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IEMI AC Harmonic Vulnerability of Small External Power Supplies

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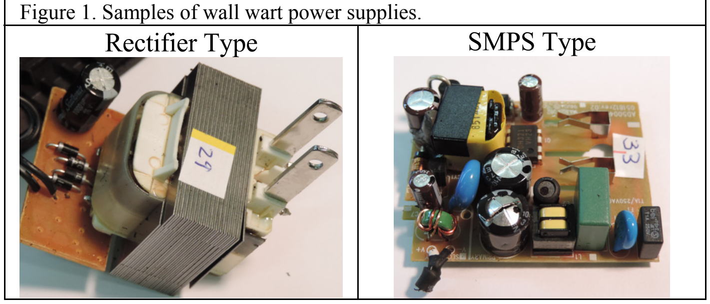
***Abstract*—A typical IEMI attack on a facility would involve high frequency (or fast transients) high-level radiative or conductive assaults resulting in transients entering equipment on their attached cabling. However, another possible attack uses low frequency and low levels – introducing harmonics onto the AC power system. Such an attack, if possible, has some differences from high-frequency attacks, including that it is less erratic – just as for the AC power itself, any low frequency signal introduced on the AC wiring will appear essentially undiminished at all attached equipment. In this paper we report on tests performed to determine the response of common low voltage power supplies when their AC power feed is distorted by various types and levels of harmonic distortion. It is found that switched mode power supplies are immune to such attacks, but rectifier type supplies are very susceptible, if the harmonic distortion is not symmetrical.**

Keywords— harmonics, wall warts, small power supplies, switched mode power supplies

I. Introduction

Many low power electrical devices are powered by (or their internal battery charged by) “wall warts”. These are small converters that typically plug directly into an AC outlet (hence their colloquial name), and put out a low voltage level (typical DC) via a cable, which plugs into the equipment and supplies its power. Older such supplies typically consist of a transformer-rectifier circuit, while newer ones are more likely to use switched mode power supply (SMPS) circuitry (Fig. 1). In our tests we looked at many samples of both types of supplies, introducing various forms of harmonic distortion, and stepping up the distortion level, trying to find damage levels. The basic results were that the rectifier types of units were easily and consistently fully damaged, while the SMPS types could not be damaged.

Figure 1. Samples of wall wart power supplies.



II. Test Setup and Procedures

The basis for our tests was a Schaffner NSG 1007-5-208-413 AC Power Source (harmonic generator). The generator provided the AC power to the test sample, which was loaded on its output side by a 50 Ω resistor. Measurements were made of the input and output waveforms, along with the DC output voltage. We also recorded the case temperature of the test sample. For harmonic distortion we only used single harmonics – either 2nd or 3rd harmonic. For either, the waveform shape varied with harmonic phase. We also did tests with added DC (zeroth harmonic). Each test point (selection of harmonic number, phase, and percent distortion level) was applied for five minutes, while we watched to see if the test sample “died”. We gradually increased the distortion level in successive test points, in order to determine damage levels. Four test waveforms were selected, two using 2nd harmonic and two with 3rd harmonic. Three of these waveforms had polarity symmetry – for a given waveform the negative peaks were the same as the positive peaks, while one was asymmetrical, with the negative peaks twice the amplitude of the positive peaks. Additional tests used DC offsets, which also had the effect of producing an asymmetrical waveform.

III. Test Results

Four of the test samples were of the SMPS type (more are to be tested), and these were very hard to damage. (One did die, at the very extremes of our test conditions, in which the AC waveform had peaks of 644 volts, with almost 100% distortion of a 230 V_{RMS} AC fundamental power feed.) Besides this one unit that died at our highest test levels, the devices all easily survived the worse distortion available from the test generator – almost 100% distortion, or up to 70 volts added DC. These devices also did not show the temperature effects noted with the rectifier supplies.

However, our 16 samples of rectifier type supplies were very different – we completely damaged every unit. For symmetrical waveforms, however, the units did not show any adverse effects, up to almost 100% distortion. But with asymmetrical distortion, they died (the transformer primary windings opened) at low distortion levels – typically at a few tens of percent distortion. They also similarly died at added DC levels of a few tens of volts. For both damage modes the units also had extreme temperature increases.