NETLAKE Guidelines for automated monitoring system development

005 How to cope with lightning

Objective

The purpose of this fact sheet is to provide some practical advice on how to minimize potentially destructive effects of lightning and lightning induced voltage transients.

Considerations

Automated monitoring systems (AMS) used for lake studies can be deployed on both land and water, and are comprised of sensors, data loggers, and can also include telecommunication and power cables. All of these components can be affected by direct lightning strikes and more commonly lightning induced voltage transients. This fact sheet provides some basic information on how to best protect water based and land based systems from lightning.

Nature of the Problem

Lightning is the result of the rising air currents often associated with cumulus clouds. Within these clouds electrical charges develop that lead to electrical discharge within the clouds and also between the cloud and the earth surface (lightning strikes). There are two ways that lightning strikes can affect AMS: 1) a direct strike where the system components (antennas masts etc.) become part of the circuit path between the cloud and ground and 2) Lightning induced voltage transients, where a nearby lightning strike induces voltages into sensors and electrical cabling. This can be considered analogous to an electrical generator where a magnet passing by a coil induces the generated voltage. In the case of lightning the electrostatic discharge (ESD) serves as the magnet, and the sensor, power and communication cables server as the coil. Lightning induced voltage transients are much more common than direct lightning strikes. In our experience at Lake Erken, these occur multiple times each year, while direct strikes have rarely occurred. When long power or communication cables are used another transient problem can arise if a lightning strike leads to a momentary difference in the voltage potential between the two ends of the cable (Fig. 1).

Basics of Protection

Many data loggers are built with lightning and ESD protection circuity, so the first source of information in developing a protection strategy should be to consult the data logger manual for suggestions on grounding and wiring. Protection from direct strikes is achieved by providing a favorable low resistance path that bypasses the monitoring system, so that the strike can pass directly to ground without flowing through the monitoring system. Typically a lightning rod is placed at the highest point of the measurement system above all other sensors and antennas. This is connected to a conductive tower or mast (aluminum) which is in turn connected to a suitable earth ground using a heavy copper wire. The earth ground will be different depending on the application, but generally is a 2-2.5 meter copper/bronze stake driven into the ground or a conductor submersed in the lake water. Protection against direct strikes can be also considered the first line of defense against ESD induced transients. The same system can also be effective in leading ESD around the monitoring system. However ESD transients are also induced in sensor cables. The longer the cable the greater the risk. Long communication and power cables are clearly a risk and require separate ESD transient protection. Additional protection from ESD transients is achieved using a variety of electronic devices. The basic principle behind all of these is that in the presence of a high voltage surge to rapidly (nsec – msec) transfer that surge to system ground, thereby protecting the data logger and sensor. Different surge suppressing components have different response times, voltage and current capacities. Many commercial protection systems make use of multiple components to optimize protection. For example, Campbell Scientific data loggers (i.e., Ref Cr10000 manual) use both gas discharge tubes and Zener diodes as part of the wiring panel transient protection circuitry.

Protection of Water Based Systems

Water based systems are generally less complex to protect than land based systems since they are relatively compact, lack long cables that can induce ESD transients, and since the water serves as the ground. Our general advice on these systems is to use a lightning rod that is approximately 0.5-1.0 meters above any antenna or meteorological instruments, and to connect this to an underwater ground. The data logger ground should also be connected to the same ground using at least a 12 AWG (3.3 mm^2) copper wire. If the data logger itself does not include transient protection circuitry, this could be added to sensors above the water. Underwater sensors are in effect submerged in the ground, so even long cable lengths (i.e. thermistor strings) should be safe. The most complex issue here is developing a good water based ground. There is very little guidance on this issue, the most relevant that can be found is that related to grounding of boats generally in marine systems. A recommendation by the American Boat and Yacht Council (ABYC 2006) is to use an underwater ground plate that is copper or copper alloy that is at least 5 mm thick and having an area of at least 0.1 m^2. There is also some belief that the ESD dissipation will occur along the edges of the copper plate, leading to the suggestion that a long copper strip is more effective than a square plate. At Lake Erken we use a heavy copper wire that goes around the periphery of our float below the water line (Fig 2). This is connected to a common bus that also has connections to our buoy instrument mast and data logger ground. Placing the ground cable around the float prevents entanglement with other sensors.

Protection of land based systems

Land based automated monitoring systems are often used to collect meteorological, water quality and gas flux data from island, near shore, or pier based locations. Island stations are particularly attractive as they can provide in lake measurement sites that are much less affected by ice and do not require the maintenance needed by buoy based systems. Protection from direct lightning strikes is the same as described above for water based systems, with a lightning rod placed above all sensors and antennas, and a connection to earth ground using a heavy copper wire. Development of a good earth ground is critical, and can be difficult especially on islands that are usually mostly rock or from piers. In these cases the typical ground stake can be supplemented or replaced with a water ground. At an island based station in Lake Erken (Fig. 3), we use both a ground stake and a 1m^2 copper plate (following recommendations from the local phone company) submerged underwater as our ground. Both grounds are connected to a common bus to which we also connect meteorological masts and data logger grounds. ESD transients are more problematic on land based sites since instruments tend to be spread out more providing longer cables to collect transients. A useful strategy for land based systems with sensors constrained to a small area is to have multiple ground points, around the perimeter of the instrument area. When connected to a common ground bus this reduces the potential for transient formation. If the system data logger does not have in built transient protection, it is recommended that sensors with leads longer than 3-4 m be protected with some type of transient protection. Sensor manufacturers can offer this as an option, or individual protection devices can be purchased separately. A second ESD transient issue often occurs when the land station is supplied with AC electric power or telecommunication cables. These long cables are highly susceptible to lightning induce voltage transients, and are almost inevitably grounded some distance from the monitoring station. Direct connection of the AC power ground to the local station ground sets up the perfect situation for transients occurring as depicted in example 1. To avoid this the AC line should be protected with a transient protection system, which shorts transients to the local system ground. This is best done by an electrician familiar with installation of transient protection systems. Similar protection is needed for telecommunications cables for example phone lines or lines to short haul modems. However, the issue can be eliminated if fiber optic communications are used.

Examples

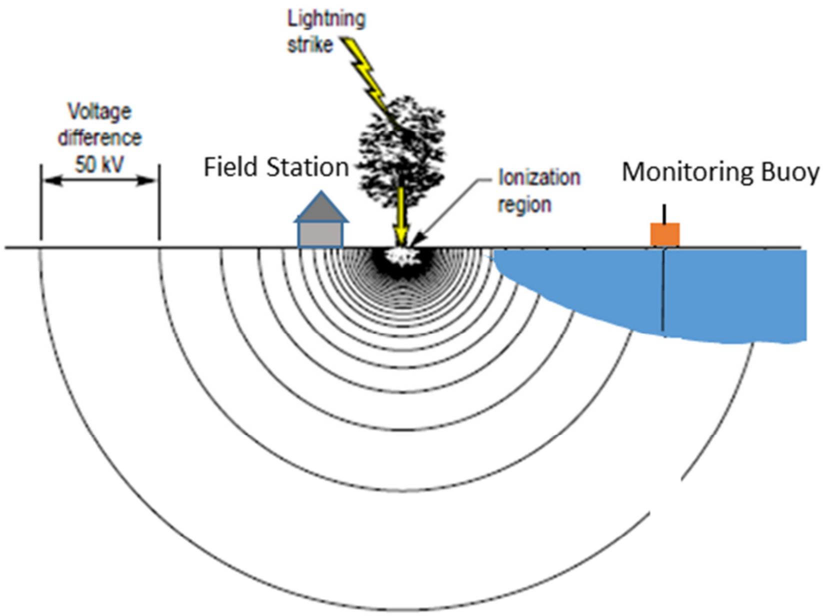

Figure 1. Illustration of the process leading to a large ESD voltage transient. If the monitoring buoy is connected to the field station with a data or power cable the buoy logger and sensors will see and induced transient. Modified from (http://www.slopeindicator.com/instruments/transient-protection.php).

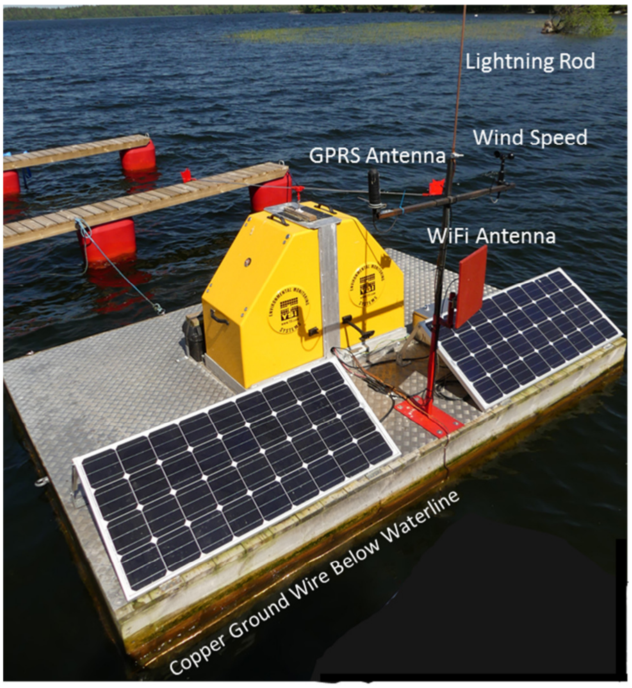

Figure 2. Lightning protection applied to a floating platform used in Lake Erken. Lightning rod is highest point on the platform. Ground wire is approximately 8 cm below the water line.

Figure 3. Lightning Rod protecting Gas flux tower on Malma Island, Lake Erken.

Likely Problems

Potential damage to sensors and data loggers.
Loss of data.

More information

ABYC. 2006. Lightning Protection. Standards and Technical Information Reports for Small Craft. American Boat and Yacht Council (ABYC)
https://en.wikipedia.org/wiki/Surge_protector

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