Lightning Protection for a Complex Isolated Renewable and Diesel Power Network – Micro Grid

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Abstract: In this paper a specific Lightning Protection System (LPS) design for an isolated complex renewable and diesel power network – micro grid will be described. This isolated power network was established in 1992 on the Holy Mount – Agion Oros – for the Simonopetra monastery in northern Hellas. It is composed of a 33kW Hydro generator, a 45kW Solar system, and 60kVA Diesel generator.

Due to the wide space area of the installation a specific external LPS needed to be designed. Additionally due to the sensitive electronics of the control and protection systems of the network, surge protection (Surge Protection Devices - SPDs), equipotential bonding and shielding were also of major importance.

The high altitude in addition to the high ground flash density made this system vulnerable to lightning flashes. Ten years now the isolated power network it is protected against lightning. The paper apart from the LPS design, which was used it also aims to evaluate the performance of the LPS that is now in use over this ten years period.

Keywords: Lightning protection system, surge protection devices – SPDs, Micro-Grid, photovoltaic system, hydro generator, diesel generator

1. Introduction

The seven-stored monastery of Simonas Petra or Simonopetra is the most audacious construction, which was build on Athos mountain (see Figure 1), on the south-western part of the peninsula of Agion Oros in north Hellas and is dedicated to the birth of Christ. The name comes from the founder of the monastery, Hosios Simonas, who lived in Athos in the mid 14th c. The monastery is inhabited by a brotherhood of 60 monks [1].

The Monastery stands at a height of 330 meters on a rocky mountain and the electricity supply comes from a local and isolated from the main grid, network which contains 936 photovoltaic cells able to deliver 45kW, one small hydro power station generating 33kW and a diesel generator of 60kVA in order to cover and support the renewable generators. The entire system was active from 1992 and during two years of operation many damages occurred to it due to lightning strokes. In 1994 it was decided to apply lightning protection to it and since then no further damage was reported.

2. Site survey

Due to the volume and the complexity of the power system it was not possible to have all the sources in a single location. Therefore each individual unit (PV, Hydro, Diesel) was installed in different locations from each other.
Figure 2: Schematic configuration of the site

Figure 2 shows a simplified sketch of the entire system. The photovoltaic cells were installed in an open field area on an incline hill. Two 150mm² cables deliver the generated energy from the photovoltaic cells to a control building near the monastery. The altitude of the hill where the photovoltaic cells are installed is 650m.

At the same altitude of the photovoltaic cells, a water reservoir was developed to collect rainwater, which is flowing through streams down the mountain and also water from local mountain springs. The reservoir is connected with a water tank and depending on the level of the water in the water tank the water is released and driven through a 1.3km water pipe gives the required rotation to the turbine of the hydro station. The altitude difference between water tank and the hydro station is 330m. The generated energy is then delivered to the same control building as the energy from the photovoltaic cells. The hydro and the control building are in a close distance.

Finally the diesel generator is installed close to the control building. In the same building are all the required equipment such as regulators, DC/AC converters, batteries and also all the control equipment for the operation of this isolated power system. Figure 3 shows a simplified electrical schematic of the entire system.

According to the national standard ELOT 1197 [2] the area has 50 thunderstorm days per year, which is a quite high figure.

3. External LPS – Protection against direct lightning

A risk analysis, prior to the LPS design was not possible to be performed since European and national standards did not exist at that period. Reviewing the installation now and by applying the current national risk analysis standards [3] the LPS should have been designed according to level III. The external LPS design was done according to the Hellenic standard ELOT 1197 [2] equivalent to IEC 61024 standard [4]. Reviewing the existing LPS design fulfill the requirements of level III, which should have been initially designed for. Each individual unit was considered separately.

Photovoltaic: As shown in figure 4 and 5 the air termination system for the photovoltaic panels is composed of nine, 10m tall masts with an inception rod on the top of each mast. All the masts were interconnected through the earthing system. The earthing system (figure 6) is a combined type B and A according to [2]. All the photovoltaic panels had a local earth and were also bonded to the main earthing system, which has a DC resistance of 1Ohm. The soil where the earthing system was installed has a low resistivity. The total area of the photovoltaic cells is about 416m² and the total installations surface is about 2.500m².

Hydro: The Hydro station was installed indoors and therefore the risk of a direct lightning on the turbine is very low. The size of the building did not cause high risk for a direct lightning stroke either but due to its importance it was decided to install a meshed air terminal with embedded lightning protection rods and two down conductors, which were connecting the air terminal with the earthing system. At each down conductor a type A earthing system was applied.

Diesel and Control building: Similar to the previous two the external LPS of the building that contains the diesel generator and the control room was designed according to [2] by applying the Faraday cage principle.
Figure 3: Schematic configuration of the electric layout in the site
Photovoltaic: Data and power surge protection devices (SPDs) were installed at both ends of all the cables, which were connecting each photovoltaic unit and a local regulator situated in a local PV control structure (see figure 7). All the equipment cabinets, cables ducts etc that were installed inside the local PV control structure were bonded with each other and to the earthing system.

Hydro: All metallic parts including the turbine, the generator, cable ducts etc were bonded directly to the earthing system. SPDs were installed in all the incoming and outgoing cables. The water pipe coming from the water tank was bonded to the earthing system through isolating spark gaps (ISG) to avoid interference with the cathodic protection.
Diesel and Control building: Inside the control building a horizontal equipotential ring conductor was installed in the perimeter of the building, which was connected to the earthing system. All the metallic equipment such as enclosures, cable screens & ducts etc were bonded on the equipotential horizontal ring conductor. All the control and power cables (incoming and outgoing) were bonded through SPDs to the equipotential ring as well. All the leads connecting the SPDs were kept at the minimum length and their installation position was as close as possible to the under protection equipment. More information about protection against lightning inside structures can be found in [5-7]. Regarding SPD selection and application further details can be found in [8-10].

5. Discussions & Conclusions

The development of a lightning protection system for a complex and isolated power system, which was based on renewable and diesel generators – micro grid, was presented. The elaboration of this design solved many problems that were caused due to lightning discharges and improved the reliability of the micro grid system operating conditions. Further development and improvement of the current and future designs is always an issue that should be considered.

Prior to the application of the previously described lightning protection system, the micro-grid suffered serious damage due to lightning discharges. The system is protected over ten years now and no further damage was reported. All the SPDs that were installed were based on varistor technology with discharge current capability varying between 4-40kA. None of them over the ten-year period did ever fail due to an excessive lightning current overstress.

This particular case may reinforce conclusions that were derived in other similar cases [11], where an LPS design, which was installed to protect specific equipment on a high altitude in a high ground flash density area, has provided efficient protection over a long period without having heavy duty SPDs installed.

Finally due to increase number of micro grid users [12] the need of a detailed lightning protection is necessary to avoid undesired damage to these installations. Considerations in both technical and financial fields need to be taken when designing the lightning protection system of a micro grid system, risk analysis as suggested by others [13] is a good practice of estimating the need of such an installation.

6. References

[7] IEC 61312-3, Protection against lightning electromagnetic impulse, Part 3: Requirements of surge protective devices (SPDs)
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[9] IEC 61643-12, Surge protective devices connected to low-voltage power distribution systems, Part 12: Selection and application principles
[10] IEC 60364-4-44, Electrical installations of buildings, Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances