

Infrared inspections of electric substations: the importance of developing a Plan

James Dan Roark, Knoxville Utilities Board (KUB), Knoxville, Tennessee

System Operations Department, System Operations Technician II

Certification: Level II Thermographer, Certification No.: 12424

ABSTRACT

Infrared thermography has become an integral part of maintenance programs throughout the utility industry. It is by far the most efficient and effective technology available today for locating and evaluating thermal anomalies.

KUB, for many years, contracted for this service, but it became economically advantageous for KUB to develop its own program. In Fall 2000, KUB purchased the FLIR ThermaCam 695 camera and provided resources for training.

I was asked to develop KUB's program. While investigating this new career opportunity, it became evident that a solid commitment to training and a willingness to make sound but difficult decisions were essential to maximize the benefits of this technology.

This paper relates our program progress and describes what we at KUB are doing to ensure that our substation inspections are thorough and complete.

Keywords:

1. INTRODUCTION

KUB incorporated infrared thermography into our scheduled maintenance plan in January 2001. I was asked to develop the program. Many companies proved more than willing to provide the camera and other equipment, but developing a complete infrared predictive plan and effective condition-monitoring program requires much more effort. At a minimum, these issues must be considered:

- Overall system size
- Importance of equipment, based on system integrity
- A plan to be developed, considered, and approved by management
- Program implementation, and
- Provision for periodic progress updates

Management approved a 3-year plan for completion as follows:

1. Initiate the program in January 2001.
2. Create a 3-level priority list of all KUB facilities.
3. Schedule all infeed electric substations within the first six months of plan implementation.
4. Schedule infeed substations on an 18-month cycle, allowing more frequent inspections and during varied weather conditions.
5. Provide time in plan for any trouble requiring investigation.
6. Test all KUB facilities within 36 months.

On plan completion, perform annual inspections of all electric substations.

2. CLASSIFICATION OF PROBLEM

Infrared camera purchase is a simple task. Most manufacturers provide equipment appropriate for evaluating electrical equipment. Yet two other issues are critical to the success of a solid thermography program:

1. Thorough training at a qualified training facility offering accreditation.
2. A complete plan and, if required, appending a checklist to ensure that inspections overlook no equipment. (You may not get a second chance!)

Twelve months into its initial program, by December 2001, we were ahead of schedule. If progress continues at this rate, KUB will complete its 3-year plan by Spring 2003.

With properly trained personnel and a thorough plan, an infrared program can succeed. This paper provides some program insight and suggests ways of performing substation inspections with completeness and efficiency.

3. PLAN DEVELOPMENT

Planning is the first step in successful substation inspection. Ours is simple to follow:

Start at the top and work down!

This may seem elementary, but it works well. Let me explain. To ensure that nothing is overlooked, inspect all high voltage structure equipment first – structure mounted potential and current transformers, air break switches, bus connections, and substation line terminations.

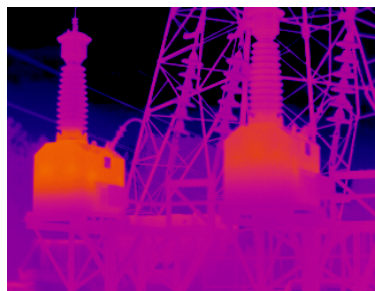


Figure 1a



Figure 1b

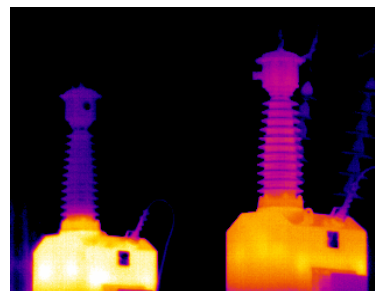


Figure 1c

Figures 1a-1c: 69KV Potential Transformers. Empty Bushing on Left

Be very careful with camera settings. Figures 1a and 1c show the same image. If slight thermal variations are present and go undetected, extremely dangerous situations may be overlooked!

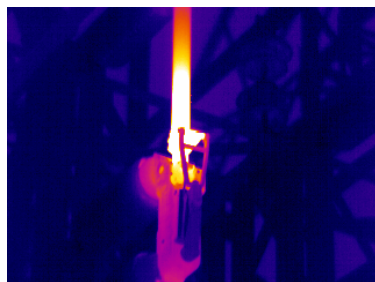


Figure 2a



Figure 2b

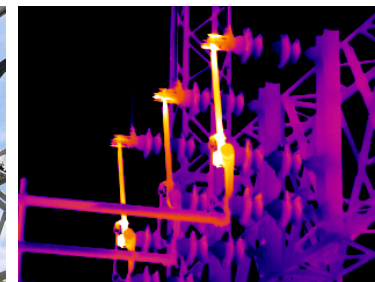


Figure 2c

Figures 2a-2c: 69KV Air Break Switches. Anomalies within the contacts and mechanism.

A quick scan of the high voltage structure easily detects this type of problems.

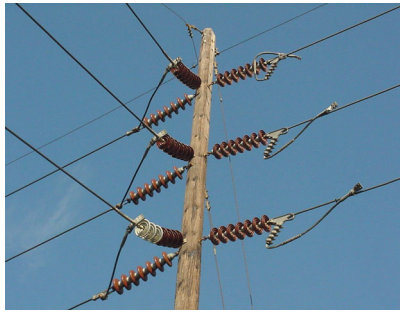


Figure 3a

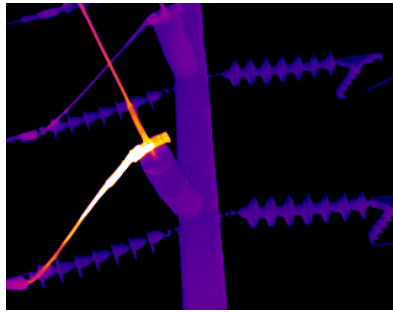


Figure 3b

Figures 3a-3b: 69KV Line Connections supporting substation

After high voltage structure inspection is complete, evaluate distribution equipment, including main substation transformers, regulators, circuit breakers, and low voltage disconnect switch structures.

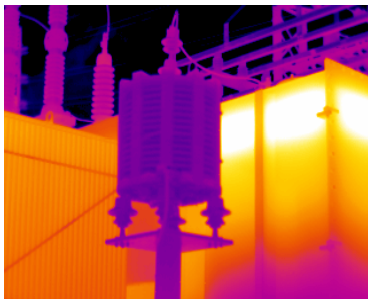


Figure 4a



Figure 4b

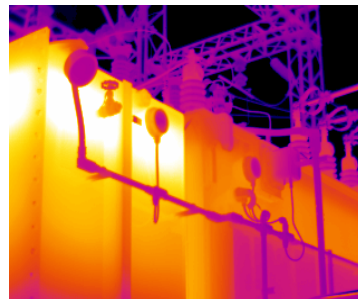


Figure 4c

Figures 4a-4c: 25MVA Transformer

Thermal levels in tapchanger compartments should never be higher than winding compartments. The images above indicate a critical condition within this tapchanger!

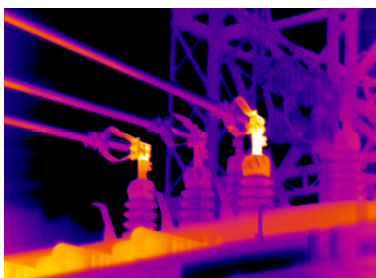


Figure 5a

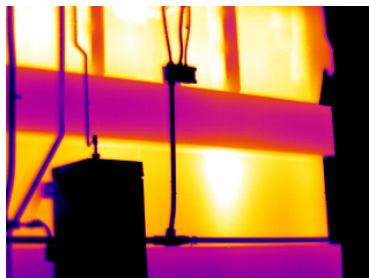


Figure 5b

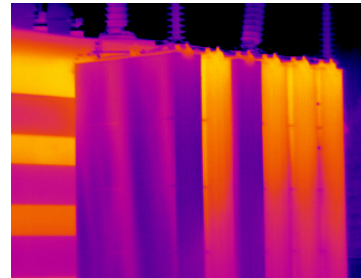


Figure 5c

Figures 5a-5c: Transformer conditions

All three images above show conditions thermographers may encounter. Figure 5a shows connection problems on secondary bushings. Figure 5b indicates a secondary core ground that allows iron of the winding structure to become a current path. Figure 5c shows malfunctioning radiators. All three conditions may cause premature unit deterioration.

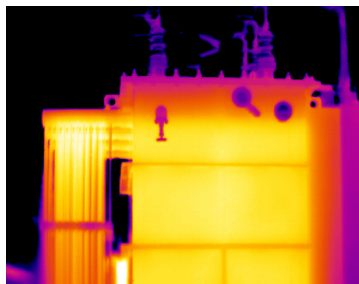


Figure 6a



Figure 6b

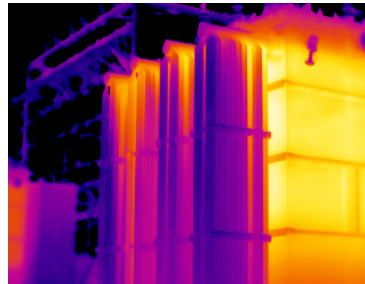


Figure 6c

Figures 6a-6c: 25MVA Regulating Transformer

When evaluating transformers and regulators, scan from different angles. From Figure 6a, one might assume this regulator has an adequate oil level for proper radiator function. Figure 6c indicates differently!

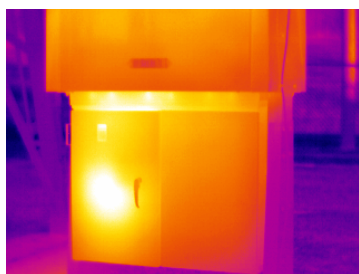


Figure 7a



Figure 7b



Figure 7c

Figures 7a-7c: 14.4KV Vacuum Circuit Breakers

Not all elevated readings indicate abnormal situations. An inspector might think an internal control wiring problem exists in the breaker shown in Figure 7a, but that is not the case. In fact, that image is normal. The control cabinets of outdoor switchgear are heated. The heater of the circuit breaker in Figure 7c is inoperative, and in danger of moisture encroachment, one of leading causes of switchgear failure.

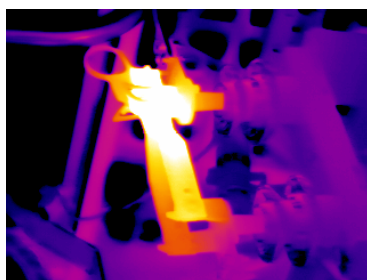


Figure 8a



Figure 8b

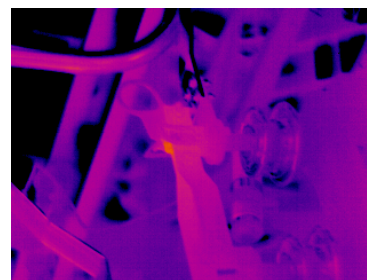


Figure 8c

Figures 8a-8c: 15 KV Disconnect Switches: Before & After Replacement

The problem most frequently encountered will be overheated disconnect switches. Usually, only cleaning, adjustment and lubrication are necessary to eliminate that condition, but not always! When extreme cases are documented, it is important to re-evaluate after maintenance is performed. If the condition persists, replacement may be required.

All outside inspections should be completed at this point. Briefly examine the entire station yard visually to ensure that nothing was overlooked. Structure mounted equipment is often hard to locate. From my experience, this will be time well spent.

Then move indoors. Most KUB substations have control houses, but not all. In either case, protected areas are established where our controls and monitoring systems are located.

Loose connections and overloaded circuits are the most common control system problems. Also check heating systems' operation to maintain an environment suitable for relay and control systems.

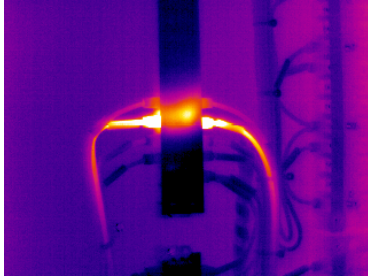


Figure 9a

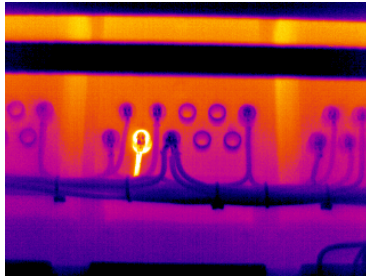


Figure 9b

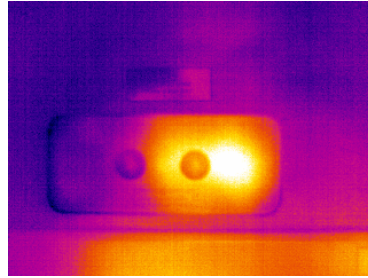


Figure 9c

Figures 9a-9c: Common Control System Problems

Often, tightening a terminal screw is all that is needed. Even if this is the case, allow time for cooling to ensure that the problem is resolved. Other conditions that may cause this abnormal thermal signature include improperly pressed crimp connections, broken terminal screws, and deteriorated control wire. The problem source must be positively identified and eliminated, or system protection may be jeopardized.



Figure 10a

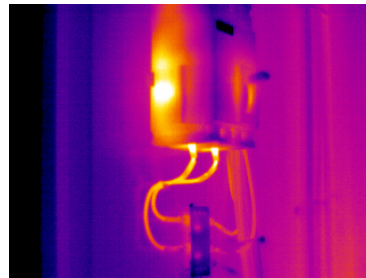


Figure 10b

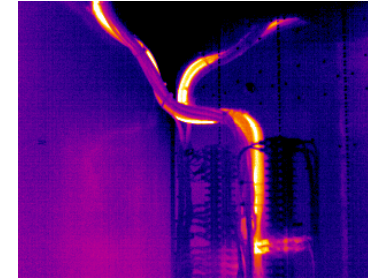


Figure 10c

Figures 10a-10c: Overloaded Circuits

Inspect all control wiring for overloaded circuits. Undersized wire or excessive current levels can cause this condition. In either case, this condition poses an extremely dangerous situation. Control system failure can have catastrophic consequences!

4. MAINTAINING RECORDS

Developing a functional system for maintaining records is critical. During our program's first year, more than 650 images were taken, so we had to develop a system that let us locate and access information quickly for future reference. We dealt with two issues – (1) permanent storage of images and presentation reports and (2) hard-copy image data.

The FLIR ThermaCam 695 with its 160MB flash memory storage held almost an entire year's worth of images. But beyond that point, we required permanent Compact Disk storage. I strongly recommend recording a back-up copy of all images. (Better safe than sorry!)

We created a database file (Fig. 11) to handle the image data issue. Each page held complete information of 30 images, including location, directory, identification number and whether the image is thermal or digital, a brief equipment description, and load conditions.

List of Images

Load Condition

<u>Number</u>	<u>Location</u>	<u>Directory</u>	<u>Image(T-D)</u>	<u>Equipment</u>	<u>A ph.</u>	<u>B Ph.</u>	<u>C Ph.</u>
1.	66PS	B0612#01	0612-01T	PS11 Line Side A Ph. Sw.	120	130	120
2.							
3.							
4.							
5.							
6.							
7.							
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Figure 11: Typical page of “List of Images” Report

5. REPORT TEMPLATES

Among the most important aspects of developing a professional infrared thermography program is providing well-prepared reports and presentations. The ThermaCAM Reporter 2000 software is a powerful tool for building and modifying templates. I propose personalizing reports using custom cover pages, corporate logos, and sound recommendations supported by quantifiable data and results. Also include individual certification information to provide credibility to the overall program.

6. CONCLUSION

No electrical system is 100 percent efficient. Harsh environmental conditions cause deterioration of equipment. Vibration, load imbalance, structural fatigue, and age also accelerate equipment degradation.

System components and contact surfaces develop resistance over time. By understanding basic power loss principles, a thermographer can determine likely areas of concern. Temperature is among the first indicators of equipment condition. Using a normal thermal signature, any abnormal (anomaly) can be evaluated. Defects will alter the thermal signature of the component due to I²R losses.

Once an anomaly is detected, the thermographer must ascertain the seriousness of the problem and recommend whether intervention is required. Also, a decision must be made as to how quickly personnel must respond based on the thermal level. Any condition present should be identified as proficiently as possible to allow time for repair prior to failure.

Since the thermographers' integrity will be on the line at some point, it is important that recommendations are based on knowledge, camera skill and experience. Be aware of reflections, solar loading and, most importantly, emittance variations that can cause greatly exaggerated readings. So be careful! You can easily be fooled into believing there are problems where none exist.

Solid thermography programs begin with properly training personnel. A trained thermographer should be able to accurately diagnose thermal problems and make valid recommendations. Design custom report templates for professional presentations. Maintain records that afford quick access to past information, and above all, perform thorough and complete inspections.

These elements are the fundamental building blocks of a thermography plan that will become an integral part of a successful predictive and preventive maintenance program.