ISSN 1392 – 1215 ELECTRONICS AND ELECTRICAL ENGINEERING 2011. No. 6(112)
ELEKTRONIKA IR ELEKTROTECHNIKA

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ELEKTROS INŽINERIJA

Lightning Protection for Buildings Energized by Renewable Energy Sources

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crossref http://dx.doi.org/10.5755/j01.eee.112.6.434

Introduction

Hybrid Renewable Energy Systems (HRESs) use renewable energy sources such as wind, hydrogen, solar etc. simultaneously. In recent years, increase in oil prices, running out fossil fuel reserves and their irreparable harmful effects and political instabilities in the regions of energy sources have been accelerated to make on studies on the renewable energy systems, especially in rural areas and developing countries where it is usually difficult to have access to the national electricity grid [1]. Recently, fuel cells using hydrogen as a fuel have been also used in the form of small modular systems [2]. In energy systems, protection must be taken into consideration against lightning strikes. It is highly possible that a strike may cause damages in expensive system components and/or human lives. Effective protection of objects and their contents against direct lightning strikes requires estimation of lightning threat [3]. Lightning protection theory was and is formed at the junction of sciences of high voltage equipment, geophysics and meteorology [4]. In typical high voltage substation are present electronic devices. They are very sensitive for any transient state especially for transients caused by lightning strike [5].

For smaller wind turbines, their realization is hardly possible although the smaller turbines are also strongly endangered to lightning strikes if they are located at high sites. For photovoltaic systems, protection against direct lightning strikes is not considered sufficiently and the protection is focused only on a strike in a far away distance leading to comparatively low-energy induced over-voltages. Those over-voltages are limited by weak surge protective devices like return-current diodes, bypass diodes or overstressed small varistors. Therefore electronic devices are destroyed in case of direct and nearby strikes. In addition, both direct and nearby strikes may lead to a weakening of the electrical strength of the PV module isolation causing a locally and extremely high heat development up to the melting of glass [6].

The damages and failures of lightning strike may also spread the surroundings of the structure and may even involve the local environment. The scale of this extension depends on the characteristics of the structure and the lightning flash [7].

In this study, design and installment procedures of the lightning protection system in the photovoltaic-wind-fuel cell hybrid energy system at the **C**lean **E**nergy **H**ouse (CEH) of Pamukkale University, in Denizli, Turkey are considered. A proper lightning protection installment process for hybrid renewable energy systems is examined and conducted for CEH.

Lightning current

If a load-independent active electric current flows through conductive components, the amplitude of the current, and the impedance of the conductive component the current flows through, help to regulate the potential drop across the component flown through by the current. In the simplest case, this relationship can be described using Ohm´s Law [8].

The steepness of lightning current $\Delta i/\Delta t$, which is effective during the interval Δt, determines the height of the electromagnetically induced voltages. The square wave voltage U induced in a conductor loop during the interval Δt is [8]

$$U = M^{*}\Delta i/\Delta t. \quad (1)$$

where M denotes mutual inductance of the loop and $\Delta i/\Delta t$ denotes steepness of lightning current [8].

The charge of the lightning current (Q) determines the energy deposited at the precise striking point, and at all points where the lightning current continues in the shape of an electric arc along an insulated path [8]

$$Q= \int idt. \quad (2)$$

The energy W deposited at the base of the electric arc is given by the product of the charge Q and the anode-/cathode voltage drop with values in the micrometer range $U_{A,K}$. The average value of $U_{A,K}$ is a few 10 V and depends on influences such as the height and shape of the current [8]

$$W= Q*U_{A,K} , \quad (3)$$

where Q denotes charge of lightning current and $U_{A,K}$ denotes anode/cathode voltage drop [8]. The specific energy W/R of an impulse current is the energy deposited by the impulse current in a resistance of 1 Ω. This energy deposition is the integral of the square of the impulse current over the time for the duration of the impulse current [8]

$$W / R= \int i^2 dt. \quad (4)$$

The specific energy is therefore often called the current square impulse. It is relevant for the temperature rise in conductors through which a lightning impulse current is flowing, as well as for the force exerted between conductors flown through by a lightning impulse current. For the energy W deposited in a conductor with resistance R we have [8]

$$W=R. \int i^2 dt=R*W / R, \quad (5)$$

where R denotes (temperature dependent) d.c. resistance of the conductor and W/R denotes specific energy [8].

Description of the hybrid renewable energy system

One of the integrated renewable - fuel cell energy systems combined solar and wind energies as primary energy sources was installed on the campus of Pamukkale University in Denizli, Turkey (Fig. 1) as a CEH center.

Fig. 1. Clean energy house

CEH is located at 37°46' North latitude, 29°05' East longitude. The aim is to design a unique integrated system for the house using solar and wind energies to procure all energy needs without using any fossil based energy sources and to provide an environmentally benign design and operation. For this purpose, a photovoltaic-fuel cell-wind energy system was designed and installed in 2007. Therefore, the hybrid energy system is composed of a 5 kWp photovoltaic panels, a 2.4 kWp fuel cell modules and 2x400 Wp wind turbines. For performance evaluation, one-half of the photovoltaic panels [9] are located on fixed tilt and the other half are mounted on solar trackers.

The fixed tilt (45^o south) photovoltaic modules are located on the roof of the building. Two solar trackers are used in accordance with the number of photovoltaic modules which are appropriate for Zomeworks UTRF-120 model [10]. Each tracker consists of ten modules with nominal power 1.25 kWp. A Proton Exchange Membrane (PEM) type electrolyzer [11] was used in the system. In this project, two PEM fuel cell modules [12] are used to produce electricity from stored hydrogen. The Nexa™ power module provides up to 1.2 kW of unregulated DC power at a nominal output voltage of 26 VDC.

Installation of a grounding system

After insufficiencies in the existing grounding system were determined, surroundings of the CEH building was dig to lay down the stainless steel conductors for grounding. At the six points around the CEH, a round grounding was installed. The round grounding around the building can be seen in In Fig. 2. In Fig. 3, digging work for the round grounding are given [13].

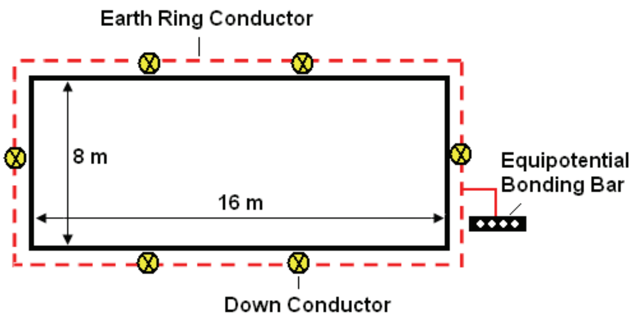

Fig. 2. The round grounding around the CEH

Fig. 3. Digging work for the round grounding

As seen in Fig. 2, there are an equipotential bonding bar and six down conductors on the building. Minimum number of down conductors (n) is calculated as [14]

$$n = l / 20. \quad (6)$$

The total length of the building (l) is 48 m. Then, n is calculated as 2.4. To enhance the lightning electricity flow, n was chosen as six.

A round grounding is the grounding method which was buried in 0.5 m depth with the formation of a closed round and 1 m away from the building base [19]. Dissemination resistance of the round grounding can be formulated as [15]

$$R_E = \frac{\rho_E}{\pi^2 D} ln \frac{2\pi D}{d}, \qquad (7)$$

where D denotes diameter of the round grounding (m), d denotes diameter of the grounding conductor (m), and ρ_E denotes specific resistance of the soil (Ωm). Grounding conductors were laid and conduction through the deepness of the ground was provided with the grounding rods from six different points.

Installation of a lightning protection system

For the lightning protection, connections from the grounding conductors to the air termination rods and equipotential bonding of the building were established, and then fixed grounding terminals were mounted to their ends. An output from the connection between the grounding conductor and the grounding rod buried in the soil was attached to a test clamp. In this way, six test points were created. The earth resistances could be measured via these test points. After the installation of the test clamps, air termination rods were placed on the roof of building.

After the installation of the conductors on the roof, the air termination rods were placed for protecting the building against lightning. This situation is seen in Fig. 4 [13]. In addition to the air termination system on the roof, a process of mounting the air termination rods protecting two passive solar trackers from lightning has been started (Fig. 5) [13]. The last installation point of the air termination rods was the wind turbine. It can be seen in Fig. 6 [13].

Fig. 4. CEH with air termination rods

The 3.2 m air termination rod for the wind turbine has a down conductor with the specification of HVI (High Voltage Insulation). This specification provides protection of the electronic cards inside the wind turbine from electromagnetic waves caused by lightning hits.

Fig. 5. Solar trackers with air termination rods.

Fig. 6. Wind turbine with HVI air termination rod

All conductors in the lightning protection system were contacted with the equipotential bonding that is outside of the building. For preventing the hybrid energy system from the surge coming from the national grid, a surge arrester was set up to the entrance of the line (Fig. 7). Electrical installation of CEH is 3-phase TT-system. In 3-phase TT-system, protection conductors of devices are separated from 3-phase energy source. Thus, a surge arrester was chosen for 3-phase TT-system.

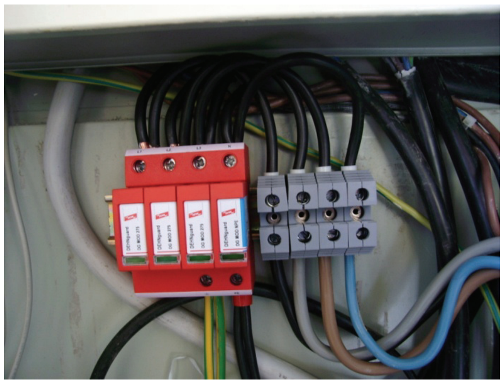

Fig. 7. 3-phase surge arrester

Conclusions

Thunderstorms are natural weather phenomena and there are no devices and methods capable of preventing lightning discharges. Direct and nearby lightning strikes can be hazardous to structures, humans, installations and other things in or on them. Therefore, application of the lightning protection system should be considered. RHESs may be exposed to lightning damages without well-arranged and reliable protection mechanisms. Nowadays, RHESs are expensive due to the current status of the technology. In order to keep the safety of human beings working in buildings and equipments in the systems, it is needed to have a lightning protection system. In this study, design and installation processes of a lightning protection system for the hybrid renewable energy system are considered. The earth resistance of the CEH was measured as 6.5 Ω by a meger for the CEH. The specific earth resistance of the CEH zone was measured as 75 Ωm. These datas are average results for yearly period.

Acknowledgements

The authors gratefully acknowledge the support provided by the Scientific Research Projects Council of PAU, Turkish State Planning Organization (DPT), the Scientific and Technological Research Council of Turkey (TUBITAK), Bereket Energy Inc. (Turkey), Nexans Cable Inc. (Turkey) and Siemens (Turkey).

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Recevied 2011 02 08

E. Cetin, A. Yilanci, H. K. Ozturk, G. Uckan, M. Hekim, M. Colak, S. Icli. Lightning Protection for Buildings Energized by Renewable Energy Sources // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 6(112). – P. 7–10.

Renewable energy systems are of importance as being modular, nature-friendly and domestic. Among the renewable energy systems, a great deal of research has been conducted especially on photovoltaic, wind energy and fuel cell in the recent years. One of the hybrid renewable energy systems consisting of 5 kWp photovoltaic panels, 800 Wp wind turbines and 2.4 kWp fuel cell modules was installed at **C**lean **E**nergy **H**ouse (CEH), Pamukkale University in Denizli, Turkey. To protect this laboratory, a "Lightning Protection System" was installed at the CEH. In this study, design and installation processes of a lightning protection system for the hybrid renewable energy system at the CEH are considered. Ill. 7, bibl. 15 (in English; abstracts in English and Lithuanian).

E. Cetin, A. Yilanci, H. K. Ozturk, G. Uckan, M. Hekim, M. Colak, S. Icli. Apsaugos nuo žaibo taikymas pastatuose su atsinaujinančios elektros energijos tiekimo sistemomis // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 6(112). – P. 7–10.

Atsinaujinantys energijos šaltiniai yra tausojantys gamtą. Pastaraisiais metais atlikta daug iš saulės ir vėjo elektros energiją gaunančių sistemomų tyrimų. Tirta pastatą elektros energija aprūpinanti hibridinė sistema, sudaryta iš saulės elementų plokštės (5 kW), vėjo turbinos (800 Wp) ir PSG kuro elementų. Įdiegta apsauga nuo žaibo. Pateiktas atsinaujinančių energijos šaltinių projektavimo ir diegimo procesas įvertinant apsaugą nuo žaibo. Il. 7, bibl. 15 (anglų kalba; santraukos anglų ir lietuvių k.).