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HIGH TOWER LIGTHNING SUPERVISION : A SIMPLE WAY

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Abstract - lightning strike counters are used for many reasons on Lightning Protection Systems. They may trigger a maintenance inspection when a lightning has been recorded. The counter being used directly on the LPS (generally on the downconductors) it is possible to make the maintenance only on the concerned structure and not on a complete site. It is possible to use lightning strike counters on SPD circuits and if the place of the counter is appropriate it can be able to determine if the LPS has been struck and even if the LPS is totally or partially made of natural components. Counters need to be reliable and they should then comply with the more recent standards. Additional requirements such as EMC tests or field experiment are proposed. Some applications for counters connected to a remote site by an optical fiber are presented.

1 INTRODUCTION

There are several equipments as storm detectors or lightning strike counters that are not directly part of a Lightning Protection System (LPS) but are very useful to reduce or to register the threat to the installations. This paper presents some applications of special lightning strike counters for use preponderantly in high towers struck by lightning strokes and measurement of lightning current characteristics. The LPS standards states that the measurement of lightning parameters are necessary to assure the best protection possible [1, 2]. The authors present some studied cases as well as laboratory test results.

2 LIGHTNING STRIKECOUNTERS

There are several lightning strike counter designs. The basic ones count only the number of strikes flowing through their sensor circuit. Others are more sophisticated and are also giving valuable data regarding the lightning strike including current magnitude, charge to differentiate the 8/20 surges from the 10/350 surges for example. Others are also providing time stamping (usually date and time of the strike) that can be used either for triggering the maintenance of the LPS or to provide information to allow exchanging Surge Protective Device before they reach their lightning withstand capability or even to help insurers to make their survey on a site supposedly damaged by lightning.
All lightning strike counters are connected to the path where the lightning strike current is supposed to flow in case of a lightning strike. It may be at the terminal location (even if generally this point is not easily accessible), it may be on the downconductor near ground level (in that case multiple path to the ground should be investigated as the current flowing through the monitored path needs to be high enough to trigger the lightning strike counter sensor) or even in the inspection pit of the earthing systems (in that case, the main problem results in the risk of water ingress). It also happens that the lightning strike counter is connected in the earthing path of SPD and in such case they are often named "surge counters" even if their design is similar or even identical to lightning strike counters. The lightning strike counters may be connected in series with the current math describe above or in parallel. In the first case, the current generally flows through a coil and the voltage obtained at the coil output is connected to an electronic or electromechanical circuit. In the second case, the magnetic field generated by the current flow is monitored by a sensor that may be as simple as a coil (generally a flat coil or even a coil mounted on a printed circuit board) and the voltage generated at the output of the sensor is connected to an electronic or electromechanical circuit. The main advantage of the second type of lightning strike counters is that it may be installed without dismantling or opening the circuit where the measured current is expected to flow.
The usefulness of each lightning strike counter design depends on its functionality and easy visualization of parameters (software on board, external software, communication system, etc.).
Most of the counters provide basic visual information on their enclosure such as a digital counter, a mechanical counter or a led (in this case, it is not possible to use the counter without his handbook) to show how many impact

have been counted or just that an additional impact has been counted. Some counters, are providing more information locally (either always listed or by activating the counter with a local or a distance mean such as a button or a magnet. The use of activating means allow saving battery for the stand alone counters). Other counters are able to send remote information in addition to local information. Purpose is either to duplicate the local information at a remote site, to enhance this local information or just to inform about the counter activity. These counters are using generally an optical fiber link to make a decoupling between the emitter and the receiver and to avoid additional EMC disturbances on this link. Others are using a radio link. One of the issues for the lightning strike counter is the power. Most of them are stand alone counters relying on imbedded batteries to power the electronic circuits and/or the digital display. For simple counters, the coil is usually able to generate enough energy when lightning current flows through its sensor to count 1 on an electromechanical counter with no battery at all. When electronic counter/display is used, the battery is used to powered the display and need to be changed after a period depending mainly on the temperature cycles, usually ten years or more. For more sophisticated counters (providing more data) the lightning current flow is only used to activate the electronic circuits or to wake-up the circuit should it be sleeping for battery saving sake and most of the process is made due to the batteries. A few counters are externally powered as this is making their use limited to experiments. Others are provided with solar cells to help keeping the battery charged but once again this limits their use (avoid shadow for outdoor use, no indoor use allowed).
Reset is a function that some counters provide. This may be made by the user himself (in that case the handbook needs to be used in order to avoid the counter to be reset before reading of the counter being done) or by the manufacturer at his factory. When counters are used for triggering maintenance of LPS or by insurers, it is preferred that resetting is not allowed.

The main problems with the counter coming from field evaluations are:
- some of them are bulky and not practical for other use than scientific ones (they are generally not used on lightning protection systems).
- some counters are very sensitive to EMC disturbances. A famous case is one of a counter installed on a bridge that was counting millions of strikes in spite of no marks on the LPS. After study is was found that it was too sensitive to disturbances and that the radar beam of the boats was in the right direction, the counter was counting instead of remaining at 0. The development of standards for lightning strike counters has been made to avoid this type of drawbacks.
- counters are more often damaged by pollution, water ingress, temperature cycles or even small animals than any other cause. Before using on a large scale such counters they should be tested on various places where such conditions exist.

The lightning counter presented in this paper is a stand-alone model that can be read at a determined frequency depending on lightning storm frequency or using other parameters decided by the user.

Access to the lightning counter parameters is easy and can be made by reading directly a digital display with all functions as can be seen in Fig. 1. A button located below the counter allows reading the data recorded for all the strikes that have passed through the counter in a decreasing time order. For each strike, the magnitude, charge, date and time (hour-minute) is recorded. A magnetic link allows changing the button functions for example for changing time (e.g. to move to summer time) and no reset is allowed by the user.

Fig. 1 – Front view of the lightning strike counter.

The original use of this counter was for railway surge arresters in Asia where it was used to count the threat on the arresters allowing to change them before they fail (short-circuit on a DC railway system may be damaging). A breathing membrane is also present at the bottom near the function button to sustain harsh environment. As a matter of fact, in wet heat experience proved that a breathing enclosure is behaving better than an expected tight enclosure. It is the case for example in Kourou (French Guyana) or in many Caribbean islands.

3 TYPICAL LIGHTNING STRIKE COUNTER APPLICATIONS

Usually the lightning strike counter applications are as follows (it should be noted than application of such counters in places with difficult access can be performed using optical fiber connections):

• Monitoring of surge current flowing through low voltage Surge Protection Devices or high voltage Surge

Arresters. In that case, it can be based on a simple counting of surge currents or based on magnitude or even charge indications.
Purpose for the simple counting is to be able to know when then SPD or SA has been working and to decide based on this either to replace them in advance or test them (locally with a portable generator) or in a laboratory). For SPDs it is particularly important for the gap technology as very often there is no other way to know if the gap has been damaged or not (for Metal Oxide Varistor based SPD there is an internal fault indicator that doesn't exist for gap type SPDs, even if a few manufacturers provide nowadays a limited number of gap type SPDs with internal monitoring.
Purpose for magnitude measurement or even better magnitude/charge measurement, it is to make a valid estimation of the remaining lifetime. Manufacturers have generally (even if not published in the regular datasheets) a magnitude (or charge) .vs. admissible curve number of shots and this can be used to estimate if it is easier to replace the SPD before it fails or if the SPD can sustain more shots.
It should be also noted that the equipotential bonding SPDs (Type 1 SPD - tested with a 10/350 waveshape - in case of a structure protected by a LPS) installed at the entrance of the power lines will drive a significant part of the lightning current reaching the LPS. It may be around 50% (or even more when using the formulas given in IEC 62305-1 [2]) of the lightning current, the remaining part of the current going to the earthing system. By monitoring the current flowing through this equipotential bonding SPD, not only the SPD is under control but in addition, the complete LPS can be controlled. Any current flowing through the LPS will rise the earthing potential that in return will inject current in the equipotential bonding SPDs. With a limited number of lightning strike counters it is then possible to monitor a LPS and launch the necessary maintenance. The alternative would be to install counter on every two dowconductors and this may lead to a significant amount of counters for a mesh system. It is even not possible to install such counters when natural components of the structure and a loop type earthing system are used. In addition, using counters inside the structure will avoid the environmental risk described above when structure are located in harsh environment (heavy rains, ice, snow, dust, saline pollution, small animals ….)

• Monitoring lightning current flowing through LPS downconductors. The number of such counters is depending on the number of downconductors (mesh lightning protection system or single rods). Due to the threshold current that counters should have to be compliant with standards (see below) it is generally recommended to install counters on every second downconductor. For a mesh system this may lead to a big number of counters and this is why they are generally mainly used for single rods. For a LPS based completely or partially on natural components of the structure, use of lightning strike counters are usually not possible due to too many paths to ground and also due to the fact that counters are generally to be connected near conductor of a specific maximum size (metal frame of structure is far too large for counter and concrete reinforcement bars are too numerous).

• Specific experiments, near the research domain, where sophisticated counters can be used due to their relatively cheap price and easiness to use, to make a large survey:

- Monitoring of lightning current in many places at the same time, for example on the earthing system of poles for distribution lines,
- Monitoring of a specific sensitive site for a few years before deciding of the appropriate lightning protection measures
- Or to understand why some equipments fails while they were supposed to be protected. For example, the lightning current magnitude is the key parameter to support any expertise on failed equipment/structure.

4 LIGHTNING STRIKE COUNTER LABORATORY TESTS

As discussed above all lightning strike counters should be submitted to laboratory tests to evaluate performance and to define application limits as current threshold level and maximum withstand current.
This is why standards on such devices have been developed.
One of the first standards for lightning strike counters was the French UTE C 17-106 dated February 2011. This standard was introducing many tests:

- mechanical tests
- electrical tests
- corrosion tests
- IP degree tests
- humidity withstand tests
- marking tests.

The structure of this standard was based on the SPD standards as many tests were the same.
A maximum withstand level was defined Imax (with a 8/20 wave only) as well as minimum detectable current level Id (also with 8/20 wave). It is interesting to note that at Id/3 the counter should not count and this is check by a test. Purpose is to avoid the counter to be sensitive to disturbances.

The EN 50164 series of standards for Lightning Protection Components also includes since January 2009, a standard for lightning strike counters EN 50164-6 [4]. The structure of this standard is derived from the structure of the other standards of the series.

The following tests are used (very similar to the previous standard even if more stringent tests requirement have been introduced):

- Mechanical tests
- Electrical tests
- Resistance test to corrosion (for metallic parts)
- Checking of IP degree
- Marking test

But new tests are introduced, once again to increase the counter immunity to disturbances: Electromagnetic compatibility (EMC) tests.

- Electromagnetic immunity
- Electromagnetic emission

The threshold current is called Itc: it is the peak value of the discharge current with an 8/20 waveform that the counter will count in 100 % of the cases. As previously, values of current lower than Itc/3, should not be counted by the counter.

The maximum counting and withstand discharge current is called Imcw. It is the peak value of a current through the conductor having an 8/20 or 10/350 waveform and magnitude. It should be noted that a 8/20 waveform can be used only for counters connected to SPDs Type 2. For this standard, most of the counters should withstand a 10/350 current and this is important for most of applications of such counters. This is why an impulse current (Iimp) is also introduced defined by three parameters, a current peak value Ipeak, a charge Q and a specific energy W/R. This is used for the current counting and withstand test and this is very similar once again to the SPD standards.

In this European standard typical values are given in a table:

Table 1: typical current values for lightning strike counter as per EN 50164-6 standard

Application	Values for I_{tc}		Values for I_{mcw}				
Connection on LPS conductors	-	1 kA 8/20	-	-	-	-	100 kA 10/350
Connection on SPD conductors	500 A 8/20	-	20 kA 8/20	40 kA 8/20	60 kA 8/20	80 kA 8/20	100 kA 8/20
Connection on LPS and SPD conductors	-	1 kA 8/20	-	-	-	-	100 kA 10/350
NOTE All current waveforms according to EN 62305-1.							

The maximum withstand value is 100 kA 10/350 and the threshold level depends on the application 1 kA for LPS and 0,5 kA for SPDs.

More recently, the IEC 62561 series of standard has proposed a similar standard IEC 62561-6 [5] that will at the end will supersedes the EN 50164-6 standard. There are only limited differences between this standard and the EN 50164-6. The non counting current is Itc/2 instead of Itc/3.

A resistance to UV radiation tests is introduced. This test is necessary for lightning strike counters with non-metallic housings designed to be installed outdoors or in specific environments.

Multipulse test are also listed even if no test procedure is provided at this stage.

Based on our experience, the EMC tests included in the standard are a good basis but may not be enough in some electromagnetic environments. EMC standards that are referred to in the standard are IEC 61000-6-2 and -4 for immunity and emission respectively. IEC 61000-4-8 (power frequency magnetic field) would be a valid candidate to be introduced in the standard as field experience has shown (counter tested according to this standard have a good behavior in real environment). Lightning strike counters should be tested with a stronger field (1600A/m) than the one use for standard industrial (10A/m defined for CE marking in European directives). A proposed test circuit is given in Fig. 2.

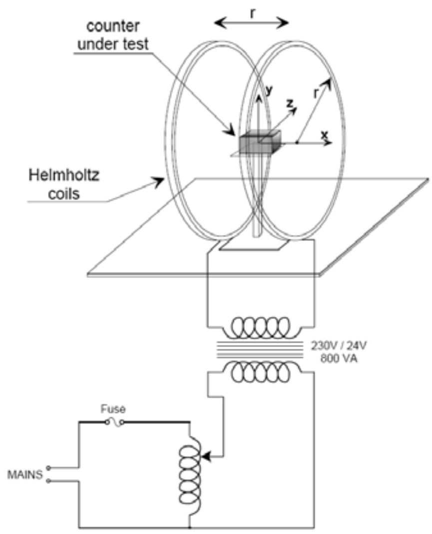

Fig. 2 – Proposed testing circuit for lightning strike counter power frequency magnetic field immunity tests.

In addition, as mentioned before the environmental tests included in the standards are not enough for harsh environment applications such as the tropical ones. To cover them specific investigation tests with temperature cycles to simulate the water pumping effect need to be investigated. In some hard cases (mountain applications or tropical weather) these cycles temperature tests are even not enough and only field experiment (over one season is generally enough to discover any possible drawback in the counter design) can prove that lightning strike counters will behave well in field, for the more severe environmental conditions.

5 APPLICATION CASES

One of the usual cases of lightning counter application is in mobile telephone communication towers [6] that present in its top a lightning rod to protect antennas, as shown in Fig. 3.

As can be seen in the mobile telephone communication tower the use of lightning counter is a good measure of system performance due to the following aspects:

- The exposition of mobile telephone communication towers can be evaluated by the number of lightning attachments to it;
- The current amplitude of lightning that were attached to the mobile telephone communication towers can be compared with the electrical resistibility of low voltage equipment and surge protective devices;
- Measures can be taken to avoid damages to mobile telephone equipment, as new grounding configuration [7], improvement of surge protective devices, etc.

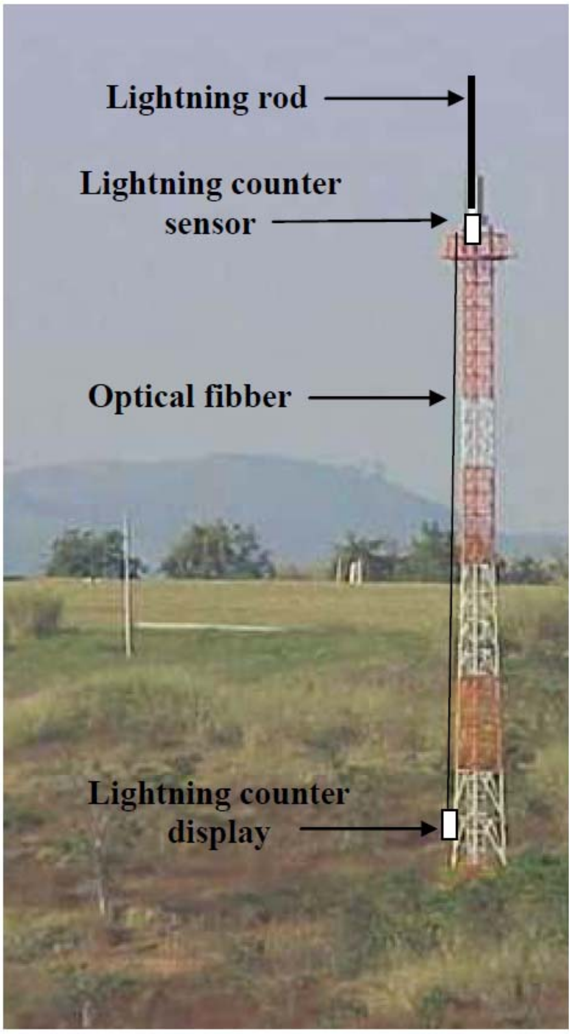

Fig. 3 – Mobile telephone communication tower.

Results regarding this application will be presented in a future paper.

There are other cases where the application of lightning strike counters may help determining the optimum LPS solution:

One of them is for insulation coordination on very high voltage DC. Due to many parameters such as pollution or significant DC permanent high voltage or even bad high frequency earthing, there may be more flashovers on some lines than the usual model may predict. One of the reasons may be that there are more lightning attachments to these lines than the model predict. To verify this, on a large scale basis, it is possible to install lightning strike counters on almost every pole and to determine if lightning is the cause of flashover (it may happen that pollution is the main cause of this situation) and in this case where lightning is flowing and what are the magnitude of the lightning currents. Lightning strike counter is a mean to make this study and due to its relative cheap price allow to equip almost any pole of the studied lines for example on the stretched line (catenary) above the phase lines. It is then necessary to install an optical fiber as in previous application to bring down the data to the pole bottom. What is used is an adaptor connected to the counter with magnitude/charge and time stamp recording. For the time being the optical fiber only transfer the counting number and it is necessary at the end of the trial period to remove the counter to analyze them. A model transferring all the data may be helpful for that application and could be easily developed provided additional energy is provided (e.g. by solar cells) but this means a redesign of the actual counter with all the possible drawbacks explained before regarding water ingress and other pollution or thermal effect. Development of such a new counter is then a matter of time and experiment on a small scale basis.

The last application that we would like to mention where a counter is used with a remote optical link to a control center is for space applications. When rockets are launched, there are generally stretched wires on the launch pad to protect the rocket. A lightning strike to a launched rocket or even to a fixed rocket when boosters are loaded with combustible may be very damaging. In addition to the meteorology radars and storm detectors, there are lightning strike counters connected at various part of the stretched wires connected to the remote control center. This additional information is used for safety and must be then very reliable. There are then tested regularly by injecting a small lightning strike current with a portable generator to check both the counter and the data link. This application has proved to be working satisfactorily in harsh environment.

5 CONCLUSIONS

There are many applications where lightning strike counters can be used in conjunction to a Lightning

Protection System or to determine the best LPS. There are many available lightning strike counters. One are every simple counting only the number of strike flowing through them. Others are more sophisticated monitoring lightning current and charge and time stamping the events. Some need external energy sources and others are stand alone. For some of them, it is also possible to use a remote indicator. The main parameter for a lightning strike counter is to be compliant either with the Cenelec standard or the brand new IEC standard. Failure to comply with these standards may lead to unreliable results or even failure. However, in some difficult environments, even compliance with the standard is not enough to behave well in field. An additional EMC test is the proposed and furthermore a testing in field on a small scale is very often beneficial. Applications with remote data link presented include telecom tower monitoring (that will be expanded when more results are available), high voltage tower and space applications.

6 REFERENCES

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