E1 HEMP Testing of "Shielded" Substation Cables

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Abstract—This paper reports on the laboratory time domain testing of the shielding effectiveness of samples of substation yard cables.

Keywords- substation cables, shielding effectiveness, E1 HEMP vulnerability

I. INTRODUCTION

E1 HEMP from a high-altitude nuclear burst poses a possible threat to our critical infrastructure. A major concern is its impact on the control of the electric power grid, due to effects on the control equipment in power substations. A significant threat are the induced conductive transients on the cables leading into the control buildings from the high-voltage yard: pulses of up to 400 amperes for buried cables, and even higher for aboveground cables [1]. The cables can bring these high level fast transients into the building and then into the attached equipment, possibly causing equipment damage or malfunction, and resulting in failure to properly control and protect the grid. To help prevent such an outcome, protective measures ("hardening") can be used.

One good hardening approach is to use shielded cables. The shields must be grounded off before entering the building – the E1 HEMP transient will couple to the shield instead of the inner control wires. There are various possible issues with grounding off the shield current. For example, if done inside the building instead of outside, or if the grounding off is done poorly, then high-level EM fields re-radiate inside the building. However, another issue, which is the subject of this paper, is the quality of the "shielding effectiveness" of the cable. Often product information for yard cables may indicate which ones are shielded, but not provide much guidance on the quality of the shield. This paper discusses measurements of sample shielded yard cables.

II. TEST PROCEDURE

A traditional way to measure cable shielding effectiveness is using a tri-axial rig in the frequency domain, with a short cable sample. To then determine the implications for E1 HEMP, this shielding effectiveness result would be used in an analytical model for an appropriate length of cable, with representative loads. Additionally, it might be important to measure, and include in the modeling, the signal attenuation and velocities for the cable. Our alternative approach is to use the time domain, with a longer length cable sample. This is more directly relatable to the E1 HEMP situation.

Fig. 1 shows a sample test setup. The sample cable is laid out a fixed distance above a ground plane. On one end the inner wires are sealed off with copper tape stuck to the cable shield. An EFT pulser [2], which generates a pulse that is E1 HEMP like, is attached to this, and it sends a pulse down the cable shield. At the other end the cable shielded is sealed to a metal box; from inside this box the inner wires are connected to a coaxial line that connects outside to an oscilloscope. This is used to measure the signal leaked onto the inner wires, and another channel measures the shield drive current.

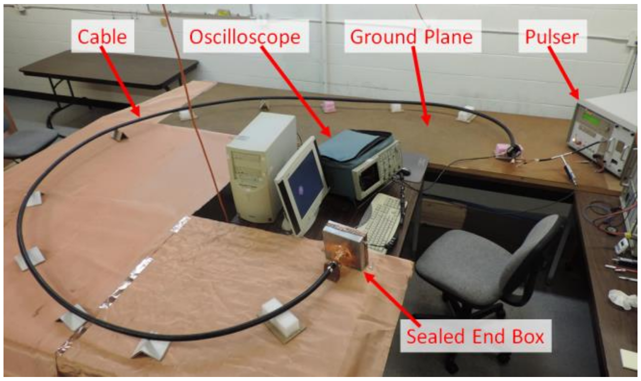

Figure 1. Sample test setup.

III. CABLE SAMPLES

Various types of shielded cables were tested. Fig. 2 shows a longitudinal wrap, a braid, and a spiral wrap.

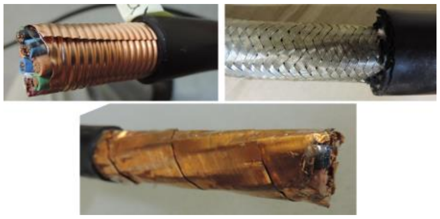

Figure 2. Some shielded yard cables.

IV. RESULTS

There was a wide variation in shielded effectiveness values found, and these will be shown in the presentation.

REFERENCES

[1] IEC 61000-20-10:1998: Electromagnetic compatibility (EMC) – Part 2-10: Environment – Description of HEMP environment – Conducted disturbance.

[2] IEC 61000-4-4:2012: Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test.