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Memo To: Staff
From: Karl B. Clark, E.E., E.I.T.
Date: January 21, 2004
Subject: TVSS Protection Modes And TVSS Performance

Mr. Ricky Fussell, a Senior Electrical Engineer, at the Surge Suppression Incorporated (SSI) laboratory built and tested a four mode wye, a seven mode wye and a ten mode wye TVSS using a standard SSI ten mode wye board. This eliminated the possibility of component, pc board and lead length variations in the test procedure and resulting measurements. The peak surge current ratings were 40 kA per mode.

The testing was accomplished by Mr. Fussell using a Velonex 587E Surge Generator, a Velonex V-2734 Backfilter, a LeCroy 9310A oscilloscope and Tektronic P5100 probes. The oscilloscope sweep rate was set to 10 microseconds per division, in the A-B (differential measurement) mode and absolute curser measurement was employed. The ANSI/IEEE B3/C1 Combination Wave surge (6kV, 3kA) was injected into the modes indicated below. The other modes were unconnected. The appropriate disturbances created by the normal action of the four, seven, and ten mode surge suppressors were recorded. The disturbance magnitudes are presented in Table 1 below.

Figure 1. provides the pictorial diagram of the four mode out of ten modes “reduced mode” or “partial protection” TVSS design.

Figure 2. provides the pictorial diagram of the seven modes out of ten “reduced mode” or “partial protection” TVSS design.

Figure 3. provides the pictorial diagram of the ten modes out of ten “true all mode” or “full protection” TVSS design.

The B3/C1 (6 kV, 3 kA) transients were applied to (injected into) the L-N and L-G modes. The disturbance voltage magnitudes produced by the normal operation of the three TVSS designs were recorded and averaged for the L-N, L-G, and L-L modes as shown in Table 1. below. The per mode, per phase and total kA ratings are provided for the three TVSS designs in the Figures 1, 2 and 3. below. The four mode TVSS will tend to have higher let-through voltages due to the limited number of protection modes (i.e., 4 modes) and lower peak surge current ratings.

The “Available Surge Current” (ASC) and let-through voltages is the greatest for the 4 mode device in the L-L modes because there is only one suppression path; namely, L-N-L. This means that the total surge current is “available surge current” for an applied L1-L2 transient. The total surge current appears in the L1-N-L2 path and is capable of being injected into the L1-N and/or L2-N distribution circuitry. The seven mode design is an improvement over the four mode design. With the seven mode design, L-L transients have two suppression paths; namely, L-N-L and L-G-L, so the available surge current is reduced as it divides between the L-N-L and L-G-L paths. The ten mode design provides the best possible performance because all three possible paths; namely, L-L, L-N-L and L-G-L are available to minimize the available surge current on any affected mode and the corresponding let-through voltages. Reduced mode TVSS designs have the ability to move the transients around on the distribution system. Reduced mode or “partial protection” designs also provide unnecessary available surge current levels.

ANSI/IEEE Std. 1100-1999, the G.E. and Harris MOV manuals recommend “true all mode protection.” NEMA LS-1, Section 2.2.7, identifies the L-L mode as a directly protected mode that should be identified on a TVSS manufacturer’s specification sheet. As shown in the IEEE “Trilogy,” transients exist in all modes. Common sense, experience, and technical guidance and standards dictate that transients be addressed in all of the modes in which they appear.

It should come as no surprise that a “true all mode protection” TVSS design minimizes the available surge current and respective let-through voltages.

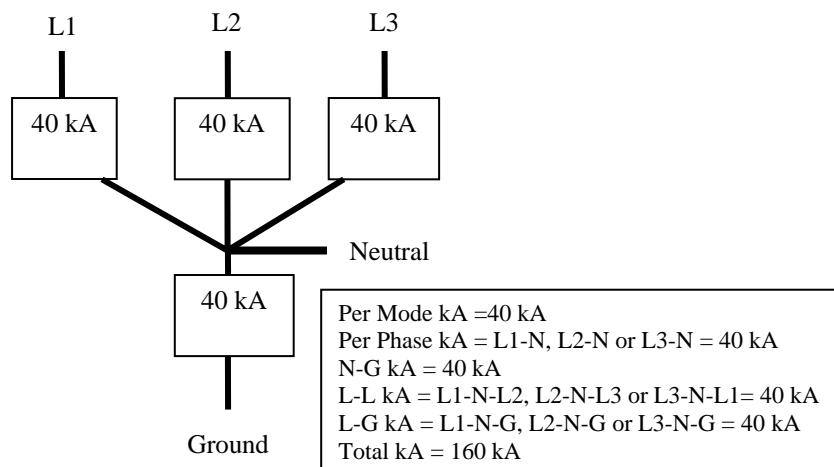


Figure 1. Four Mode Wye “Reduced Mode” or Partial Protection” TVSS Protection Scheme

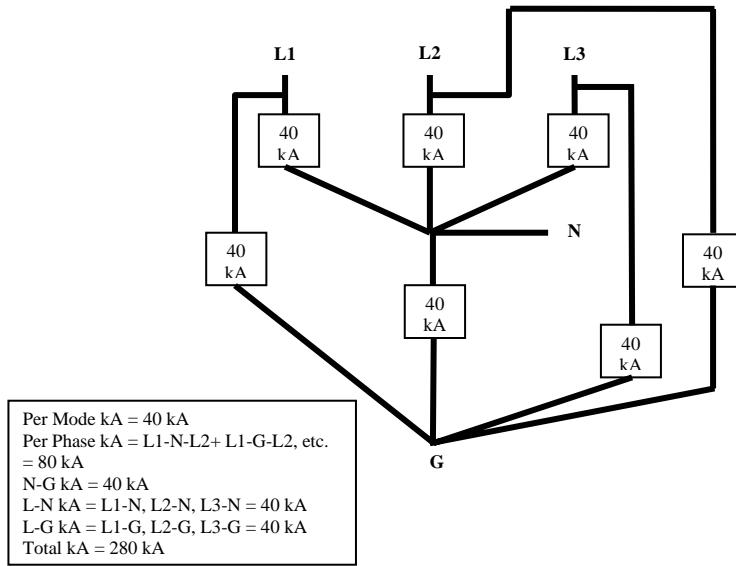


Figure 2. "Reduced mode" or "partial protection" TVSS pictorial with seven protected modes out of ten modes total.

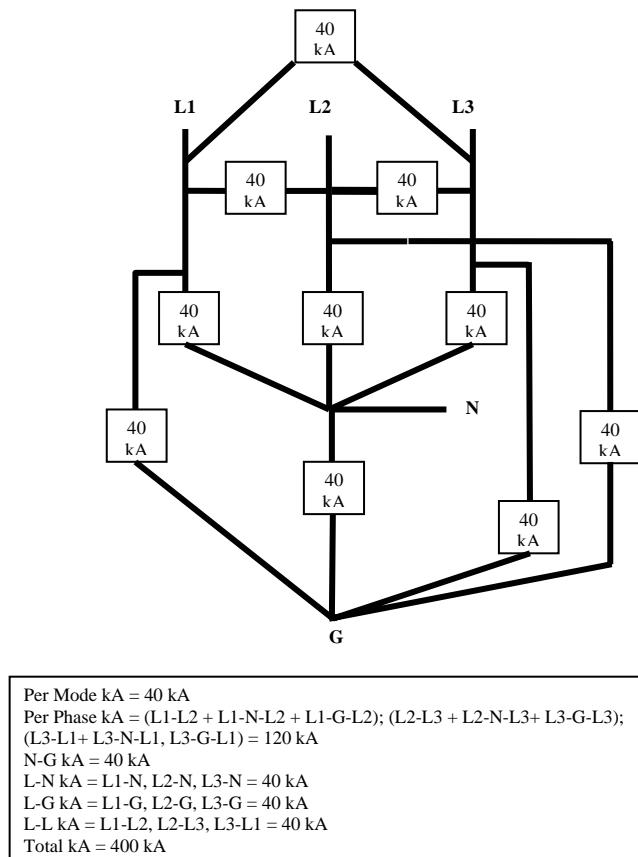
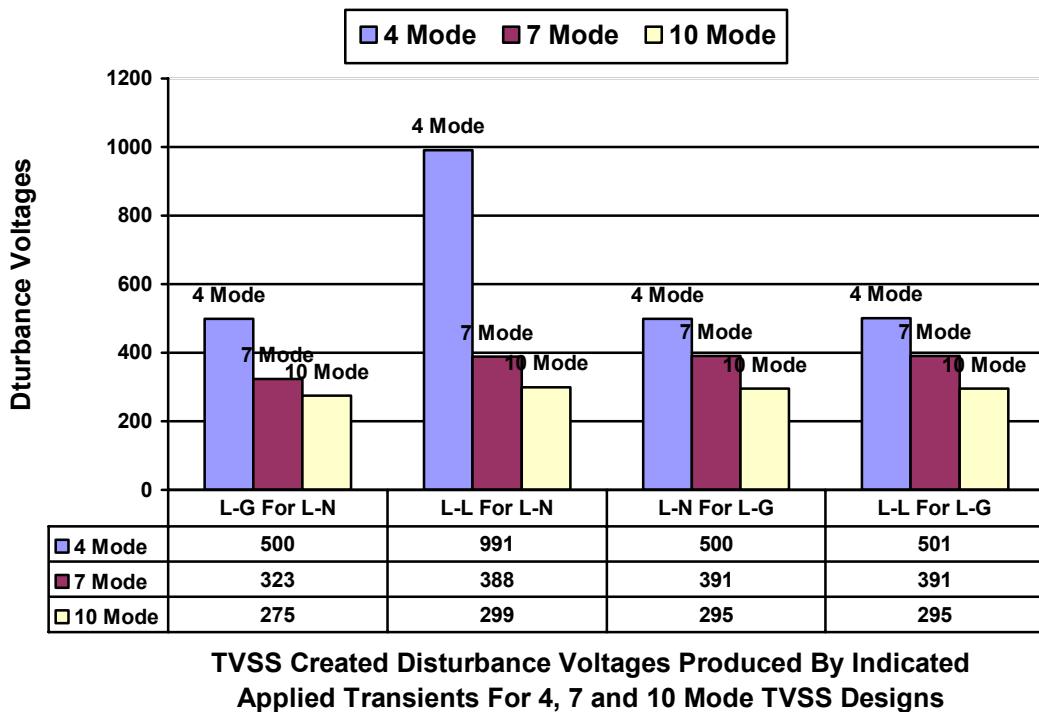


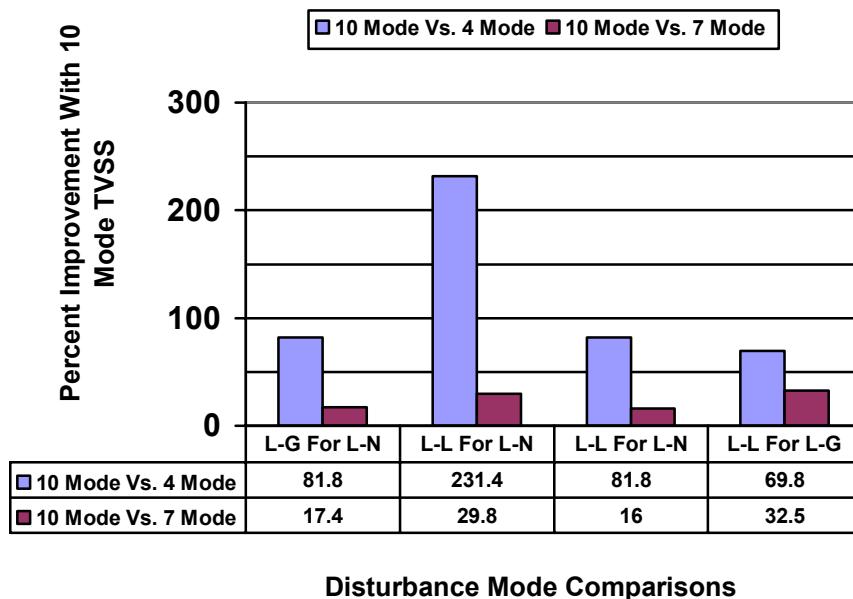
Figure 3. "True all mode" protection TVSS pictorial with ten protected modes out of ten modes total.

Table 1. Disturbance Voltages Produced By Applied Transients

| Let-Through Voltages:→ Injection And Disturbance Mode Averages: ↓ | 4 Mode TVSS LTV | 7 Mode TVSS LTV | 10 Mode TVSS LTV | % Improvement - 10 Mode Versus 4 Mode | % Improvement - 10 Mode Versus 7 Mode |
|---|-----------------------|-----------------------|------------------------|---|---|
| L-G Disturbance for L-N Transients: | 500 V | 323 V | 275 V | 81.8% | 17.4% |
| L-L Disturbance for L-N Transients: | 991 V | 388 V | 299 V | 231.4% | 29.8% |
| L-N Disturbance for L-G Transients: | 500 V | 319 V | 275 V | 81.8% | 16.0% |
| L-L Disturbance For L-G Transients: | 501 V | 391 V | 295 V | 69.8% | 32.5% |

Graph 1. TVSS Disturbance Voltages Created By Applied
Transients

**Graph 2. Per Cent Improvement In Disturbance Mode
Transient Production With 10 Mode TVSS**



Disturbance Mode Comparisons

As shown above, the four mode TVSS design should be avoided. The seven mode TVSS design, while an improvement over the four mode device, exhibits inferior performance in terms of available surge current and let-through voltage compared to the ten mode “true all mode” protection device. This is a matter of common sense.

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