Thermovision of distribution and transmission lines

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MAINS MAINTENANCE INSTRUCTION

PRIMARY SYSTEMS

<table>
<thead>
<tr>
<th>Document no.</th>
<th>Amendment no.</th>
<th>MMI 0032</th>
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MMI 0032    Thermovision of distribution and transmission lines

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1.0 PURPOSE
To specify the requirements for carrying out thermovision of distribution and transmission overhead lines.

2.0 SCOPE
This instruction guides the use of thermovision on distribution and transmission overhead lines. Thermovision may be conducted after faults have been encountered or as part of a routine inspection. Distribution and transmission thermovision surveys are divided into two (2) separate sections as transmission line surveys have additional factors that must be considered.

The required outcome of the thermovision survey and the application of this instruction are to detect hot joints that may lead to the failure of the line if not repaired.

The instruction provides a guide for the conditions under which an effective survey may be carried out and recommends compensation factors to be applied (for transmission), as well as prioritisation of defects.

This instruction specifies reporting requirements.

3.0 REFERENCES
- Company Policy 9.9.1 – Network Asset Maintenance
- Company Procedure GAM 0089 – Authorisation Governance and Management
- Company Procedure GQY 1110 - Control and calibration of instrument and test equipment
- Division Procedure GNV1092.1 – Non Invasive Network Asset Condition Assessment Testing – Infrared (Thermovision) Surveys
- Division Form FNV 1073 – Thermovision Scan Test Report – Distribution Mains
- Division Form FNV 1074 – Thermovision Survey Report – Transmission Mains
- Mains Maintenance Instruction MMI 0012 - Overhead transmission line routine inspection
- Network Management Plan December 2013 Review
- ENA National Electricity Network Safety Code (Doc. 01-2008)
- Work Health and Safety Act 2011
- Work Health and Safety Regulation 2011

4.0 DEFINITIONS AND ABBREVIATIONS

Contractor  Person bound to execute the work under a contract.
Ellipse  Endeavour Energy’s asset database
Distribution Line  11kV and 22kV overhead electricity lines
Transmission line  33kV, 66kV and 132kV overhead electricity lines
Thermovision  Process by which thermal imaging infrared equipment is used to survey overhead transmission lines to detect hot joints and zero/low insulation insulators. Also known as infra-red survey.
NATA  National Association of Testing Authorities, Australia
OH  Overhead
UGOH  Underground to overhead - a transition between underground cables and overhead mains.
5.0 ACTIONS

Thermovision of overhead distribution and transmission lines shall be carried out in accordance with this instruction.

5.1 General

Where a hot joint or connection is detected, a more detailed examination of the component or equipment shall be carried out. The healthy phases or conductors shall be used as a reference to determine the relative temperature rise of the hot joint. As potentially all phases may be defective for a set of connections, in such cases the reference shall be used from nearby components on the line (for example, the connections on adjacent poles). Where no suitable reference is available, temperature rise and/or absolute temperature shall be recorded and reported.

5.2 Authorisations

These instructions shall be carried out only by Endeavour Energy employees who have been authorised in accordance with GAM 0089 - Authorisation Governance and Management.

5.3 Thermovision equipment

Equipment used for thermovision shall be approved by the Network Maintenance Manager, Primary Systems to confirm that it is capable of fulfilling the requirements of this instruction. It shall be calibrated based on the manufacturer’s recommended calibration interval, and carry a current calibration sticker in accordance with GQY 1110 - Control and calibration of instrument and test equipment.

Calibration must be carried out by a laboratory competent to carry out calibration of thermovision cameras, using equipment certified by NATA or equivalent.
5.4 Thermovision survey conditions

In order to minimise possible negative effects and increase the accuracy of the survey result, thermovision surveys shall fulfil the conditions shown in the following table.

<table>
<thead>
<tr>
<th>Basic operational conditions for thermovision</th>
<th>Ground survey</th>
<th>Helicopter survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>No rain, no mist</td>
<td>Same as ground survey</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>No strict limitations but temperature must be steady without rapid change</td>
<td>6 deg. C ~ 21 deg. C</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>No limitations</td>
<td>≤ 85%, dry season preferred</td>
</tr>
<tr>
<td>Wind speed</td>
<td>≤ 5.0 m/s (18km/hr), with wind speed preferably 0.2~1.5 m/s (5.4 km/hr)</td>
<td>Same as ground survey</td>
</tr>
<tr>
<td>Circuit loading requirement</td>
<td>Transmission: 100% full load preferable. If not, it should not be less than 40% full load</td>
<td>Same as ground survey</td>
</tr>
<tr>
<td></td>
<td>Distribution: No strict limitations. However, feeder load above 40% full load is recommended.</td>
<td></td>
</tr>
<tr>
<td>Time of loading the circuit</td>
<td>Steady running at the required condition at least one (1) hour before the survey starts</td>
<td>Steady running at the required condition at least 1.5 hours before the survey starts</td>
</tr>
<tr>
<td>Survey distance</td>
<td>As close as possible</td>
<td>As close as possible</td>
</tr>
</tbody>
</table>

5.5 Thermovision of transmission lines

5.5.1 Basis of surveying

The transmission lines that shall be surveyed and the frequencies at which they are to be carried out are specified in MMI0012 - Overhead transmission line routine inspection.

The scan shall be carried out up to the UGOH termination structure, or the first connection point to the substation after the landing span (such as the first isolator, or the transformer bushing in the case of a tail-ended transformer), as applicable.

5.5.2 Components to survey

Unless otherwise specified, the thermovision survey is required at joints, bonds and terminations in the conductors and associated equipment, including the detection of zero/low insulation insulators along the full length of the line. Damage to conductors at spacer locations must also be considered.
5.5.3 **Survey Method**

5.5.3.1 **Measurements**

Step 1 Measure the temperature of the Hot Spot, $T_H$ deg. C.

Step 2 Measure the temperature of the reference location, $T_R$ deg C.

Step 3 Calculate the temperature rise of the hot spot $T_H$ above the reference phase $T_R$, $T_{RR}$ deg. C ($T_{RR} = T_H - T_R$).

5.5.3.2 **Load correction factor**

Before the survey, the thermovision operator shall make arrangements with the System Operations Branch to load the lines under survey within the required range.

A load correction factor shall be applied to the measured results to reflect the actual temperature under full load conditions.

The correction can be calculated using the following formula:

$$T_2 = (I_a/I_f)^2 \times T_1$$

where:

- $T_1$ = The temperature rise (deg. C) [relative to the healthy conductor] at the actual load when the test is carried out (i.e. $T_{RR}$).
- $T_2$ = The temperature rise (deg. C) [relative to the healthy conductor] at full load.
- $I_a$ = Actual load (in amperes) at the time of test.
- $I_f$ = Full load (in amperes).

5.5.3.3 **Wind correction factor**

In order to obtain better accuracy of measurement, thermovision surveys shall be carried out only when wind speeds are less than 5.0 m/s (18km/hr).

Where a hot joint or connection is detected, a wind speed correction factor shall be applied to the measured temperature rise in order to convert the final result to a one meter per second wind speed.

When selecting the correction factor, the local wind speed should be obtained from an anemometer. Measurements of the wind speed shall be obtained as close to the conductor as practically feasible.

Wind speed correction factors are shown below:

<table>
<thead>
<tr>
<th>Wind speed (m/s)</th>
<th>Correction factor $C_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 1$</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>1.36</td>
</tr>
<tr>
<td>3</td>
<td>1.64</td>
</tr>
<tr>
<td>4</td>
<td>1.86</td>
</tr>
<tr>
<td>5</td>
<td>2.06</td>
</tr>
</tbody>
</table>
The final temperature rise at full load after taking the correction factors into account is given as:

\[ T_f = T_2 \times C_w \]

where:

- \( T_f \) = Corrected temperature rise (deg. C) of the connection above the healthy conductor.
- \( T_2 \) = The temperature rise (deg. C) [relative to the healthy conductor] at full load.
- \( C_w \) = Wind speed correction factor.

### 5.5.3.4 Prioritisation of defects

For overheating joints and connections defects, the following repair priorities shall be used:

<table>
<thead>
<tr>
<th>Corrected temperature rise deg. C (above reference) ( T_f )</th>
<th>Required Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>(&lt; 5)</td>
<td>Nil</td>
</tr>
<tr>
<td>(5 – 15)</td>
<td>Report only (watch)</td>
</tr>
<tr>
<td>(15 – 30)</td>
<td>Repair within 3 months</td>
</tr>
<tr>
<td>(30 – 45)</td>
<td>Repair within 1 month</td>
</tr>
<tr>
<td>(&gt; 45)</td>
<td>Repair within 48 hours</td>
</tr>
</tbody>
</table>

Additionally, if the **measured absolute temperature** of a connection exceeds 100 deg.C, it shall be repaired immediately (within 48 hours).

**Note:** Data entry into the Ellipse database is specified in MMI 0012 – Overhead transmission line routine inspection.

### 5.5.3.5 Reporting requirements

A report shall be produced in accordance with Division Procedure GNV 1092.1 - Non Invasive Network Asset Condition Assessment Testing – Infrared (Thermovision) Surveys, for each hot connection, zero insulation insulator or low insulation insulator detected and included in the monthly performance report. The following information should be recorded and provided in the report:

- Time and date of test.
- Weather conditions.
- Address/location.
- Approximate wind velocity.
- Feeder name/number.
- Nearest pole/structure number.
- Conductor/phase.
- Specified maximum rating of the feeder in the season of survey.
- Actual load current and load current as a percentage of the maximum current.
- The ambient temperature.
- The actual measured temperature rise (before adjustments).
- The wind and loading correction factors used in the calculation.
- Colour thermograph of the hot connection.
- Normal colour photograph of the hot connection.
5.6 Thermovision of distribution lines

5.6.1 Basis of surveying

The distribution feeders and the extent of each feeder that needs to be routinely surveyed are to be identified on the following basis:

5.6.1.1 Routine survey - at least once in three (3) years

A minimum of seven (7) switches out from the zone or transmission substation shall be scanned, including each main branch (if there is more than one). If a significant amount of defects are found in the first seven (7) switches, the operator shall scan further along the feeder.

5.6.1.2 Survey on request

The Manager System Control may request a survey of the following, as required:

- Sections of feeders that have carried a through fault current.
- Sections of feeders to which load is to be transferred from adjacent feeders prior to a prolonged planned outage.

The Power Quality & Reliability Planning Manager shall request surveys of poorly performing feeders on an ad-hoc basis, or following receipt of quarterly regulatory reports on performance of individual feeders. The Power Quality & Reliability Manager will specify the sections of the feeder to be surveyed.

In general, requested surveys of feeders will take priority over routine surveys.

5.6.2 Components to survey

Only joints, terminations, and the associated current-carrying moving parts shall be surveyed. It will not normally be necessary to scan straight conductors without joints, terminations and the like, however, the connections to associated equipment should be surveyed (for example, drop out fuses into a substation).

5.6.3 Survey Method

5.6.3.1 Measurements

Step 1 Measure the temperature of the Hot Spot, $T_H$ deg. C.

Step 2 Measure the temperature of the reference location, $T_R$ deg C.

Step 3 Calculate the temperature rise of the hot spot $T_H$ above the reference phase $T_R$, $T_{RR}$ deg. C ($T_{RR} = T_H - T_R$).

5.6.3.2 Priority classification of defects

Any abnormalities or defects shall be classified in accordance with the following table.

<table>
<thead>
<tr>
<th>Temperature rise above reference ($T_{RR}$)</th>
<th>Required Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>No action required</td>
</tr>
<tr>
<td>10 - 35</td>
<td>Report only (watch)</td>
</tr>
<tr>
<td>35 - 50</td>
<td>Repair within 3 months</td>
</tr>
<tr>
<td>50 - 65</td>
<td>Repair within 1 month</td>
</tr>
<tr>
<td>&gt; 65</td>
<td>Repair within 48 hours</td>
</tr>
</tbody>
</table>
Note: The priority of an identified fault shall be increased (where applicable) if the feeder load is less than 100 amps. Similarly, the priority may be increased if the operator identifies the defect as being at a strategic location of the feeder.

5.6.3.3 Recording details

The reference, hot spot and ambient temperatures shall be recorded on the Thermovision Scan Test Report - Distribution Mains (Division Form FNV 1073) in accordance with GNV 1092.1 - Non Invasive Network Asset Condition Assessment Testing – Infrared (Thermovision) Surveys. The defects shall be priority classified as set out in clause 5.5.6.

5.6.3.4 Low voltage defects

In the process of performing an thermovision survey of 11/22kV OH feeders, if an obvious low voltage defect is found that is considered dangerous to people or property, it shall be reported to the System Controller or Regional Distribution Manager in accordance with the appropriate priority rating.

5.6.4 Monthly summary of defects

A tabulated summary of defects shall be forwarded to the Regional Distribution Managers at the end of each month.

5.7 Entering data into the Asset Management database (Ellipse)

Any thermovision defects detected shall be entered into Ellipse within two (2) weeks of the completion of the survey of the line. All lines thermally scanned shall be registered in Ellipse irrespective of any faults being detected.

Defects shall be entered against the asset. If there is no switch, fuse, and the like, then it should go against the nearest power pole asset.

The System Controller shall be notified as soon as possible of any defect that needs immediate action.

If, in the process of performing thermovision surveys, it becomes apparent that other adjacent equipment may have suffered damage due to heat, or other damaged or faulty equipment is observed, this shall be entered as a defect in the Ellipse database in an appropriate manner.

6.0 AUTHORITIES AND RESPONSIBILITIES

The Chief Engineer has the authority and responsibility for approving this instruction.

The Manager Primary Systems has the delegated authority and responsibility for approving this instruction.

The Network Maintenance Manager, Primary Systems has the authority and responsibility for keeping the content of this instruction up to date.

The Power Quality & Reliability Planning Manager has the authority and responsibility for requesting ad-hoc thermovision surveys of poor performing feeders.

The Regional Transmission Managers have the authority and responsibility for:

- confirming that the requirements of this instruction are met when carrying out thermovision surveys on distribution and transmission lines;
- confirming that Endeavour Energy employees and/or contractors engaged to perform the work have appropriate qualifications and are competent to carry out the work;
- providing appropriate equipment and training;
- verifying that data is entered into the Endeavour Energy Asset Management database; and,
verifying that data is analysed and necessary follow-up action is undertaken to rectify the defects identified.

The **Regional Distribution Managers** have the authority and responsibility for:

- verifying that data is entered into the Endeavour Energy Asset Management database; and,
- verifying that data is analysed and necessary follow-up action is undertaken to rectify the defects identified.

All **Endeavour Energy employees and/or contractors** have the authority and responsibility for:

- meeting the requirements of this instruction when carrying out thermovision surveys on distribution and transmission lines;
- working in accordance with local and statutory requirements;
- upholding a high level of public safety;
- working in accordance with Endeavour Energy’s Electrical Safety Rules;
- updating Endeavour Energy’s Ellipse database; and,
- communicating abnormalities found in the distribution and transmission lines to the relevant Regional Distribution Manager or Regional Transmission Manager.

### 7.0 DOCUMENT CONTROL

**Documentation content coordinator:** Network Maintenance Manager  
**Documentation process coordinator:** Standards Process Coordinator