CONSTRUCTION OF WATERPROOF UNDERGROUND SUBSTATIONS M.V. / L.V.

Ernesto VIDAL
Edenor S.A. - Argentina
evidal@edenor.com

Miguel PULICE
Edenor S.A. - Argentina
mpulice@edenor.com

ABSTRACT
Due to an increase of rainfall caused by climate change, the City of Buenos Aires had been suffering from intense flooding. This directly effects underground substations, and causes problems in mid and low voltage installations, which affects end customers. For this reason, EDENOR S.A. (Empresa Distribuidora y Comercializadora Norte SA) had to launch a campaign to find a practical yet economical way to make the underground vaults waterproof in order to prevent problems in the future. The campaign resulted in the replacement of the vault grilled-ventilations at sidewalk level for others with high columns (chimney) and minimum environmental impact, as well as the replacement of conventional manhole covers, and transformer entry covers for waterproof ones. Its success improved the quality of service, costs of operation, and reduced outages resulting in a better Company’s image.

INTRODUCTION
In many cases during heavy rain (more than 70 mm/hr), the water coming in through the grilled-ventilations placed at sidewalk level, and some more water coming in through the manholes and transformer entry, flooded the underground substations. In order to make them waterproof, many different alternatives were analyzed. Because of its low cost, free maintenance, and minimal environmental impact, the solution adopted was to deploy column-style natural ventilations on the sidewalk, and to replace the traditional manhole covers and transformer entry covers for waterproof ones.

PROPOSED ALTERNATIVES:
1) Ventilations with sidewalls and elevated grills on sidewalks.
2) Forced/natural ventilations with hydraulic closings.
3) Submergible electrical equipment.
4) Natural ventilation with raised columns on the sidewalk.

ADOPTED SYSTEM:
NATURAL VENTILATION WITH RAISED COLUMNS ON THE SIDEWALK

Advantages:
- It keeps the existing equipment in place making it a relatively inexpensive solution
- It ensures in most cases the right natural ventilation, even when facing different atmospheric and service conditions.
- The manhole covers require minimum maintenance, and the chimneys reduce the frequency of cleaning.

Plan of work and execution
For the implementation of the plan, the following considerations were taken into account:
- Areas prone to flood
- Location of the underground substations
- Underground substations that were flooded at least once.
- Structural characteristics of the underground substations (dimensions, air flow, etc).

This system was already applied to 294 substations so far.

The scheme of substations with grids at the sidewalk level can be seen in figure n°1
A preliminary plan for each transformation center was developed, which established the minimum structural changes that needed to be done in order to make them waterproof:

- Place the air duct not higher than 0.3m above the chamber’s ground level to ensure a convective flow.
- Structural modification of the vault for the air ducts taking into consideration the location of the ventilation grill, and defining the new position of the ventilation columns to avoid garage entrances, fronts of business stores, sidewalk corners, etc.
- Demolition of internal walls that may obstruct the airflow through the entrance ventilation, the transformer and the exit ventilation.
**Constructive Characteristics**

The tasks were performed by adjusting ventilations (ducts) and covers as described below, taking on average about 5 days, and without the need of cutting power.

**Ducts**

The section of the duct is 0.6 m x 0.4 m which in most cases provided the necessary ventilation without the need of fans. The material used is a fiberglass PRFV reinforced plastic, which meets the following requirements:

- Waterproof
- Reduced thermal conductivity
- Self-extinguishable
- Dielectric
- Shock resistant
- Low environmental degradation (UV radiation resistance)
- Resistant to contact with concrete
- It allows the modular coupling

Once inside the substation, the duct was installed by connecting the PRFV panels together, gluing them with a silicon sealer, and then clamping it to the walls or ceilings.

On the outside of the chamber the ducts were wrapped with a small concrete structure at ground level, which served as a mechanical protection as well as a second layer of water insulation.

The ducts had to be connected to the substation as close as possible to the sidewalk level in order to reduce the influence of hydraulic pressure due to ground water raise or leaks in sidewalk water installations.

As last, these external ventilations were painted according to government regulations.

**Manhole/Transformer covers**

They’re made of steel sheet and its thickness is:

- a. In the sidewalk 3.2 mm
- b. In the road 7.9 mm

The cover has a non-slippery surface, and it was placed fixing a weather strip on the bottom all along its perimeter. For personnel entrance a hatchway with a rubber weather strip was placed on the cover. Its perfect leveling was accomplished by a spring suspended system, which allows a correct settling of the hatchway on the cover.

The cover was treated to improve its water resistance, and then it was placed on a cast iron frame (existing), which guarantees the system’s impermeableness.

The fit between the frame and cover was made from inside the enclosure with turnbuckles ensuring the waterproofness.

**Thermal Considerations**

From a thermodynamic point of view, the area (from now on defined as System) behaves according to:

1) In permanent regime as an open circulating system where the amount of air that enters the system is the same than the one that comes out, ensuring this way a mass flow.

2) In the transitory as an open system in a non-permanent regime - when the amount of mass that comes out is not the same as the one that comes in or vice versa. That means that the amount of mass that forms the system varies during the transitory regime. Even if the mass amount doesn’t vary, its condition varies.

If we consider the system in a transitory regime, it will behave as an open system in a non-permanent regime. That means that at the moment where it is out of balance (situation where it starts to vary the amount of heat exchanged between the system and the environment, whether it is due to a variation in the transformer’s charge, or due to the environmental conditions, for example temperature/ pressure/ humidity, etc.), it will behave according to the first principle of thermodynamic for open systems in a non-permanent regime. Therefore appealing to the balance of energy we could say:

“In an open system in a non-permanent regime, the energy that is added by the mass that is incorporated into the system, plus the net heat added to it, is equal to the energy that is taken by the mass that exits the system, the net work done by the system, and the variation of its total energy.”

On the other hand, once the permanent regime is reached reached the system will behave as an open circulating system.

Taking into consideration that in most of the technical applications, the variation of potential energy of the fluid may be dismissed (since for representing a kilocalorie a height difference of 427 m would be necessary), as well as the variation of kinetic energy, resulting in the following expression:

$$Q - Lc = m (h_2 - h_1)$$
Q = Amount of Heat
Le = Work
m = mass of air
h2 = air enthalpy at the exit of the system
h1 = air enthalpy at the entrance of the system

If we consider for the waterproof substation, that the variables of the first term are maintained practically constant, and if we suppose that the air mass decreases as a consequence of the impermeabilization, it results that the term (h2 – h1) “Enthalpy differences” Δh is increased, which implies an increase in the air temperature at the exit of the system.

The vault’s aptitude for supplying the required ventilation in a natural way (not forced) is determined by the following parameters:

a) Transformer’s power
b) Electromechanical equipment associated to the substation
c) Charge’s condition
d) Structural characteristics of the vault
e) Room temperature

The general equation for the air flow of the area will be:

\[ F = \frac{P_v}{\rho \cdot C_p \cdot \Delta \theta} \]  \hspace{1cm} (2)

Where:

F= Ventilation Air flow
Pv= Power of losses
\rho = Air density (constant)
Cp= Specific heat of the air (constant)
\Delta \theta = Difference of air temperature between exit and entrance.

Considering the constants, the equation could be expressed as:

\[ F = K_0 \cdot \frac{P_v}{\Delta \theta} \]  \hspace{1cm} (3)

\[ K_0 = \frac{1}{\rho \cdot C_p} \]  \hspace{1cm} (4)

K0= 2774 m3.K/kWh

For our analysis we will dismiss from the constant the altitude correction factor, and we will only consider the correction factor by temperature, supposing the air is an ideal gas.

If we take a pretty unfavorable condition such as for example a room temperature of 35 °C it results that the constant K0 will be affected by this condition according to:

\[ K_{t35} = \frac{T}{T_0} = \frac{308}{273} = 1.128 \]  \hspace{1cm} (5)

**Thermal tests**

The experimental verification required for measurements to be taken. To do so, the following instrumentation was used:

- Temperature sensors
- Current transducer 0/800 A

For the measurement, the sensors were placed in the following way:

1) One temperature sensor 2 meters high, facing the low voltage panel (vault’s temperature).
2) One temperature sensor at the extreme top of the transformer radiator (radiator temperature).
3) A current transducer placed on the phase T of the transformer that was being measured.
Figure N° 3

From figure 3 we see that:

a) The maximum temperature that the transformer reached was 30°C, which is far from its critical temperature.

b) The temperature in the vault does not follow the one of the transformer in a linear way. It does it with certain inertia.

c) The difference between the temperature in the vault and the transformer temperature was less than 10°C.

CONCLUSIONS

1) The adopted solution maintains the existing electromechanical equipment, which ensures in most cases, the right natural ventilation, even when facing different atmospheric and service condition.

2) It has allowed the continuity of power distribution when facing adverse weather conditions, which improved the quality of service, and the Company’s image.

3) Operational and maintenance expenses were reduced.

REFERENCES

