Instruction guide
Medium Voltage equipment on sites exposed to high humidity and/or heavy pollution

Recommendations for installation and use
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Introduction

Use of MV equipment

MV switchboards fulfill safety functions and must therefore be installed in line with certain profession practices.

The purpose of this document is to provide general guidelines on how to avoid or greatly reduce MV equipment degradation on sites exposed to high humidity and heavy pollution.

Normal service conditions for indoor MV equipment

MV equipment consists of modular MV cubicles or compact Ring Main units generally installed in prefabricated substations along with transformers and LV switchgear.

All MV equipments comply with specific standards and with the IEC 60694 «Common specifications for high-voltage switchgear and controlgear». The latter defines the normal conditions for the installation and use of such equipment.

For instance, regarding humidity, the standard mentions:

e) The conditions of humidity are as follows:
   - the average value of the relative humidity, measured over a period of 24 h does not exceed 90 %;
   - the average value of the water vapour pressure, over a period of 24 h does not exceed 2.2 kPa;
   - the average value of the relative humidity, over a period one month does not exceed 90 %;
   - the average value of water vapour pressure, over a period one month does not exceed 1.8 kPa;

For these conditions, condensation may occasionally occur.

NOTE 1 Condensation can be expected where sudden temperature changes occur in period of high humidity.

NOTE 2 To withstand the effects of high humidity and condensation, such as a breakdown of insulation or corrosion of metallic parts, switchgear designed for such conditions and tested accordingly should be used.

NOTE 3 Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by use of dehumidifying equipment.

As indicated in the standard, condensation may occasionally occur even under normal conditions. The standard goes on to indicate special measures concerning the substation premises that can be implemented to prevent condensation (Note 3).

Use under severe conditions

Under certain severe conditions concerning humidity and pollution, largely beyond the normal conditions of use mentioned above, correctly designed electrical equipment can be subject to damage by rapid corrosion of metal parts and surface degradation of insulating parts.
Introduction

Guidelines

Remedial measures for condensation problems

Carefully design or adapt substation ventilation

- Keep substation ventilation to the minimum required for evacuation of transformer heat to reduce temperature variations.
- Use natural ventilation rather than forced ventilation whenever possible.
- If forced ventilation is required, run fans continuously.
- Locate the substation ventilation openings as far as possible from the MV cubicle.
- Never add ventilation openings to MV cubicles.

Avoid temperature variations

- Install anti-condensation heaters inside MV cubicles and let them run continuously, i.e. without automatic or manual control.
- Improve the thermal insulation of the substation.
- Avoid substation heating if possible.
- If heating is required, make sure the temperature regulation system avoids large temperature swings or leave heating on continuously.
- Eliminate cold air drafts from cable trenches, under doors, etc.

Eliminate sources of humidity in the substation environment

- Avoid excessive plant growth around the substation.
- Repair any leaks in the substation roof.
- Prevent humidity from cable trenches from entering MV cubicles.

Install an air conditioning system

- Air conditioning is the surest way of controlling humidity and temperature.
- Always use a reputed supplier.
- Clearly define your needs.

Make sure cabling is in accordance with applicable rules

- Pay special attention to the positioning of earthing screens, stress control screens and semiconductor screens).
- Use cold-shrink cable terminations is possible, but make sure they are properly installed.

Remedial measures for pollution problems

- Equip substation ventilation openings with chevron-type baffles to reduce entry of dust and pollution.
- Keep substation ventilation to the minimum required for evacuation of transformer heat to reduce entry of pollution and dust.
- Use MV cubicles with a sufficiently high degree of protection (IP).
- Use air conditioning systems with filters to restrict entry of pollution and dust.
- Regularly clean all traces of pollution from metal and insulating parts.
Sources of degradation

Condensation

How condensation occurs

Condensation is the transformation of a gas or vapour into a liquid. It takes place in air when the air becomes saturated with water vapour and results in the formation of liquid water.

Two processes can lead to the saturation of air with water vapour and subsequent condensation:

- An increase in humidity at constant temperature
- A drop in temperature at constant humidity

The relationship between temperature, humidity and condensation is described by the «dew point» curve. The dew point is the temperature to which a parcel of air at a given level of humidity and a given barometric pressure must be cooled to condense into water.
Sources of degradation

Condensation (cont’d)

Sources of humidity
The humidity causing condensation in MV cubicles can come from four different sources:

- The atmosphere

- Water leaks in the building or substation

- The presence of water in cable trenches

- The presence of excessive plant growth around the substation
Sources of degradation

Condensation (cont’d)

Sources of temperature variation
Temperature variation causing condensation in MV cubicles may result from:

- Excessive or discontinuous ventilation

- Insufficient thermal insulation of the substation

- Substation heating control systems

- Cold air drafts from cable trenches or other openings (under doors, etc.)
Sources of degradation

Pollution

General
Certain regions or sites are exposed to heavy pollution.

Related problems
If no precautions are taken, pollution will be deposited on:

- Insulating components, leading to degradation by corona and tracking
- Metal parts, leading to corrosion.
Detection of degradation  
Site inspection and diagnosis

The presence of the following phenomena can be used to detect MV equipment degradation problems related to condensation and pollution.

**Inside the substation**
- Condensation
- Accumulation of dust or contamination from pollution
- Buzzing sound (corona)
- Ozone smell.

**Inside the cubicle**
- Condensation
- Accumulation of dust or contamination from pollution
- Corrosion of metal components (e.g. voltage divider, cable lugs, connection terminals)
- Visible discharges around the cable terminations (switchgear insulation, capacitive dividers, cable ends).
- Chalking (white tracks) on the insulation (switchgear insulation, capacitive dividers, cable ends).
- Erosion and treeing (black tracks) on the insulation.

If in doubt, contact your Schneider Electric correspondent.

**Conclusions**
When site inspection reveals problems related to condensation and pollution, remedial measures can be implemented to avoid degradation of MV equipment.

Remedial measures may concern:
- Ventilation
- Temperature
- Substation environment and humidity
- Pollution protection and cleaning
- Air conditioning
- Cabling
Remedial measures

Ventilation

General

Substation ventilation is generally required to dissipate the heat produced by transformers and to allow drying after particularly wet or humid periods.

However, a number of studies have shown that excessive ventilation can drastically increase condensation.

For instance, the following graph shows the risk of condensation in an MV substation cooled by natural ventilation with the ventilation openings opened and with the ventilation openings blocked to 40% and 20% of their initial area.

![Graph showing risk of condensation](image)

Note that if, for instance, the heat to be evacuated from the substation is less than A, the red and blue curves reflect greatly overdesigned ventilation, corresponding to a far higher risk of condensation in the substation.

**Ventilation should therefore be kept to the minimum level required.**

Furthermore, ventilation should never generate sudden temperature variations that can cause the dew point to be reached.

For this reason:

- **Natural ventilation should be used whenever possible.** If forced ventilation is necessary, the fans should operate continuously to avoid temperature fluctuations.

- Note that excessive ventilation will also increase the ingress of dust and pollution.

- **Guidelines for sizing the air entry and exit openings of substations are presented hereafter.**
Sizing the ventilation openings

Calculation methods

A number of calculation methods are available to estimate the required size of substation ventilation openings, either for the design of new substations or the adaptation of existing substations for which condensation problems have occurred.

Basic method

This method is based on transformer dissipation.

The required ventilation opening surface areas S and S' can be estimated using the following formulas:

\[
S = \frac{18 \times 10^{-4} \cdot P}{\sqrt{H}} \quad \text{and} \quad S' = 1.10 \times S
\]

where:

- S = Lower (air entry) ventilation opening area [m²] (grid surface deducted)
- S' = Upper (air exit) ventilation opening area [m²] (grid surface deducted)
- P = Total dissipated power [W]
- P is the sum of the power dissipated by:
  - the transformer (dissipation at no load and due to load)
  - the LV switchgear
  - the MV switchgear
- H = Height between ventilation opening mid-points [m]

Note:

This formula is valid for a yearly average temperature of 20 °C and a maximum altitude of 1000 m.

Example:

Transformer dissipation = 7 970 W
LV switchgear dissipation = 750 W
MV switchgear dissipation = 300 W
The height between ventilation opening mid-points is 1.5 m.

Calculation:

Dissipated Power \( P = 7970 + 750 + 300 = 9020 \) W

\[
S = \frac{18 \times 10^{-4} \cdot 9020}{\sqrt{1.5}} = 1.32 \text{ m}^2 \quad \text{and} \quad S' = 1.1 \times 1.32 = 1.46 \text{ m}^2
\]
### Remediaw measures

### Ventilation (cont’d)

#### Sizing the ventilation openings (cont’d)

- **More complete method**

  Another possibility is the following formula based on various aspects of substation design:

  $$ S = \frac{(P - 2.4 \Sigma (K_i S_i) T)}{417 G^* \sqrt{H} T^{1.5}} $$

  and

  $$ S' = 1.10 S $$

  where:

  - $S$ = Lower (air entry) ventilation opening area [m²]
  - $S'$ = Upper (air exit) ventilation opening area [m²]
  - $P$ = Total dissipated power [W]
  - $P$ is the sum of the power dissipated by:
    - the transformer (dissipation at no load and due to load)
    - the LV switchgear
    - the MV switchgear
  - $S_i$ = Area of enclosure surface $i$ [m²]
  - $K_i$ = Transmission coefficient of surface $i$ [W/m²K]
  - $G$ = Grid coefficient
    - $G = 0.28$ to $0.77$ for chevron blade louvers ($0.38$ for $90^\circ$ simple chevrons)
    - $G < 0.2$ for more complex types such as overlapped C beams
    - $G$ around $0.6$ for punched sheet with rectangular holes
  - $T$ = Class of enclosure (transformer temperature rise) [K]
  - $K = 0$ for the ground (no heat transmission through the ground)
    - $K = 3$ for $10$ cm and $2.5$ for $20$ cm of concrete
    - $K = 7$ for steel sheets
  - $H$ = Height between ventilation opening mid-points [m]

  **Note:**

  This gives smaller ventilation opening areas than the previous method because it takes dissipation through the walls, roof and doors into account.

- **Example:**

  Transformer dissipation = 7 970 W  
  LV switchgear dissipation = 750 W  
  MV switchgear dissipation = 300 W

  The substation area is made up of:

  - $14.6$ m² of concrete walls (10 cm thick)
  - $7.0$ m² of concrete roof (10 cm thick)
  - $6.2$ m² of metallic doors

  The enclosure class is $10$ K

  The ventilation grid is of the chevron louver type ($G = 0.4$).

  The height between ventilation opening mid-points is $1.5$ m.

  **Calculation:**

  $$ P = 7970 + 750 + 300 = 9020 \text{ W} $$

  $$ \Sigma (K_i S_i) = 14.6 \times 3 + 7.0 \times 3 + 6.2 \times 7 = 108.2 \text{ W/K} $$

  $$ S = \frac{(9020 - 2.4 \times 108.2 \times 10)}{417 \times 0.4 \times \sqrt{1.5} \times 10^{1.5}} = 0.99 \text{ m² and } S' = 1.10 \times 0.99 = 1.09 \text{ m²} $$
Remedial measures  Ventilation (cont’d)

Sizing the ventilation openings (cont’d)

Testing

The above methods can be used to estimate the required size of substation ventilation openings, however the best results are obtained by testing.

☐ For new substations, tests should be carried out by the substation supplier to ensure that the provided ventilation system is not oversized.

☐ For existing substations presenting condensation, tests can be carried out to determine whether ventilation opening areas can be reduced without exceeding the maximum temperature rise limits of the transformer under the worst possible conditions.

Ventilation opening locations

To favour evacuation of the heat produced by the transformer via natural convection, ventilation openings should be located at the top and bottom of the wall near the transformer.

The heat dissipated by the MV switchboard is negligible.

To avoid condensation problems, the substation ventilation openings should be located as far as possible from the switchboard.

«Over» ventilated MV/LV Substation
The MV cubicle is subjected to sudden temperature variations.

Substation with adapted ventilation
The MV cubicle is no longer subjected to sudden temperature variations.
**Remedial measures**

**Ventilation (cont’d)**

**Ventilation opening locations** (cont’d)
If the MV switchboard is separated from the transformer, the room containing the switchboard requires only minimal ventilation to allow drying of any humidity that may enter the room.

**Type of ventilation openings**
To reduce the entry of dust, pollution, mist, etc., the substation ventilation openings should be equipped with chevron-blade baffles. Always make sure the baffles are oriented in the right direction.

**MV cubicle ventilation**
Any need for natural ventilation is taken into account by the manufacturer in the design of MV cubicles. Ventilation openings should never be added to the original design.
Remedial measures

Temperature

General
As already mentioned, temperature variations lead to condensation under high humidity conditions.

Temperature variations inside cubicles
To reduce temperature variations, always install anti-condensation heaters inside MV cubicles if the average relative humidity can remain high over a long period of time.

The heaters must operate continuously, 24 hours a day all year long.

Never connect them to a temperature control or regulation system as this could lead to temperature variations and condensation as well as a shorter service life for the heating elements.

Make sure the heaters offer an adequate service life (standard versions are generally sufficient).

Temperature variations inside the substation
The following measures can be taken to reduce temperature variations inside the substation:

- Implement the measures described in the previous section concerning ventilation.
- Improve the thermal insulation of the substation to reduce the effects of outdoor temperature variations on the temperature inside the substation.
- Avoid substation heating if possible. If heating is required, make sure the regulation system and/or thermostat are sufficiently accurate and designed to avoid excessive temperature swings (e.g. no greater than 1 °C).

If a sufficiently accurate temperature regulation system is not available, leave the heating on continuously, 24 hours a day all year long.

- Eliminate cold air drafts from cable trenches under cubicles or from openings in the substation (under doors, roof joints, etc.).
Remedial measures

Substation environment and humidity

General
Various factors outside the substation can affect the humidity inside.

Plants
Avoid excessive plant growth around the substation.

Substation waterproofing
The substation roof must not leak. Avoid flat roofs for which waterproofing is difficult to implement and maintain.

Humidity from cable trenches
Make sure cable trenches are dry under all conditions. A partial solution is to add sand to the bottom of the cable trench.

Studies have shown that this reduces corrosion inside the cubicle, however if internal arc protection is required, this solution requires careful investigation as to how it is implemented.
Remedial measures

Pollution protection and cleaning

General
Excessive pollution favours leakage current, tracking and flashover on insulators. To prevent MV equipment degradation by pollution, it is possible to either protect the equipment against pollution or regularly clean the resulting contamination.

Protection
Indoor MV switchgear can be protected by enclosures providing a sufficiently high degree of protection (IP)

Cleaning
If not fully protected, MV equipment must be cleaned regularly to prevent degradation by contamination from pollution.

Cleaning is a critical process. The use of unsuitable products can irreversibly damage the equipment.

For cleaning procedures, please contact your Schneider Electric correspondent.
Remedial measures

Air conditioning

General
Air conditioning is the ideal way to control temperature and humidity in a substation.
A number of efficient systems are now available on the market.

Some are equipped with filters to reduce the entry of pollution and dust.

Recommendations
If you are considering this type of system:

- Contact a reputed air conditioning manufacturer or specialist.

- Define your need clearly:
  - the combination of temperature and humidity must remain above the dew point curve to avoid condensation
  - temperature range (-5 °C to 40 °C)
  - filter to reduce pollution and dust entry
  - expected service life
Remedial measures

Cabling

General
The MV equipment must be cabled in accordance with applicable rules and regulations. Some cabling rules are described in the installation manuals.

Incorrect cabling can cause partial discharges that produce ozone.

Ozone is an aggressive gas that attacks the chemical bonds of insulation materials, especially in the presence of condensation or pollution.

Recommendations

- Pay special attention to the positioning of earthing screens, stress control screens and semiconductor screens.

- Cable terminations:
  - As cable terminations differ from one range to another, consult the respective catalogue for the most suitable solution.