Investigation of Voltage Notch on Waveform Leads to Saving 500kV PT

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The Tennessee Valley Authority (TVA) provides electricity for approximately 9 million people in the southeastern region of the United States. TVA is committed to providing safe, clean, reliable, and affordable electric power to homes and businesses within the valley. Since low rates are a priority for TVA, it is imperative to get the full lifespan of equipment while reducing unplanned outages.

On July 20th, 2015, it was discovered that both the power quality monitor and digital fault recorder which monitor the voltages from a 500kV Bus PT set had been repeatedly recording "notching" type waveforms in the A-phase voltage. Such waveforms had been being triggered since mid-June with increasing frequency and severity. There was concern that these waveforms could be an indication of an incipient failure of the PT or other component in the PT secondary circuit.

Between June 1st and August 1st, over 15,000 transient events were recorded by the PQ monitor connected to the 500kV Bus PT. The transient events all had the same characteristics. As can be seen in figure 1, the four characteristics were:

1. Notching at 0 crossing
2. Perturbation at Voltage Peak
3. A-Phase Voltage Only (Red Trace)
4. No corresponding response on the current channels.

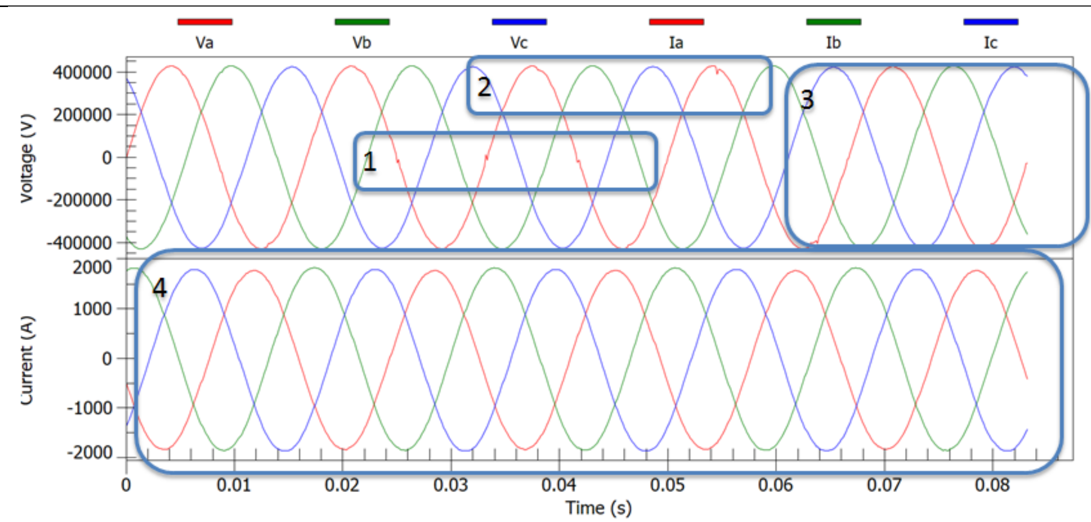

Figure 1-Typical Waveform

Initially, the thought was that the event was a metering artifact and not actually occurring. However, a DFR was connected to the secondary of the same PT. In addition, the metering location had two bus PTs and the busses were tied together. On the DFR trace, the voltage notch appeared on one bus but not on the other bus. This eliminated the issue as a metering artifact since multiple devices were seeing the event. As can be seen in figure 2, the purple trace is the good PT, the yellow trace contains the voltage notch just like the PQ meter. The waveform suggests that the issue is on the VT or on the secondary side.

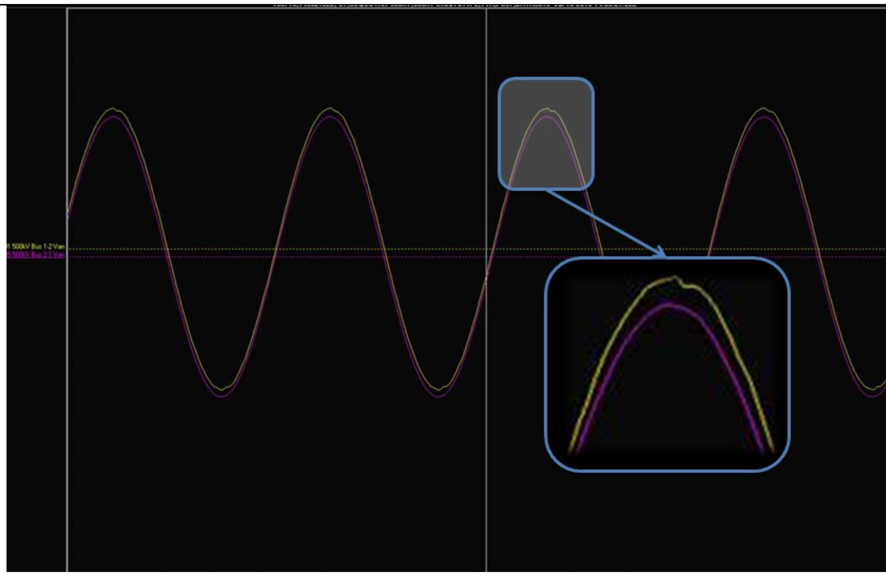

Figure 2 - Voltage Traces From DFR

Extensive troubleshooting was undertaken to determine the cause of the waveform notching. First, each device on the PT secondary circuit was isolated to ensure that it was not a device (relay, DFR, PQ monitor, or meter) that was malfunctioning. Next, infrared testing was completed on all of the bus PTs. Third, ultrasonic testing was completed on all of the bus PTs. Finally, megger testing of all cables in the secondary circuit was performed to eliminate the cable as the source of the issue.

The troubleshooting took several days to complete. Over the timeframe, it was clear that the issue was getting worse. The notching was severe enough to elevate flicker values on the PQ meter. As can be seen in figure 3.

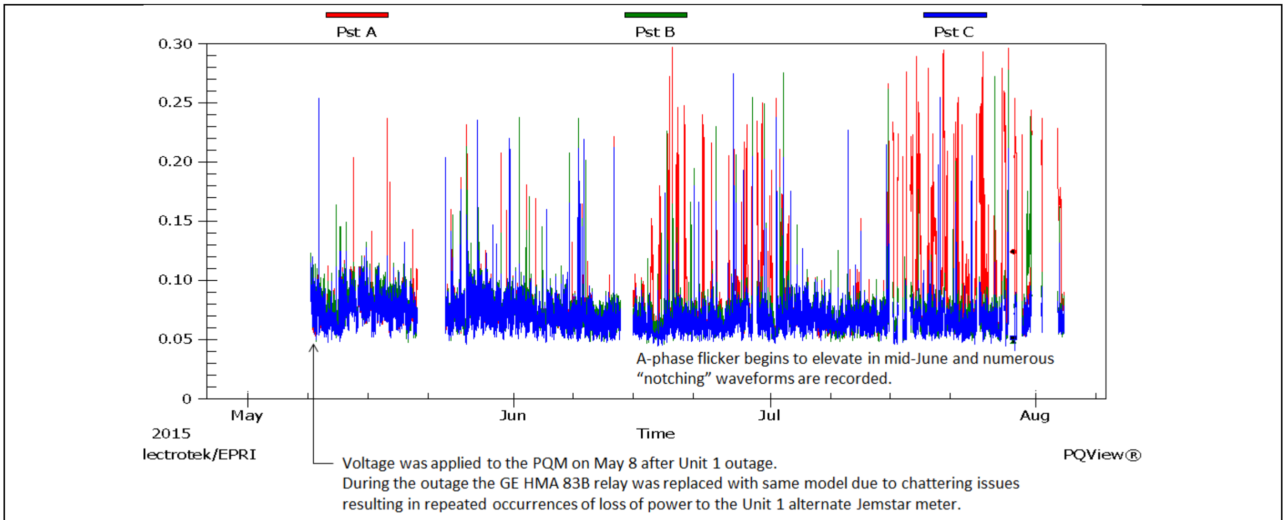

Figure 3 - Flicker Trend

During the investigation, it was discovered that a GE HMA 83B relay was replaced in May of 2015 during a planned outage. The relay was replaced because of a known chattering issue with the relay. However, the replacement relay was the same make/model/vintage as the original unit.

On Monday, August 3rd, there was a complete loss of power to the meter and PQM fed from the PT secondary. Subsequent investigation revealed that all fuses tested good; however, an auxiliary relay in the meter cabinet was found to be chattering. When the meter lost power, a noticeable drop in the A-Phase flicker levels was observed as shown in figure 4.

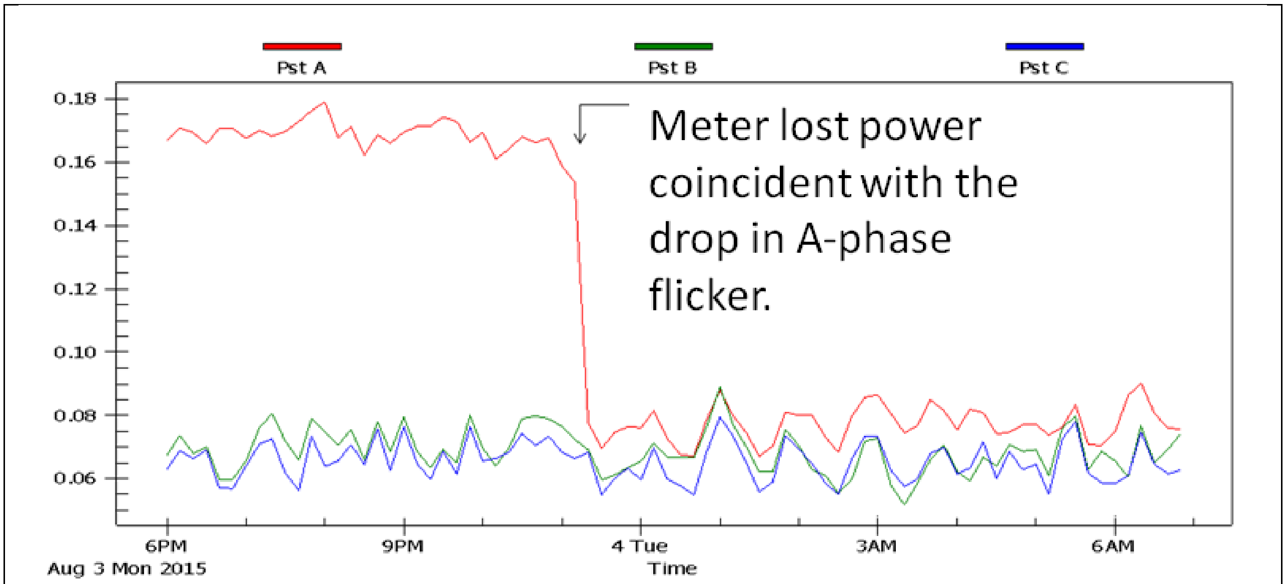

Figure 4 - Flicker During Meter Outage

The HMA relay is used to power the meter and power quality meter from the A-phase bus PT when there is an outage to the primary feed (station service). As can be seen in figure 5, an intermittent arc could be visually seen between contacts 1 and 7 of this relay. The arcing had pitted the contacts to the point that it had resulted in an open condition and a loss of power to both the meter and PQM. Additionally, any slight vibration to the meter cabinet could cause the HMA contacts to make or break.

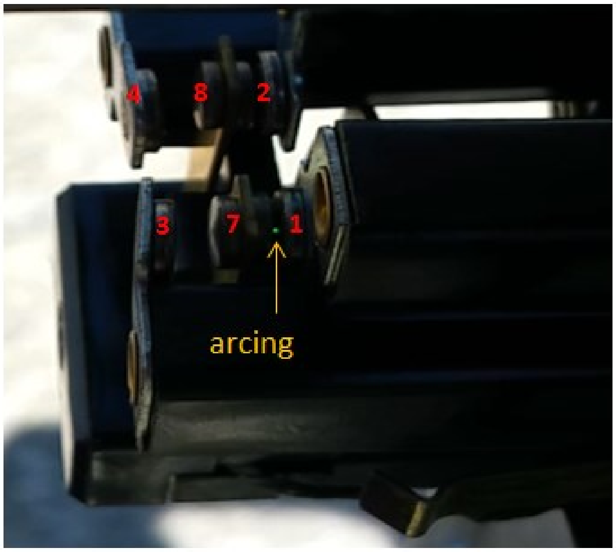

Figure 5 - Picture of Arcing in HMA Relay

Figure 6 - Picture of Incorrect Shorting Slugs

Further investigation found that a copper tube with smaller diameter had been used in place of the copper slug that was to be in-line with the relay as can be seen in figure 6. This high impedance connection resulted in a lower voltage across the relay coil and the relay chattering. This is a known issue with this model relay and there is a replacement model. As a temporary fix, the relay was replaced with an identical model and the copper-tube was strapped over eliminating the notching waveforms. Ultimately, the relay was replaced with a new model.

Tribal knowledge about the auxiliary relay problems had been communicated to field personnel. However, the field used the same vintage relay which exhibited the same problem. The change was one of many changes performed during a planned outage and was largely forgotten. However, as a result of solid investigative practices, TVA was able to effectively save the cost of replacing a 500 kV bus PT. The cost of replacing a PT can be as high as $70k. In addition to the cost of the replacement of a PT, a critical 500 kV bus emergency outage was avoided. During the course of the investigation, other issues were identified and remediated.

In conclusion, it is important to identify the correct problem before taking drastic action. Additionally, acting quickly to prevent catastrophic failure is important for reliability. A systematic root cause analysis provides the framework to resolve the problem. Further, this knowledge was used to identify two other locations with a similar problem. Ultimately, this approach results in a lower cost of delivered power.