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Lightning Protection of Golf Courses and outdoor activities

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***Abstract*— Playing golf is becoming more and more widespread. Golfers consider that rain and wind are part of the game and are then reluctant to listen to some signs that would push other people to go back to a safer and drier place. The lightning risk is then non nil as being outside by a stormy weather increase drastically the human risk.**

Basically the best protection is named prevention. When a stormy weather is present all people on a golf course should go back to a safe shelter protected against direct and indirect effect of lightning. This also applies to many outdoor activities such as camping, tree climbing, entertainment parks …

The paper first concentrate on the medical aspects. The major risk is cardiac arrest caused by lightning when current passes through the body. Then it deals with how to provide protection and prevention including the design of the protected shelter including lightning protection means and earthing system as well as protection against step and touch voltage. Reliability of protection means is important. It should be maintained and well calibrated. Associated procedures should also be quite clear and efficient. The tests to perform as included in a recent IEC standard are discussed.

Keywords—storm; detector, Thunderstorm Warning System, Lightning, prevention, protection

I. INTRODUCTION

Playing golf is becoming more and more widespread. Golfers consider that rain and wind are part of the game and are then reluctant to listen to some signs that would push other people to go back to a safer and drier place. The lightning risk is then non nil as being outside by a stormy weather increase drastically the human risk. Every year 4,500 people die on a golf course in the world, and 5% of those affected by lightning in the world are on a golf course. In France there were two deaths of young adult males on golf courses. Interestingly, both were struck by the first bolt from the thundercloud. The famous international golfer Lee Trevino survived two lightning strikes including one at a major competition in the US in 1975. Another international golf player, Retief Goosen, was hit also and survived. Numerous individual and collective occurrences of lightings are published around the world concerning golf players. Undoubtedly, the golf courses are interesting fields where sportsmen are exposed to the lightning risk and thus have to be informed, warned, protected and educated, including a training for lifesaving procedures.

Basically the best protection is named prevention. When a stormy weather is present all people on a golf course should go back to a safe shelter protected against direct and indirect effect of lightning. This also applies to many outdoor activities such as camping, tree climbing, entertainment parks, fishing, cycling.

II. MEDICAL ASPECTS

If lightning strikes a person, what to do is to apply usual procedures: if the victim is unconscious, perform as soon as possible a heart massage and mouth to mouth ventilation, and call urgently for help and bringing on site a defibrillator in order to deliver the electrical shock which can save a life. Indeed, the major risk is cardiac arrest caused by lightning when current passes through the body.

Fig. 1. Real example of a strike on a gof player near Paris

The most common case is the direct lightning strike on the golfer himself. It is facilitated by the fact that he often stands on an open area, higher than the surrounding space. Moreover, he can hold up towards the storm cloud objects like a golf club or an umbrella. The lightning current then passes through the body of the unfortunate golfer, being able to follow two paths:

- Either external at the surface of the body, burning the skin especially near the metal parts of clothing (necklace, belt buckle, jewels, etc.). Those electrical burns may be severe and deep, but not always. They tend to focus on the points of entry and exit of the current. A benign typical consequence of the external flash is the Lichtenberg figure yielding ramified red drawings on the skin along the current ways, which faint and disappear in a few days.
- Either internal flash that can cause internal injuries , the most serious being cardiac arrest by fibrillation if it crosses the heart during a vulnerable period. The nervous system, the muscles, the blood vessels may be injured too. Every body structure involved may be electrically stimulated or burned according to the amount of current delivered.

Fig. 2. Injury to a golfer, same case than Figure 1

Those paths are not mutually exclusive and may coexist. The other consequences of lightning on man are numerous and may vary a lot, but some are worth to mention:

- Electrical stimulation can cause muscle contraction, either at the heart or at the skeletal level. The most severe consequence is heart rhythm disturbance, which at the ventricular level give extrasystole and in the worst cases fibrillation. In the nervous system, a curious phenomenon called keraunoparalysis results from the sideration of the spinal cord and nerves following the passage of the lightning current. A ground current traversing from a foot to another (especially if they are apart) thus yields during a couple of minutes or hours a paraplegy. But more severe sequels of nervous lightning include nerve, spinal cord or brain burning with permanent deficits, or blood vessel obstruction.
- Thermo- and photo-traumatism due to lightning combine when the eyes are exposed: hence burning of the eyelids or cornea, and lens or retinal injury which may evolve towards cataract and temporary or permanent blindness.
- The barotraumatism may yield eardrum rupture and deafness.
- The psychotraumatism following lightning exposure is as a rule serious. It may require specialized care even if the person has not been physically injured.
- Sometimes traumatic consequences combine to lightning current, for example when muscle contraction or paralysis has provoked the golfer’s fall from a cliff or any high situation.

Although direct lightning is frequent, other possibilities are dependent on the path of the lightning current. A typical event is the passage of lightning in a tree and then jumping from the trunk of the tree to a nearby person. A variant is the bolt striking a wooden unearthed hut where golfers were waiting seeking shelter; a collective lightning of this type occurred in Germany and 3 of the 4 golfers died.

As people may be too far from a safe shelter the usual rules to follow to minimize the danger are to squat on the ground, to protect ears and to wait until the storm passes by.

Fig. 3. How to be protected outside of a safe shelter ?

III. PROTECTION PRINCIPLES

The problem nowadays is how to provide protection and prevention. The progress in the storm detectors make them available for golf courses and integrated solutions for computer-based warning of the golfers on the course are affordable. Moreover, recent court rulings condemning unequipped golf courses to pay for the hospital fees of the lightning victims indicate that the time for technical investment has come for them.

A modern system intended to protect an entire golf course for the lightning risk includes a well-calibrated, robust and error-proof detection system, and protection of every building of the course. The design of the protected shelters and golf clubhouse should include lightning protection means and earthing system as well as protection against step and touch voltage.

At last the specification for prevention means has to follow the latest norms. The system should be reliable and taking care of the time needed to stop activities and have people going to a safe shelter. Reliability is important. A recent accident in China has shown that a lonely storm detector is not enough to avoid problems. It should be maintained and well calibrated, and combined with weather and electric field monitoring. Associated procedures should also be quite clear and efficient. At the present time the European standard of storm detectors doesn't include tests and they are generally calibrated in laboratories in dry conditions. But they need to be outdoor and then these devices are subjected to pollution, rain, UV … This can change their detection ability or create too many false alarms that the user will, after some time, neglect. The IEC standard 62793 [1] hopefully introduces some test to take care of this drawback.

And finally, information, education, and training of the persons are important. An annual rehearsal of the safety measures and procedures, combined with simulation of the life-saving techniques and the inspection of the protecting devices is mandatory to ensure that the protection level remains optimal.

IV. LIGHTNING PROTECTION SYSTEM

A suitable and standardized protection scheme [2] should be implemented not only on the club house but also on local shelters following a preliminary lightning risk assessment. As a matter of fact, distance may be quite large between the isolated golfer and the club house. Protection of the club house will include lightning rod(s), downconductors and a suitable lightning earthing system. Surge protective device should also be implemented due to the presence of the lightning rod but also to take care of safety devices (fire detectors, emergency telecom line, warning siren and so on). For the shelters that are supposed to protect the far away golfers, a lightning rod and down-conductor system should be implemented. Step and touch voltages should be taken into account by using specific rules (specific isolated downconductor, gravel, isolating material …).

Fig. 4. Example of a shelter protected against direct strike

These safety rules are valid inside and outside the shelter in an area of 3 m around the downconductors. It should be a pity that the lightning rod is catching the lightning strike but people are injured by a side flash or a step voltage. The lightning protection scheme should be defined by a professional having a justified qualification (such as Qualifoudre in France), installed by a professional with the same qualifications and finally inspected by a professional (different from the installer but could be the same than the designer) also duly qualified. A badly designed and installed LPS could be as dangerous as no LPS at all.

V. TESTING OF TWS

Annex F of IEC 62793 (Thunderstorm Warning Systems, presently at final voting stage) is introducing tests for TWS detectors. This annex doesn't apply to sensors used by Lightning Location Systems where maintenance is the duty of LLS operator. This annex only applies to outdoor thunderstorm detectors. Software and indoor hardware are only covered in this annex through proposed testing in open air laboratory. All these tests are unfortunately so far not mandatory and only optional.

Non-metallic sensor housings for outdoor application shall withstand UV effects. The tests is similar to the one described for LPS fasteners in IEC 6256-4. The specimen is deemed to have passed this part of the test if there are no signs of disintegration and no cracks visible to normal or corrected vision.

The specimen used above shall be subjected to corrosion tests as per IEC 62561-1 (LPS connector) consisting of a salt mist treatment followed by a humid sulphurous atmosphere treatment. Specimen under test should not present any trace of rust on surfaces.

The specimen used above shall be stressed three times by a mechanical test consisting in applying mechanical impacts. The impacts are carried out on the accessible parts of the sensor which may be mechanically stressed accidentally. After the test, the sensor shall show no cracks or similar damage visible to normal or corrected vision without magnification and shall not present damage which can potentially affect its later use.

Electrical tests are then performed on the same specimen than above. It consists of:

- Test under DC electric field. In this test the sensor is mounted below a testing plate with dimensions such that the electric field in the area centered below it is homogeneous. The sensor should be mounted as in normal use and should be located so that its highest point is at 1 m above the ground plate located below the testing plate. The testing plate should be at 2 m. The voltage applied on the plate should be a DC high voltage (negative polarity) to obtain an electric field at sensor head varying from 1 kV/m to 10 kV/m. No detectors should be disturbed by this test. A sensor that does not lead to a valid indication (warning or measurement of electric field to meet the criteria defined by the manufacturer) on the remote control for that test should provide such a valid indication for the following test.
- Test with high current impulse. In this test the sensor is located at least 5 m from a discharge path created between two electrodes with a distance of at least 1 m

between them and with a Marx generator, organized in such a way that the impulse current meets the criteria of a 8/20 µs waveshape. No detectors should be disturbed by this test. This is checked by monitoring the data collected on the remote control. A sensor that does not lead to valid electric indications (according to the manufacturer's specifications) on the remote control for that test, should provide a valid indication for the test mentioned above.

- Sensor should be able to meet the Electromagnetic compatibility (EMC) criteria regarding electromagnetic immunity and electromagnetic emission.
- Optional test on an open air platform under natural lightning conditions. Due to the difficulty in representing the lightning conditions in a laboratory, the design and use of a thunderstorm detector should be validated either by field application under a valid testing scheme, using if possible third party approval, or to test it on an open air platform. The platform should be located in an area prone to lightning, as the testing period should not exceed 1 year (ideally 6 months). A typical site should have a yearly average number of thunderstorm days of twenty or above. A lightning monitoring system should be used by this platform as a reference. This monitoring system should be validated by other means (to be determined and justified by the open air laboratory team, for example the parameters of the reference system may be checked under triggered lightning conditions) and will be used as a reference for the experiment. The thunderstorm detectors under test should be located on an open air platform in conditions defined by the manufacturer. The basic test for a thunderstorm detector is to check if the events recorded by the thunderstorm detector under test are consistent with the events recorded by the reference system. Failure to do so regularly, will give an indication of the inability of the thunderstorm detector to perform as announced. Thus, many events are needed and it is foreseen that at least 10 thunderstorm events are needed to validate the operational quality of the thunderstorm detector. This means that the testing duration is usually between 6 months to one year. False warnings may occur and also need to be evaluated.

VI. CONCLUSIONS

Many activities are performed outdoor nowadays, in spite of bad weather conditions. This is specifically true for golf courses where people are used to rash weather. Multiple examples, hopefully not all fatal, show that people have a great risk of injury in case of stormy weather. A thunderstorm warning system is then needed as well as a club house protected by a complete lightning protection system. As golf course can be quite large it is also needed to provide various protected shelters along the golf course. A recent accident on a golf course has shown that a badly selected Thunderstorm Warning System could lead to a fatal injury if the warning is not occurring or too late. Local TWS should then be tested in laboratory and probably as well in an open air testing platform. These tests are not mandatory in the soon to be published IEC standard for TWS but are strongly recommended of course. In addition, the TWS should be installed and maintain by a professional. These rules are also valid of course for other outdoor activities such as camping site, recreational areas, temporary events, tree climbing park and so on.

REFERENCES

[1] IEC 62793 Protection against lightning – Thunderstorm Warning System, to be published in 2016

[2] IEC 62305-3 Protection against lightning – Part 3: Physical damage to structures and life hazard, 2010.