Tall elevated objects struck by lightning: theoretical and experimental analysis of the spatial-temporal distribution of the lightning current

Elisa Garavini

Diploma these (2002)

The lightning stroke is one of the most fascinating natural phenomena, but it can also cause damages, of direct or indirect type, to power systems. For both of the two cases, it is essential to know the spatial-temporal distribution of the lightning current along the return stroke channel, that is the so called *return stroke model*. The biggest problem about this is that experimental data are, for obvious reasons, available only at the channel-base; so, researchers try to find out the so called *Engineering models*, where it is relatively easy, compatibly with the precision of the results, to find a relation between the current along the return stroke channel and the current at the base of it. The most popular model among them is the *Transmission line model*, according to which the pulse propagates as if it ware along a uniform transmission line, and no reflections are considered of any kind.

The first purpose of this work is to assess the adequateness of the assumption of considering the vertical object struck by lightning as a uniform transmission line: this has been done at the *Swiss Federal Institute of Technology*, by means of experiments on a reduced scale object.

Assuming this hypothesis, and also that the current pulses transmitted into the channel follow the TL model (with a propagation speed equal to the speed of light), it has been possible to analyse the influence of an elevated strike object on the spatial-temporal distribution of the return stroke lightning current, taking into consideration the reflections at the top and at the base of the object.

Then, in order to analyse the influence of the current reflections at the return stroke wavefront on the lightning current distribution, I finally accomplished a lightning current model, taking into account all the reflections, by the introduction of a solely recursive form. Being recursive, it cannot be expressed by an equation, but only by a software language, and I chose *Visual Fortran*. The philosophy of the algorithm is based on the fact that each pulse reaching the top of the tower generates two additional pulses, due to its reflection and transmission; so I introduced two recursive functions, giving as a result the current value produced at a given time by a certain pulse, that has amplitude and delay specified as parameters. The value of the current, which will be the function result, is 'stepped up' each time a reflection or a transmission occurs. The recursive process ends when the time when the current pulses leave the top of the tower is subsequent to the given one.

Just to sum it up, in this work I have first of all examined the existing models describing the spatial-temporal distribution of the lightning current, for the case of an elevated object struck by lightning, focussing on the assumptions that have been adopted.

Firstly, it has been dealt with struck object and lightning channel as a uniform transmission line: the experimental results found at the EPFL confirm this approximation to be acceptable.

The second assumption, that I myself followed, is to neglect the frequency dependence of current reflection coefficients at the base and top of the object. Thirdly, in the previous works the reflections of the lightning current at the return stroke wavefront, which moves upward, had been neglected. Therefore, I developed a model capable to take into account also these reflections; I implemented the proposed model in a computer code and validated it by means of experimental results (directly measured both at the Toronto's CN Tower both at the Munich's Peissenberg Tower): the predicted wave shape is more similar to the measured one, compared to the wave shapes predicted by previous models.

In the future, it would be interesting to examine the influence of the return stroke wavefront reflections on lightning field and induced overvoltages on power systems, by integrating the Fortran program into already existing ones. Some preliminary valuations allow to affirm that the difference is of about 10%, between overvoltages calculated taking into account the above-mentioned reflections and the ones calculated neglecting them.