Remote Viewing within a High Voltage Apparatus

Blake Bagley, Julia Garcia, Erica Mathew

**Concept of Operations**

REVISION – Draft

14 September 2024

Concept of Operations

for

Remote Viewing within High Voltage Apparatus

Team <54>

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Prof. Kalafatis Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **-** | 9/14/2024 | Remote Viewing within High Voltage Apparatus |  | Draft Release |

**Table of Contents**

[**List of Figures**](#_heading=h.2et92p0) **4**

[**1.**](#_heading=h.3dy6vkm) **Executive Summary 5**

[**2.**](#_heading=h.1t3h5sf) **Introduction 5**

[2.1.](#_heading=h.4d34og8) Background 5

[2.2.](#_heading=h.2s8eyo1) Overview 5

[2.3.](#_heading=h.17dp8vu) Referenced Documents and Standards 6

[**3.**](#_heading=h.26in1rg) **Operating Concept 6**

[3.1.](#_heading=h.lnxbz9) Scope 6

[3.2.](#_heading=h.35nkun2) Operational Description and Constraints 6

[3.3.](#_heading=h.1ksv4uv) System Description 7

[3.4.](#_heading=h.44sinio) Modes of Operations 7

[3.5.](#_heading=h.2jxsxqh) Users 7

[3.6.](#_heading=h.z337ya) Support 8

[**4.**](#_heading=h.3j2qqm3) **Scenario(s) 8**

[4.1.](#_heading=h.1y810tw) Ensuring State of Switchgear 8

[**5.**](#_heading=h.4i7ojhp) **Analysis 8**

[5.1.](#_heading=h.2xcytpi) Summary of Proposed Improvements 8

[5.2.](#_heading=h.1ci93xb) Disadvantages and Limitations 9

[5.3.](#_heading=h.3whwml4) Alternatives 9

[5.4.](#_heading=h.2bn6wsx) Impact 9

**List of Figures**

Figure 1: Thermal Remote Viewing System Overview……………………….7

# Executive Summary

As the industry demand grows, space within medium voltage switchgear has become increasingly limited. Manufacturers once had the luxury of allotting one device to a dedicated space, but now they must fit multiple apparatus for different functions into that same confined space. Manufacturers are additionally being asked to include safety devices within the switchgear. These safety devices are often not in areas that are easily accessible by the operator which makes visual inspection challenging. The goal of this project is to create a solution that enables operators to remotely view the safety devices inside the switchgear. This will significantly improve both safety and efficiency for the customer by providing continuous monitoring of the mechanical switches.

# Introduction

This document is an introduction to our Proposed Thermal Remote Viewing System within High Voltage, a system capable of monitoring the mechanical safety switches within medium voltage switchgears. This project will allow operators to remotely confirm the state of the switchgear without putting themselves in danger.

## Background

Currently, there is not a good system for monitoring the inside of a switchgear. Operators currently rely on a flashlight through a small window to get a view of the inside. This method is extremely inefficient because it provides very limited visibility and is unable to view regions that are covered by wires. This can also be very dangerous and can expose the operator to the dangers of high-voltage.

Our plan of creating a remote viewing system will allow operators to monitor the switchgear from a distance. Real time streaming with the use of thermal sensors will provide a comprehensive view of the switchgears. By placing thermal sensors close to the safety switches, we are able to get a visual representation of hard-to-reach areas.

## Overview

Our system will be used to monitor safety switches within a medium voltage switchgear to check for gaps between contacts. We will use thermal sensors to create a temperature profile of the switchgear in real time. This raw thermal data from the sensor is sent to our microcontroller which converts the data into a video stream. Here we will have to perform linear interpolation to smooth the images. Our microcontroller would then send the processed data over a network via Wi–Fi. Finally we will create a website for the operators to easily interface with that displays the thermal video stream.

## Referenced Documents and Standards

* IEEE Standard C37.20.2 IEEE Standard for Metal-Clad Switchgear
* IEEE Standard C37.04 IEEE Standard for Ratings and Requirement for AC High- Voltage Circuit Breakers with a Rated Maximum Voltage Above 1000V
* IEEE Standard C37.09 IEEE Standard Test Procedures for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V
* ANSI C37.54 American National Standard for Alternating Current High-Voltage Circuit Breakers Applied in Metal-Enclosed Switchgear—Conformance Test Procedures
* NFPA 70E Standard for Electrical Safety in the Workplace
* NFPA 70 National Electrical Code

# Operating Concept

## Scope

The goal of this project is to create a system that allows for operators to remotely view a switch within a switchgear without opening it to ensure safe grounding. When an operator wants to see if the designated switch is open or closed, he/she will open a computer application that will connect to the microcontroller. A thermal image sensor will first capture a video of the designated switch; then the microcontroller will send that video to the application. One of the big constraints of this project is that we need to make sure that the dielectrics that are already in the switchgear still operate within industry standards. Due to budget constraints, the project will entail making this system for only one vertical tower of switchgear. We will still make this system expandable by having multiple towers connected to the application with their own dedicated sensors and microcontrollers. This system will help to make switchgear operators’ jobs much more safe and convenient.

## Operational Description and Constraints

This system is intended to be used by switchgear operators to make sure switchgear can be safely operated. The operator should be able to open an application on a computer and connect to the switchgear he/she is operating on to see the desired switch’s state. An image will be taken by a thermal image system placed in the switchgear, which will then be sent to an application through a microcontroller for the operator to see. According to the sponsors of this project, the system must allow for the users to see the designated switch. Graphical representations are not enough for customers, and are not enough for operators to feel certain that the switchgear they are operating on is in the right state. The system must not cause the dielectrics to fail integrity tests because of the system’s addition to the switchgear. Also, no modifications will be made to the switchgear other than allowing for the ability to mount the system. The system is purely an addition to the switchgear.

## System Description

There are three main parts of this system. The first part of this system is the thermal image sensor. This is what will create the image of the switch needed to be examined. The sensor will be placed within the switchgear at a respectful distance from the switch so that interference isn’t a problem. The second part of the system is the microcontroller. This part will configure the sensor, process the information read from the sensor, turn the information into something readable by an application, and send off the information through wi-fi. The final part of the system is an application that will take the information sent from the microcontroller and transform it into a viewable format for the operator. The system can be expanded upon by having more vertical towers connected to the application. Each vertical tower will have its own microcontroller and thermal image sensor to allow the application to connect to and view the inside of each tower.

Figure 2

*Figure 1: Thermal Remote Viewing System Overview*

## Modes of Operations

The operator only needs to view the switch through some type of produced image. The only difference between cases is that the switch might be located in a different part of the switchgear, which will cause the sensor to be placed in a new location. If this project were to be later expanded for the use of multiple towers, then this could entail the operator choosing which tower of switchgear to view.

## Users

The users of this system, as stated throughout this report, will be switchgear operators. These operators are highly trained and knowledgeable of the hardware being observed by the proposed system. It is common for these users to have engineering and/or technical degrees. Thermal sensors are commonly used in procedures for switchgear, so operators should have some knowledge of how they work. Being that a big portion of these operators' jobs is maintenance and safety, our system will ensure that their job is much easier by giving the operator a good visualization of the state that the switchgear is in.

When it comes to the proposed system, there won't need to be any training for installation. The only training needed will probably be for the use of the application. The application should be simple to learn as it is supposed to be a tool for visualization.

## Support

Support for our system will be given in the form of a manual on how to operate the system. It will detail the assembly of the system, configuration of the hardware, and operation of the application.

# Scenario(s)

## Ensuring State of Switchgear

The use of our thermal viewing system is to ensure the mechanical safety switches are open. If a maintenance worker needs to open up a switchgear and work inside, they can use our system to make sure it is depowered. The main problems with the switchgear are the density of electronics and lack of inner lighting. These issues make checking that the equipment is depowered extremely difficult. The operator cannot see the gaps from the window on the door, but our system will fix this. With a thermal image of the mechanical safety switches inside the switchgear, operators on the outside can visually see the open gaps, proving it is depowered and safe to open.

# Analysis

## Summary of Proposed Improvements

* The proposed system will make operating a switchgear much safer than it currently is. By having a thermal image sensor placed inside the switchgear, the system allows for the operator to not have to open up the back and check if the safety switch being observed is closed.
* The system will also utilize wi-fi which will make the switch observable at longer distances.
* The sensor can be remotely turned on and off, so the system is active only when needed by maintenance personnel. This ensures the system isn’t wasting any power.
* We could expand upon this project by making the system use machine learning. This will allow it to automatically classify switches as “open” or “closed”, which will improve the workflow for operators overseeing multiple switchgears.

## Disadvantages and Limitations

Our proposed thermal viewing system will have some limitations which include:

* The size of the system is very limited due to the scant amount of space available within the switchgear.
* All equipment/components used in the system must be able to withstand high temperatures.
* The sensor and accompanying equipment must be shielded to ensure they don’t interfere with the dielectrics within the switchgear.
* The locations that the thermal sensor can be mounted are limited due to the space constraints within the switchgear.
* Due to budget constraints, the resolution of the picture won’t be very sharp.

## Alternatives

Some alternatives to our proposed thermal viewing system are:

* Placing small flags behind the safety switches and using a flashlight to see inside a window on the front door of the switchgear. If the flag is visible, an operator can conclude the switches are open and the switchgear is depowered.
* Using a “normal” camera with a light source and streaming video of the switches to remote locations.
* A window placed on the backside of the switchgear closer to the mechanical safety switches. With this solution, the operator would need a light source of their own.

## Impact

* There are no ethical concerns because the proposed system is being created to ensure the safety of anyone who works with switchgear. The system is intended to protect people at no cost to any other part of the overall switchgear.
* The environmental impact of our system is minimal. Our only impact comes from power consumption, which isn’t high.
* The impact for society would be minimal, as this wouldn’t affect the everyday lives of anyone except the operators that work directly with switchgear.