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Lightning monitoring system for sustainable energy supply: A review

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A B S T R A C T

A lightning monitoring system is used to observe, collect and analyse lightning activities so that a preventive measure to protect power equipment from severe damage can be planned. An effective lightning monitoring system is crucial to ensure the reliability and sustainability of the electrical energy supply. Despite numerous published papers on this topic, there seem to be an absence of comprehensive review papers that evaluate monitoring technologies and their performances. Owing to the literature gap, this paper is written to summarise the working principles of the relevant sensors and the various methods of data transmission, storage and analysis, as well as the various ways of predicting the occurrence of lightning strikes. This knowledge will contribute to the development of a new online lightning detection system that will be more efficient, without reducing the effectiveness and sensitivity of the system, by utilizing the available technology for data transmission and analysis.

Contents

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1. Introduction

Reliability is a crucial aspect of modern electrical power supply—regardless whether the system is conventional or distributed generation. A sustainable supply of energy requires that the transmission and distribution of electrical power are guaranteed. Particularly for a distributed generation system, it is inevitable that the available energy from renewable sources (e.g. wind turbines and photovoltaic arrays) will be maximized in order to recover the high capital cost. In addition, with the expected proliferation of smart grid systems, the protection of sensitive equipment, such as telecommunication and control facilities (in smart distributed generation), must be given the priority.

Ideally, it is desirable that these power supplies be as robust as possible; however, a zero level of vulnerability is practically unattainable [1,2]. In many cases, system failures or disruptions due to natural disasters, such as severe lightning and thunderstorm events, can interrupt the energy supply to consumers. More recently, the more frequent occurrence of extreme weather conditions due to global warming and the El Niño effect [3,4] have also been identified as factors that exaggerate the problem.

For a lightning discharge, the resulting large current and/or voltage fluctuations can temporarily disrupt or permanently damage parts or components of the power supply chain [5–7]. The most common scenario is a direct or indirect strike on exposed transmission cables, with the consequence of switchgears and relays tripping. In a more severe situation, a direct strike on a substation, for example, can cause damage to the components of a distribution system (transformers, relays and switches)—resulting in a long recovery time. In a renewable energy system, the most vulnerable part is the power electronics equipment (dc–ac, dc–dc). A lightning strike (direct or indirect) can result in a total collapse of generation capability. Very likely, the electronics equipment will have to be replaced. As far as a smart grid is concerned, there is a need to adequately protect the telecommunication and control facilities. They are the backbone of the distributed generation, and the loss of communication significantly reduces the effectiveness of the system. From the above discussions, it is clear that lightning discharge must be considered one of the main variables in estimating risk factors [8–10]. It has to be evaluated meticulously in order to adjust the cash flows of power supply plants [11].

Lightning is a transient discharge of static electricity that serves to re-establish electrostatic equilibrium within a stormy environment [12]. It is commonly characterised by an extremely high current, high voltage and short-lived electrical discharge. To reduce the risk of being damaged or affected by lightning, various types of monitoring systems have been developed to detect and alert individuals of its eminent occurrence. It is important to note that lightning phenomena cannot be prevented, but they can be intercepted or diverted to a path that results in less damage [13]. Besides being used as an early warning system, monitored data can be used for the long-term meteorological evaluation, which in turn, can improve the understanding of worldwide climate change. As the interest in this issue has grown, substantial effort has been devoted to designing a reliable and cost-effective lightning monitoring system. With the proliferation of various commercial products using different concepts, the need to understand the principles behind their operations becomes more crucial. This is particularly vital when selecting the appropriate product for a particular meteorological condition or geographical location. Unfortunately, its importance has always been overlooked, even though the cost of a monitoring system is only a small fraction of the total investment of a power plant.

Despite the numerous published research studies carried out in this area, there appears to be an absence of a single, comprehensive review paper that evaluates the relevant lightning monitoring technologies and their performances. Owing to the literature gap, this review paper is written with the following goals in mind: (1) to summarise the functions and working principles of the various sensors used in the system, (2) to elaborate on the methods of predicting the occurrence of lightning strikes and their locations and (3) to describe the periphery instrumentation required for data transmission, storage and analysis. At the end of the paper, a brief comparison of the commercially available lightning monitoring systems is also provided. To complement the analysis, an exhaustive list of references is provided for those interested in further probing the issues raised in this paper.

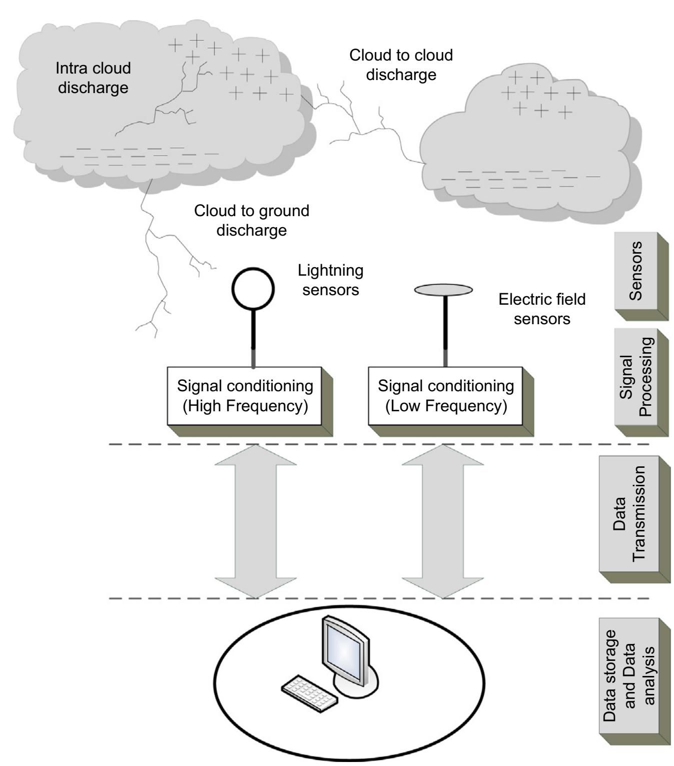

Fig. 1. General block diagram of lightning monitoring system.