by a factor determined by the CT turns ratio. Fig. 1 illustrates the concept. Assume a high impedance 87B relay is set to trip at 200V. For the Basler BE1-87B, the actual peak voltage at which the voltage clamping SCRs will turn on is VSCR = VSET * 2 * Sqrt(2), or 566V. Hence, the relay will start to turn on the SCRs at 566V, but some overshoot will occur in the following 7 microseconds it takes to turn on the SCRs. If voltage is rising at 5 million volts/second (actual rise rate requires EMTP studies), there will about 35V overshoot. Let us assume that 600V is reached. The voltage across the full 3000:5 winding will be 600*(3000/1200) or 1500V. Most CTs could handle this voltage level for short periods. For instance, IEEE C57.13-1993, Section 6.7.1 states:

"Current transformers should never be operated with the secondary circuit open because hazardous crest voltages may result. Transformers conforming to this standard shall be capable of operating under emergency conditions for 1 minute with rated primary current times the rating factor with the secondary circuit open if the open-circuit voltage does not exceed 3500 V crest."

This effectively says that the CT internal wiring should be insulated to 3500V crest. The example above indicates there is good margin below the 3500V, but one also must be aware that any wiring between the CT and the relay might also see this peak voltage. If one is going to use taps on high impedance bus schemes, it may be a good idea to consult with the CT manufacturer on the CT insulation ratings and check that all wiring and terminal blocks are rated for the voltages that will be generated.

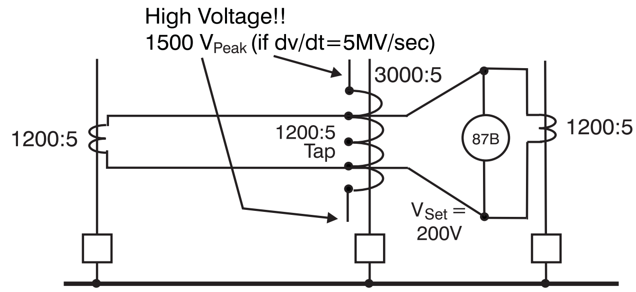

Figure 1 - High Voltage on Open Terminals of a Tapped CT

Connect Two CTs on a Breaker in Parallel

An approach to effectively obtain a lower ratio out of a CT is to connect two CTs in parallel. In Fig. 2, the parallel 3000:5 CTs give a total current that makes the two CTs effectively act as a single 1500:5 CT. This is a good approach, but it requires the luxury of two CTs.

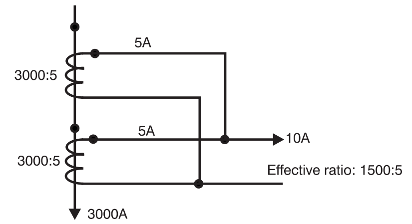

Figure 2 - Paralleling CTs

Interconnect CTs at Taps (also called an Autotransformer approach)

A third approach is to connect the lower ratio CTs into the higher ratio CT at an appropriate tap, and then connect the 87B relay across the full higher ratio tap. The concept is best seen in Fig. 3. The 87B monitors the higher ratio 3000:5 CTs and is connected across the full winding of the CTs. The lower ratio 1200:5 CTs are connected into the 1200:5 tap of the 3000:5 CTs. The interconnection of 1200:5 taps could also be extended to the other 3000:5 CTs so that several 3000:5 CTs are performing the transformation of the 1200:5 CT currents. This allows any one of the associated breakers to be taken out of service without disabling the bus protection scheme.

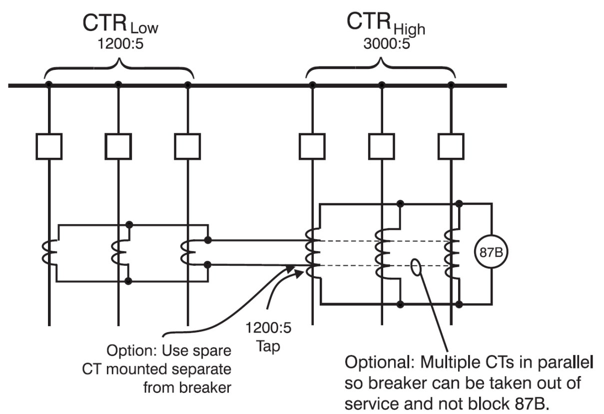

Figure 3 - Paralleling Different Ratio CTs via Tap Connections

Current balance and CT overload risks in this scheme can be seen by studying Fig. 4. Note the 3000:5 CT (which has 600 turns) is carrying 14A on the 1200:5 tap (240 turns) and 1A on the remaining 360 turns (600-240=360). The CT's flux summation is 240*14-360*1=3000, balancing the flux induced by the primary current. Note, however, that the 1200:5 tap is at risk of being driven to overload. When using this scheme, one must consider the various operating contingencies to ensure that a CT will not be driven past its TRF.

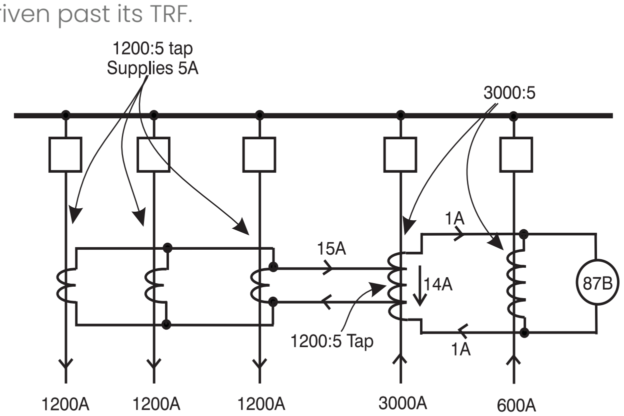

Figure 4 - CT Overload Risk

As an alternative to interconnecting CTs on actual breakers, a set of loose 3000:5 CTs with high TRF and C class rating can be purchased and mounted in a convenient location, and the interconnection would be done at these loose CTs. This removes concerns about what happens when a breaker is taken out of service and concerns about overloading of CTs.

The relay setting analysis in this application is very similar to the bus differential scheme with only one CT ratio. The concept is easiest to think through with the example in fig. 5.

- First, assume the 1200:5 CT on breaker 1 totally saturates and current is driven into the CT by the other CTs.
- Use I*R voltage drop calculations to determine the voltage at the 1200:5 tap of the 3000:5 CT. In this case, assume that we calculate 50V at the tap connection.
- Assume the 3000:5 CT operates ideally, and recall that the CT will also act as a voltage transformer in accordance with its turns ratio. The voltage at the full ratio of the tapped CT will be proportionate to the turns ratio of the CT. In this case, 3000:5 / 1200:5 = 2.5, so voltage cross the full CT will be 125V.
- Besides the voltage transformation, there is also a set of I*R voltage drop loss in the 1200:5 portion of the 3000:5 CT, so the actual voltage across the full winding of the CT will be a bit lower than predicted by the ideal equation. However, it is conservative to ignore this voltage drop.
- Next, continue with the I*R voltage drop in the leads at the second level (the 3000:5 section) of the CT string to determine what voltage will be seen at the relay. We might find 150V in this example, so it might be appropriate to set the relay at 200V.

If the CT on breaker 2 saturates, the issue is more complicated. You have two different current levels in the different parts of the CT winding and a complicated I*R voltage drop analysis. The voltage at the relay is still determinable with some thought process similar to the material above.

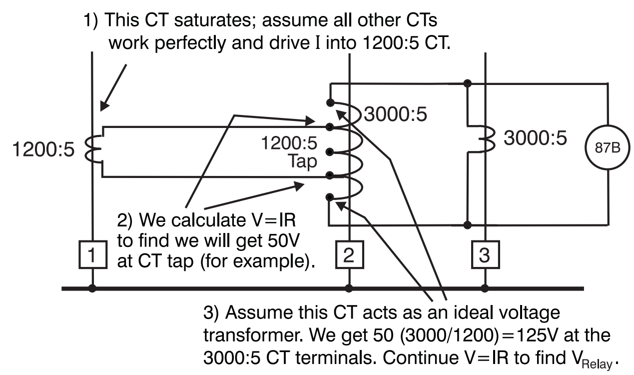

Figure 5 - Relay Voltage for Saturated CT

For More Information

To get more information on the BE1-87B, including additional application notes, product bulletins and instruction manuals, go to www.basler.com or contact Technical Support at 618-654-2341.

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