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Stray Voltage and Induced Current at FirstEnergy's Hoytdale Static Var Compensator

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SUMMARY

This paper describes the FirstEnergy's experience with stray voltage and induced current in the TCR branch fence at the Hoytdale static var compensator (SVC). It describes the investigation performed by FirstEnergy and the SVC manufacturer, the SVC ground grid design, the corrective actions taken by FirstEnergy and the SVC manufacturer, and the resolution. There is very limited information on this phenomenon in the industry, and this paper summarizes one utilities experience.

KEYWORDS

FirstEnergy, SVC, Static Var Compensator, FACTS, Induced Current, Stray Voltage, Fence

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INTRODUCTION

On April 18, 2016, a FirstEnergy commissioning engineer reported that the SVC at Hoytdale substation had been fully tested but excessively high induced currents were observed in the TCR branch fence. The SVC was de-energized and clearance was established on the SVC, while the SVC manufacturer and FirstEnergy substation engineering reviewed the issue.

1 BACKGROUND

In April 2012 PJM announce the need for a static var compensator (SVC) to mitigate N-1-1 EHV contingencies causing voltage criteria violations at multiple bus locations on the transmission system coupled with the retirement of generation in the area. In March 2014 a SVC manufacturer was contracted to engineer, procure, and construct a 138kV, -75/+150MVAR SVC at Hoytdale substation in Penn Power. FirstEnergy substation engineering in conjunction with an A/E firm reviewed the SVC manufacturer's design against FirstEnergy substation engineering standards and specifications. FirstEnergy project management worked in conjunction with the SVC manufacturer during the construction of the SVC, and FirstEnergy substation services worked with the SVC manufacturer to commission and test the SVC.

2 INVESTIGATION

The SVC manufacturer and FirstEnergy Substation Engineering opened an investigation. FirstEnergy Substation Services took current and voltage measurements in the area of concern. The recorded circulating current values in the TCR branch fence were as high as 200A. Voltage measurements were in excess of 10V across fence sections and the double gate.

Figure 1: High Current in the TCR Branch Fence

It was found that the TCR magnetic field was inducing large currents through the TCR gate, some sections of the TCR fence, and through the ground connections. The SVC manufacturer determined that currents could be removed by opening existing ground loops, but this would result in an unacceptable voltage rise, particularly at the double gate of the TCR fence and between the cooling tower and the closest fence.

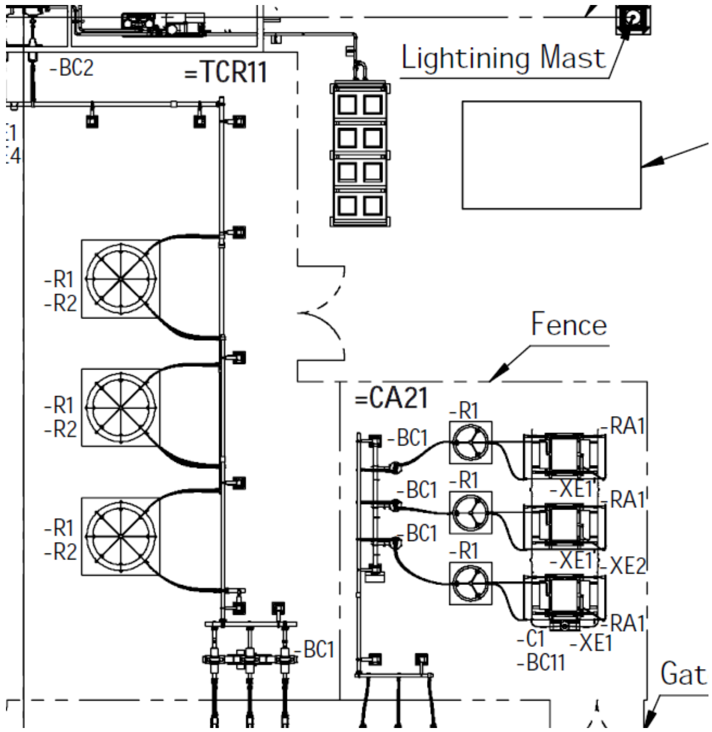

Figure 2: TCR Layout

Additional measurements where performed by the SVC manufacturer on April 27th, and a series of ground grid modifications were proposed to minimize the induced currents.

3 GROUNDING DESIGN

The primary function of a grounding system in a substation is to provide a safe return path for electrical currents during fault conditions to assure that an individual in the area of the grounded facilities is not exposed to dangerous electric shocks. The general public must also be protected from the potentially dangerous "touch" and "step" potentials that may exist around the periphery of the substation fence during ground fault conditions. These calculations and recommendations are based on IEEE Std. 80, "IEEE Guide for Safety in AC Substation Grounding".

FirstEnergy's preferred practice is to design substation ground grids using a mesh or grid pattern for the ground conductor. The SVC was designed using peninsular grounding to avoid closed loops and circulating current.

3.1 Stray Voltage

The Hoytdale SVC was designed with large air core reactors which generate strong magnetic fields. The magnetic fields induce a voltage rise on any open loops of conductive material. This potential rise is often referred to as an induced voltage or stray voltage. IEEE Std. 1695-2016 defines stray voltage as, "A voltage resulting from the normal delivery or use of electricity that may be present between two conductive surfaces that can be simultaneously contacted by members of the general public or animals. Stray voltage is not related to electrical faults." Sources of stray voltage include (1) normal system return current, and (2) in the case of a SVC reactor, electromagnetically coupled currents and voltages. Many of the mitigation strategies described in IEEE Std. 1695-2016, were not directly applicable to the Hoytdale SVC installation.

3.2 Touch Voltage

Touch voltage is defined as the potential difference between a point on the ground where a person may stand and a point that can be touched by the normal horizontal extension of the person's arm. This distance is assumed to be one meter. The distance between the TCR fence and the cooling towers at the Hoytdale SVC were located within one meter of each other and were connected to separate peninsular ground. The touch potential between the two points was approximately 10V. This exceeds the IEEE Std. 80 guidelines for allowable body current.

3.3 Body Currents

The magnitude of current that the human body can tolerate depends on the frequency of the shock, shock duration, and physical condition of the person. It is the consensus of authorities that generally for frequencies above 25 Hz and for a duration of a few seconds, the threshold of perception is one milliampere. Current flow of 9-25 milliamperes makes it difficult for a person to release his grip from a power circuit and at 30-50 milliamperes, muscular contractions may make breathing difficult and possibly result in unconsciousness. At 60-100 milliamperes, fibrillation of the heart may occur.

4 CORRECTIVE ACTIONS

4.1 Ground Grid Modifications

The SVC manufacturer recommended a modifications to the ground grid designed to minimize the induced voltage to within IEEE Std. 80 guidelines. The modifcations are show in Figure 3: Ground Grid Modifications below.

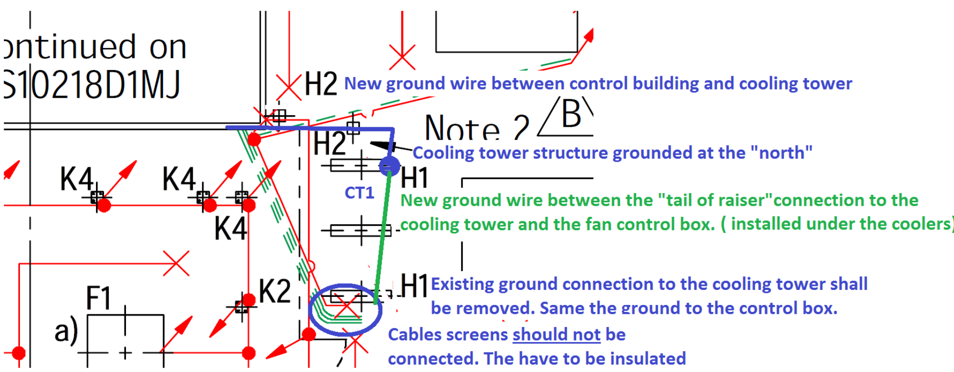

Figure 3: Ground Grid Modifications

4.2 Non-Conductive Fence

The modifications to the ground grid improved the situation significantly, but did not completely rememdy the situation. Further corrective actions included replacing a section of metallic fence with a fiberglass non-conductive fence and adding gaps to the fence. The modifications are show in Figure 4: Corrective Actions below.

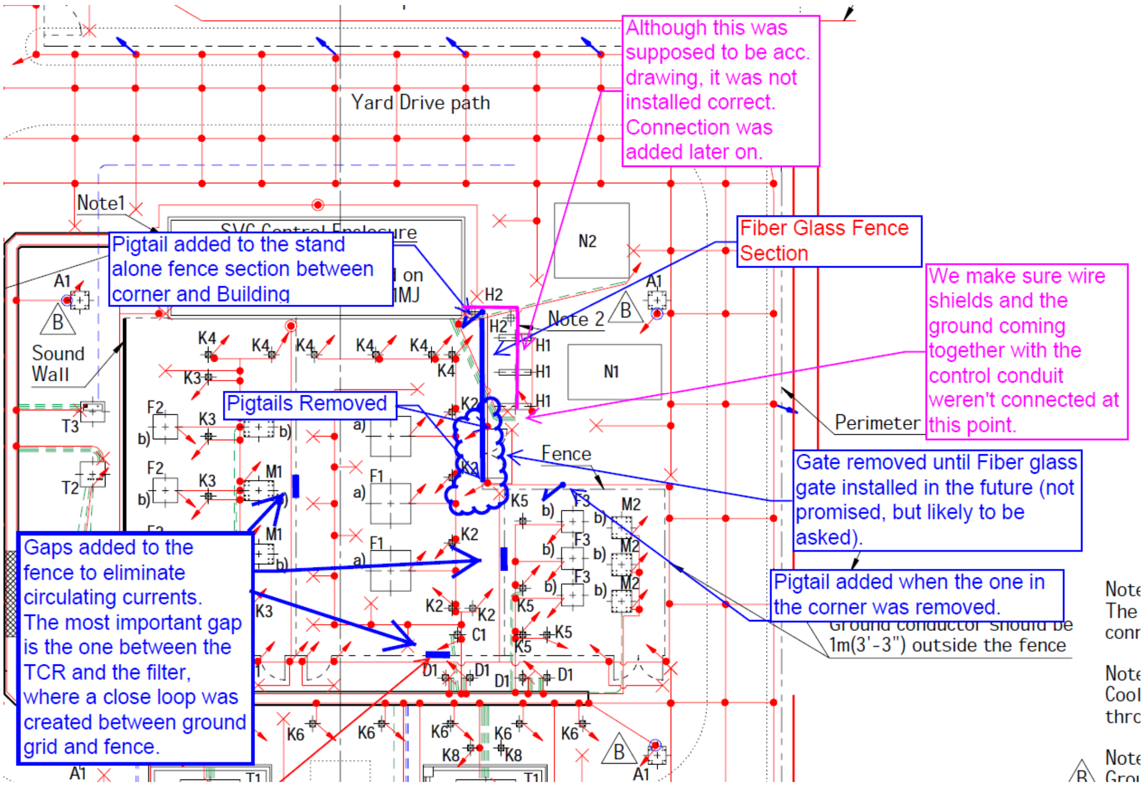

Figure 4: Corrective Actions

5 RESOLUTION

The final measured voltages were less than 1.5V. Commissioning of the SVC was completed, and the SVC was placed in commercial operation. The situation is being closely monitored.

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