

AERIAL THERMOGRAPHY SURVEYS FIND INSULATOR AND OTHER PROBLEMS

By Derrick Brydges, Hydro One

This article will examine the application of aerial thermal imaging surveying on a transmission electrical system, and new applications involving insulator failure detection and new research in wood arm deterioration.

The goal is to show the approach to an aerial survey from pre-planning the actual patrol to follow up reporting. The blackout of 2003 has placed more emphasis on proactive preventive maintenance programs. An identified component repair can be performed at 25% of the cost, versus a reactive unplanned approach. This excludes the loss to generators due to bottleneck flow. My analogy to this is similar to a toll highway. When open the client is profiting when closed the client is not.

INTRODUCTION AND HISTORY

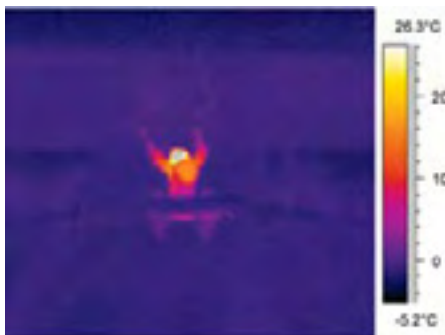
Hydro One (formerly Ontario Hydro) owns, operates and maintains 30,000 km of transmission lines in a province of more than 400,000 square miles (50% bigger than the state of Texas).

These 500-kV, 230-kV and 115-kV assets are valued at over 5 billion dollars.

Our mandate is to ensure public safety, system security and asset protection. Our infrared camera program helps to achieve these goals by continuously monitoring the transmission system. Circuits are selected for patrols on a priority basis and we maintain the flexibility to react to a system configuration that may increase the load on circuits. Power Line Surveys represent a moment in time, to guarantee future performance is risky. We attempt to obtain minimum load requirements before a survey is car-



Photos show the Gimbal mounted under the Aircraft. Notice the two monitors so the Pilot and Thermographer can work together. (At right) Work station for the Thermographer. A screen monitor and a field tablet as a second monitor and data collector.



IR image of a Skywire hardware anomaly.



Once an anomaly is detected, a closer view can be established.

ried out and this is part of the pre-planning. System outages are monitored along with seasonal weather patterns to help achieve these goals. Ontario, due to its geographic location, experiences cold winters and hot summers. In winter, home heating load is predominant in the Northern Province while in summer, air conditioning load is experienced in the South. Hence, surveys are performed in the North during the winter and late fall time frames while the South is monitored in the summer. There is a period in warmer spring when the snow melts and the Northern hydraulic dams are maximized for generation to the South.

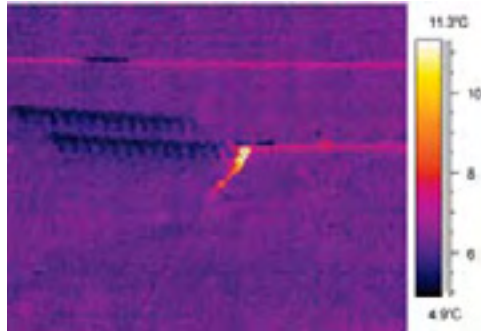
EQUIPMENT

Hydro One owns and maintains a fleet of helicopters for many applications, thermal imaging camera scans included. Surveys are carried out utilizing the Polytec Kelvin 350 Gyro stabilized Gimbal. This unit was produced as per our specifications and contains the THV 570 infrared camera (12 degree lens), along with a Sony FCB-780 Video camera and a 5 mega Pixel Canon Power shot G5 frame camera. The THV 570 is calibrated annually which includes the factor for transmission effects with the gimbal infrared glass. The infrared cam-

era is removable from the Gimbal with ease. All IR cameras operate at the same time and two can be monitored at once as per requirements.

COMPONENT ANOMALIES

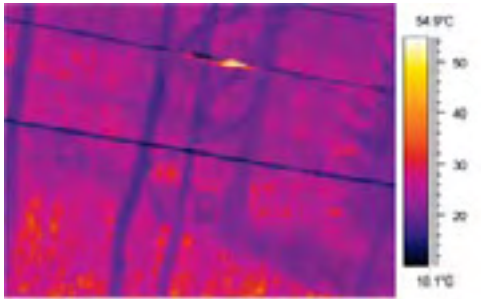
Hydro One helicopter pilots spend their days continuously close to utility wires, therefore they are comfortable being close to these structures and wires. Regulation dictates that a minimum of five feet must be maintained between the main



IR image of 230 kV bolted connector



230 KV Dead end tower



Conductor sleeve anomaly.



Aluminum conductor sleeve with Inner Steel Core sleeve.



500 KV Dead-end string.



115 KV Suspension string.

rotor and tail rotor from any solid object. This permits us to fly the circuit's low level at app. 60 knots (70mph). When an anomaly is detected we will close in and capture the image. The issue of down wash cooling the component is not a major factor as the time on station is very quick. With the two monitors the pilot can reference himself on the initial pass move in quickly and the infrared and digital cameras capture the image. At the end of the day the data is analyzed and quantitative reports are generated and sent to the local representative. All Hydro One activities are supported by documents including

the thermal imaging program. Ratings are based on documented data that has been developed in conjunction with Hydro's research department.

The most common anomaly detected is the bolted pad, which consists of two separate aluminum pads which are connected together with steel bolts and a spring loaded Belleville washer which are tightened with a pre-set torque value. This setup applies the proper pressure between the two aluminum pads. When the proper force is no longer available to the two pads, a resistance will generate heat. There are two detailed articles in the Maintenance Technology magazine. The titles are "The Trouble with Torque in Electrical Connectors" and "Creating Reliable Electrical Connections".

Another component that commonly shows up as an anomaly is conductor splices. These are used to connect the two ends of wire where the reel ends. In the transmission lines, due to the size and tension requirements of these wires, a steel core is found inside the aluminum sleeve.

In preparation for installing one of these splices, the steel sleeve is pressed onto the small diameter steel core, then the larger aluminum sleeve is installed over the top. The steel is used for strength and the aluminum for current transfer. During the preparation process, a joint compound is applied. This thin film of black compound is applied after cleaning the aluminum and may extend past the end of the connector. Without the proper settings on an IR camera, this product can give a false image of an anomaly.

INSULATOR ANOMALIES

Over the years, we have detected many insulator anomalies during aerial surveys. These would show up on transmission circuits utilizing porcelain insulators and on transmission/distribution circuits utilizing NCI (non-ceramic insulators). It was due to the high frequency of these insulator anomalies that Hydro One, in conjunction with Kinectrics (formerly Hydro Research dept.), decided to perform some lab studies utilizing IR

technology. These tests were broken down into two parts, one to study the effects of the NCI, and the other to address the Porcelain failures.

PORCELAIN:

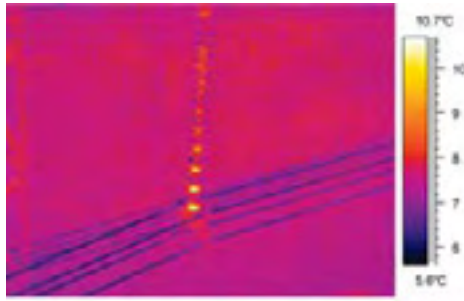
Insulators are designed to insulate the energized wire from the structure supporting it. Different voltages require different lengths of insulated distance.

Each insulator string has a set number of acceptable defec-

tive insulators. Once this number has been reached, the insulation value of the string has been compromised and replacement will be scheduled. If the infrared camera survey records a few anomalies, there will be a follow-up visit from a crew to test the rest of the string with the Hi-test insulation tester. The Hi-test insulation tester is a 10 kV di-electric device that is isolated from the line allowing the insulators to be tested while energized. If the infrared survey detects the minimum number of suspect insulators, the string will be replaced immediately without a follow-up Hi-test insulator program.

Under operational conditions, the porcelain skirt can crack which may not be detected by the naked eye. This results in causing an undesirable leakage. A good insulator behaves as a resistor and capacitor, hence any resistive leakage current will cause the metal hub to rise in temp. Once this happens, the infrared camera will detect an anomaly.

Through trial and error we have found that the best time to perform this type of survey is in a humid air climate.



IR image of a 500 kV insulator string.



Cracked insulator skirt.

This accelerates the electrical activity much more than a dry day but it is still possible to detect an insulator anomaly with any type of weather conditions. This is a non-radiometric application, as once the thermal signature is detected, we know from case studies the steel hub has a temp rise due to electrical forces concentrating on it.

NCI INSULATORS:

Non-ceramic insulators consist of a rubber material for insulation, with an internal fiberglass rod for strength. When

manufactured, the rubber is bonded to the fiberglass rod to eliminate voids. From the lab tests performed, it was determined that lack of bonding between the rubber housing and the fiberglass rod contributed to failure.

Other methods that were tested to help identify a suspect NCI:

- Visual Inspection - not helpful
- UV inspection - not helpful
- Ultrasound EM - not precise

From these trials, it was determined that inspection by thermal imaging cameras is the best.

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ELECTRICAL TRAINERS NEEDED

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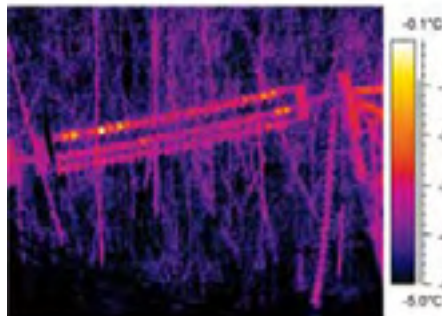


ThermoVision Measurements on NCIs.

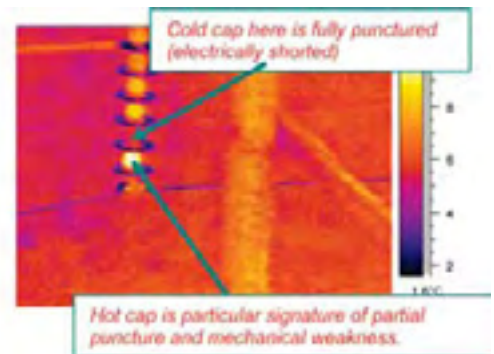


Examples of Hidden NCI Damage.

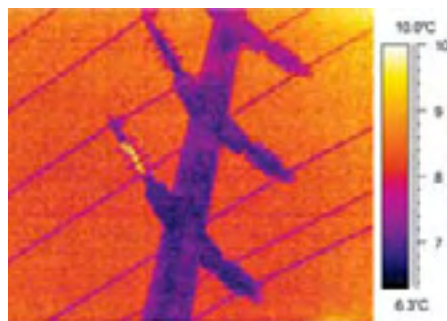
NEW RESEARCH:
We are always on the lookout for ways to improve our processes to maximize the utilization of our resources. We are in the process of performing field trials with the University of Waterloo, Ontario. Once again, with the assistance of Kinectrics, we are going to study thermal signatures on wood components and correlate the data with cross section cutting. This will enable us to identify priority repairs on Gulf Port Spar arms while on helicopter patrols.



Percentage of the total string voltage across each unit.



CONCLUSION:
Hydro One has always maintained an aggressive pro-active approach to monitoring their grid systems. Aerial thermography has played a constant and vital role in detecting anomalies in the system, enabling repairs to be initiated before failures occur. This inevitably helps to ensure system security and reduce capital costs.



Double circuit distribution line.



Flashed Insulators.

REFERENCES:
Norman Shackman P.E: Maintenance Technology: Trouble with Torque in electrical Connections and Creating reliable Electrical Connections;

D. Murphy: Insulator Evaluation: Kinectrics Inc. Report No. 2429-001-RC-0001-R00 Jan. 23/2004;

William A. Chisholm: Development of Live Line Replacement criteria for partially Defective Non Ceramic Insulators;



230 kV pole structure showing suspect locations of high failures

R. Filter and D. Mintz, "The Prevention of Pole Fires", Final Report for Canadian Electrical Association contract 265 D 748, January 1997.

ACKNOWLEDGEMENTS:
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