Electrical cabinet thermal balance for outdoor applications

This white paper focuses on the calculation of heating and cooling power for outdoor applications.

The formulas to calculate the heating power (Qheat) and cooling power (Qcool) are the following:

- Heating: Qdiss,heat+Qcool=0 [W] ①
- Cooling: Qdiss,cool+QJoule+Qsolar+Qcool=0 [W] ②

As for the adduction coefficient values α_i (cabinet interior wall) and α_e (cabinet exterior wall), refer to the previous white paper "Adduction coefficient calculation" (http://blogfandis.it/wp-content/uploads/2018/03/WhitePaper_Fandis_eng_Coefficient-Calculation.pdf), which makes the following distinction:

1. Outdoor without wind
2. Outdoor with weak wind
3. Outdoor with strong wind

From the α_i and α_e values, we can calculate the walls' thermal transmittance U (with design temperatures in case of heating and cooling) and the power dissipated through the walls Qdiss, heat and Qdiss, cool (in case of heating and cooling).

The heat provided due to the Joule effect (QJoule) is obtained by applying the IEC EN 61439 regulation.

Thermal power due to solar radiation

In outdoor environments, the solar heat input (Qsolar) must also be considered. An electrical cabinet can be installed in areas exposed to the sun, even for just a few hours a day. The heat input resulting from solar radiation cannot be disregarded, as it may be a cause of the increase in temperature.

If we divide sunlight into three components when it strikes a wall, the following equation applies:

$\alpha+\rho+\tau=1$

where:

- α=absorbance, the percentage of light absorbed by the wall;

- ρ=reflectance, the percentage of light reflected off the wall;

- τ=transmittance, percentage of light transmitted through the wall.

Generally, electrical cabinet walls do not have transparent windows. Therefore, it is impossible for direct sunlight to enter the cabinet.

The walls can be considered opaque surfaces, for which transmittance τ is equal to zero (τ=0). In this case, the following simplified equation applies: $\alpha+\rho=1$.

When calculating the solar contribution, we need to know the share of light absorbed by the cabinet's wall, which results from the following equation: $\alpha=1-\rho$ ③

Below, we provide reflectance values based on the colour of the electrical cabinet (data easy to find):

A. White: $\rho_A = 0,81$;

B. Grey: $\rho_B = 0,51$;

C. Grigio: $\rho_C = 0,31$;

D. Black: $\rho_D = 0,04$;

E. Green: $\rho_E = 0,18$;

F. Glazed surface: $\rho_F = 0,7$.

By replacing the ρ values in the equation ③, the calculation of the absorbance factors α is immediate.

The UNI 10349 regulation refers to solar radiation and is used especially for photovoltaic projects. However, in some cases, it can be used to calculate the heat input resulting from the sun. This regulation refers to Italy's latitudes. Therefore, it can be used only in countries between latitude 38°N and 46°N and indicates solar powers in W/m2 divided by each cardinal direction, along the vertical and horizontal plane. To clarify this concept, refer to the tables included in the UNI 10349 regulation.

The heat input of the sun must be integrated in the thermal balance to calculate the cooling power required by the electrical cabinet. It is often difficult to know the position of the cabinet compared to the four cardinal points beforehand. Moreover, the absorbed power also depends on the shape of the cabinet, meaning whether it is developed vertically or horizontally.

In the vast majority of cases, cabinets are more likely to develop vertically. In this case, to make calculations, the following cardinal direction must be considered: SOUTH + NORTH + EAST + WEST + HORIZONTAL (12.00 pm is the time of maximum solar input. The data for this time and for the above cardinal direction must be taken from the tables included in the UNI 10349 regulation).

On the other hand, if the electrical cabinet is developed horizontally (meaning in width more than in depth) so that some surfaces can be disregarded, we can distinguish the following cases:

1. larger surfaces are oriented to the SOUTH and NORTH (as a result, those oriented to the EAST and WEST can be disregarded). Therefore, the maximum power input is at 12 pm;
2. larger surfaces are oriented to the EAST and WEST (as a result, those oriented to the NORTH and SOUTH can be disregarded). Therefore, the maximum power input is at 9.00 am and 3 pm.

From the tables included in UNI 10349, from 9 am to 3 pm for the EASTERN and WESTERN sides, the surface thermal input is greater than the one we could have if the cabinet was oriented to the SOUTH and NORTH at 12 pm. Therefore, the EAST and WEST placement must be considered (data extracted from the UNI 10349 regulation tables for 9 am and 3 pm).

From the above situations, meaning the one where the cabinet develops vertically and cases 1) and 2) where the cabinet develops horizontally, it is possible to identify the worst case and extend a more general method to set the calculations. For each project, always consider a SOUTH+NORTH+WEST+HORIZONTAL placement and take the 9 am data for the same position from the tables included in the UNI 10349 regulation.

Once you know the specific power on the area in the worst case, meaning at 9 am with a SOUTH + NORTH + EAST + WEST + HORIZONTAL placement, the latitudes "l" can be divided into intervals with a width of 2°:

- 38°<=l<40°;
- 40°<=l<42°;
- 42°<=l<44°;
- 44°<=l<46°;
- 46°<=l<48°.

For each latitude interval, the values of SOUTH, NORTH, EAST, WEST, HORIZONTAL columns related to 9 am are extracted from the tables included in the UNI 10349 regulation. The single data must be multiplied by the absorbance α, so as to calculate the specific absorbed radiation on each surface: Psp[W/m2]=Irri* α. Then we proceed with the calculation of the sol-air temperatures T_{SA}[°C], i.e fictitious temperatures to be considered for the electrical cabinet external and internal heat exchange, for each exposed surface:

$T_{SA,i}$=Texternal+(Psp,i/ αe) ④

* αe indicates the external adduction exchange coefficient (see the "Adduction coefficient calculation" white paper);

Then, we calculate the heat exchange of all the surfaces:

Qsolar[W]=ΣQsolars= U*($T_{SA,i}$-Tinternal)*Ai

* U is the thermal transmittance of the electrical cabinet's walls and Ai are the thermal exchange areas.

Once the sun's heat input is found, all the variables for calculating the heating and cooling powers required to maintain the desired temperatures inside the electrical cabinet at the design conditions are known:

- Thermal power balance for heating: Qdiss +Qheat=0 ①
- Thermal power balance for cooling: Qdiss+QJoule+Qsolar+Qcool=0 ②

From which we can obtain Qheat and Qcool, expressed in [W] and matching the theoretical thermal powers to be installed on the electrical cabinet to ensure the desired conditions.

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