WORLD MEETING ON LIGHTNING

LIGHTNING AND POWER SYSTEMS

Presented at the World Meeting on Lightning

Cartagena de Indias, Colombia

April 6-8

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LIGHTNING FLASH PARAMETERS

- Time interval between strokes
- Peak current for the first and subsequent strokes
- Flash and stroke duration
- Current time variations (impulse shape)
- Current time derivative (dI/dt - max. value, time function)
- Existence and nature of continuing current between strokes

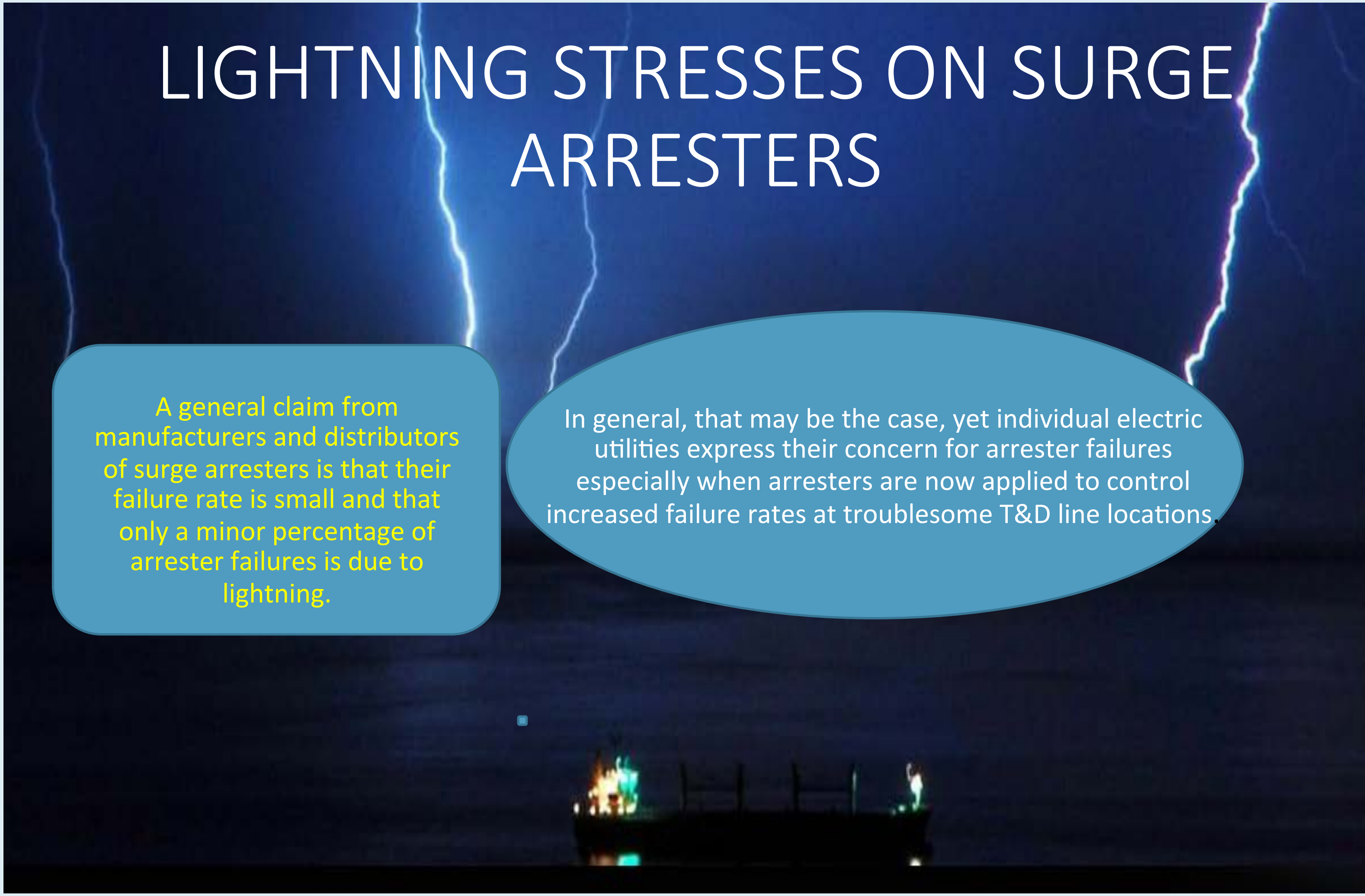
LIGHTNING STRESSES ON SURGE ARRESTERS

According to Rakov et al. (1994), around 50% of all flashes contain subsequent strokes with different spatial terminations on ground.

This means that the energy of all subsequent strokes is being discharged through the same path in about half of all CG flashes.

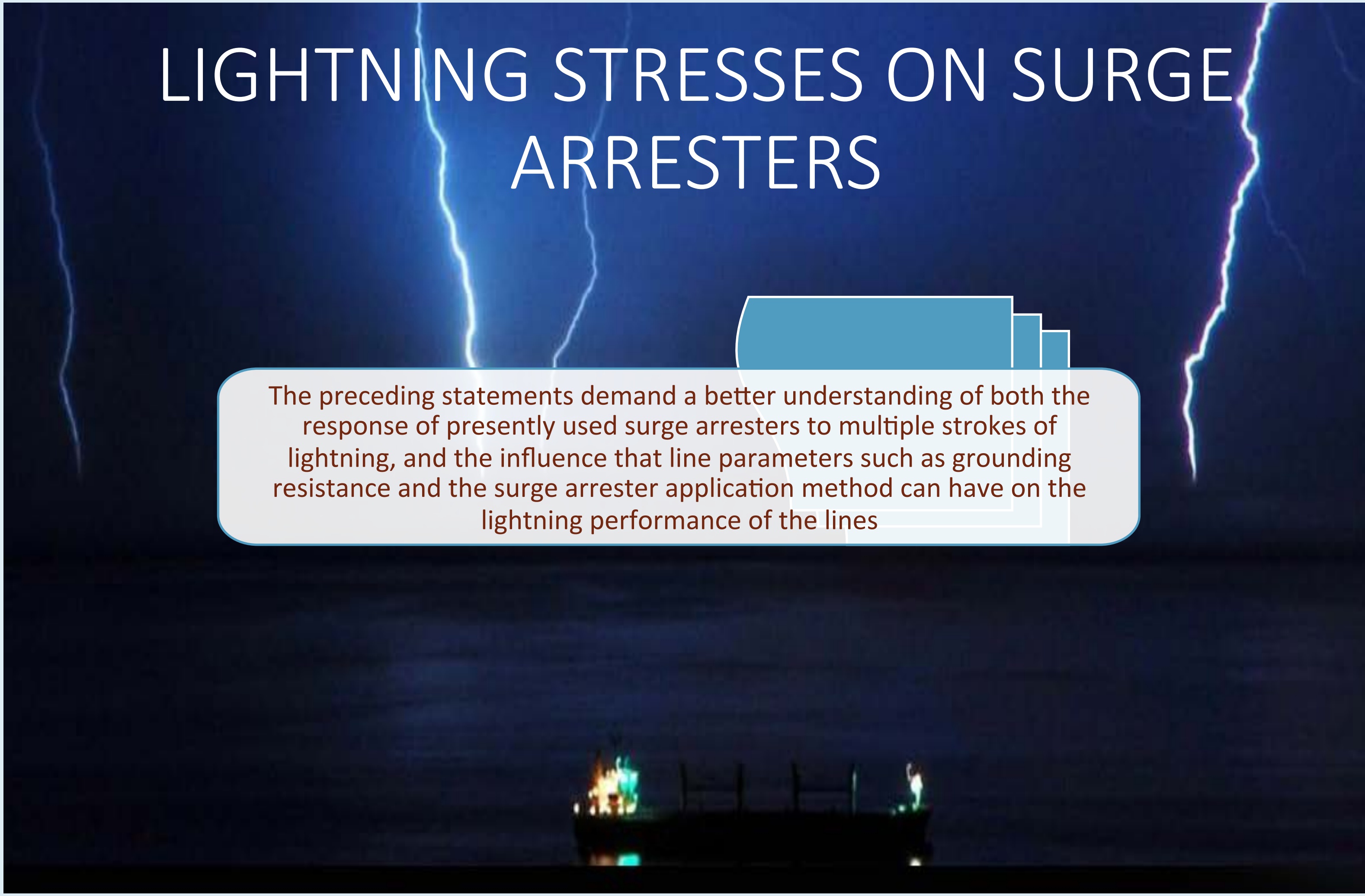
Protective surge arresters are thus experiencing the full multi-pulse stress in about 50% of the cases

LIGHTNING STRESSES ON SURGE ARRESTERS



A general claim from manufacturers and distributors of surge arresters is that their failure rate is small and that only a minor percentage of arrester failures is due to lightning.

In general, that may be the case, yet individual electric utilities express their concern for arrester failures especially when arresters are now applied to control increased failure rates at troublesome T&D line locations.



LIGHTNING STRESSES ON SURGE ARRESTERS

The preceding statements demand a better understanding of both the response of presently used surge arresters to multiple strokes of lightning, and the influence that line parameters such as grounding resistance and the surge arrester application method can have on the lightning performance of the lines

MULTI-PULSE EFFECTS

A significant finding in Darveniza et al. (1997), was that multi-pulse currents can give rise to changes in varistor characteristics that are not evident during tests with single impulses. This includes the possibility of varistor failures.

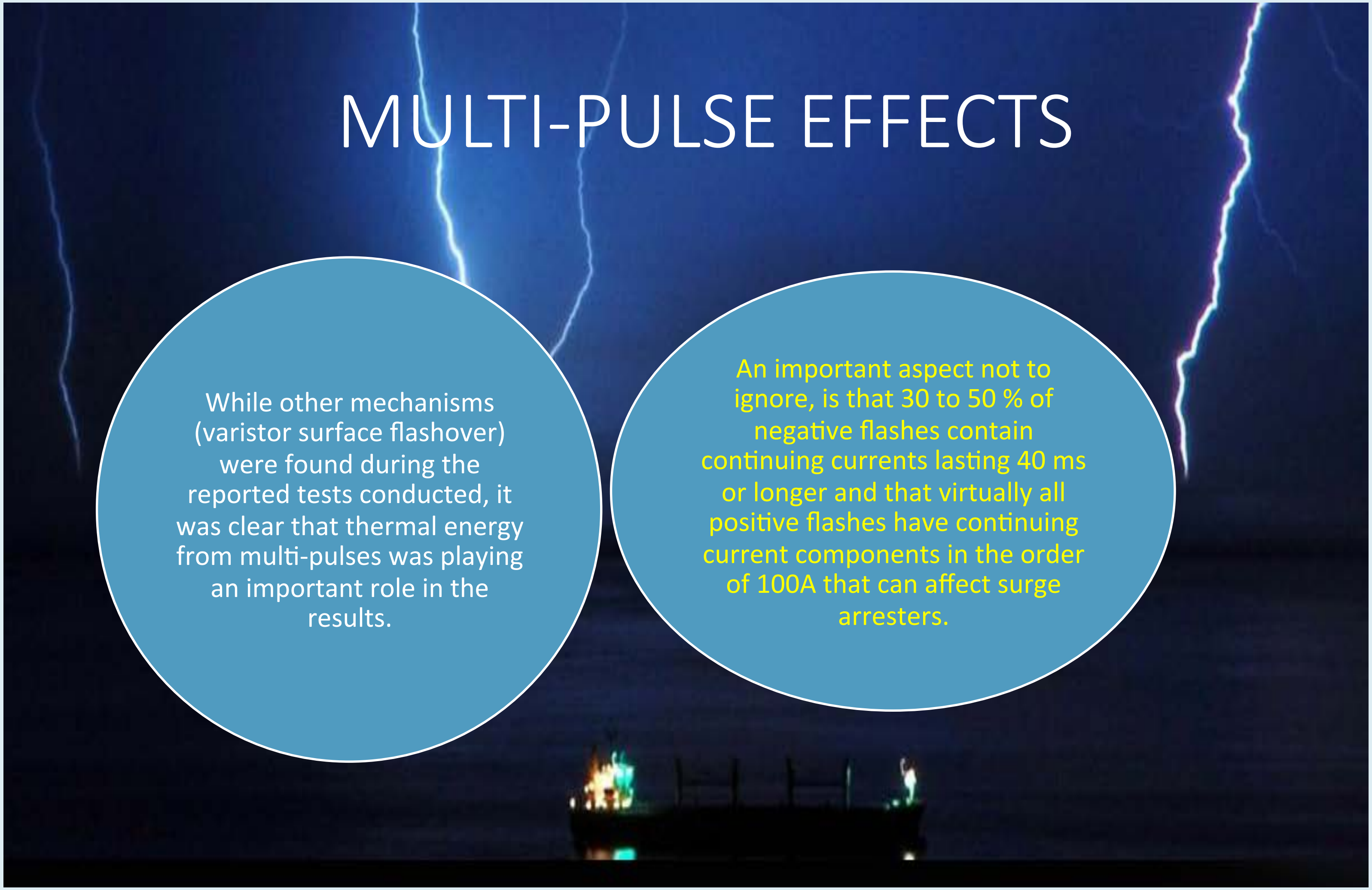
Based on their results, the Australian investigators established thermal stability, subsequent changes in residual and d.c. reference voltages, and power losses as the basic criteria to assess the effects of multi-pulse testing.

MULTI-PULSE EFFECTS

Recent findings suggest the likelihood that multi-pulsed lightning is playing a significant role in the deterioration process of the arresters.

The expected effect of multi-pulse lightning is a faster deterioration of the surge arresters. Failure modes in porcelain housed arresters have been largely attributed to moisture ingress in the past.

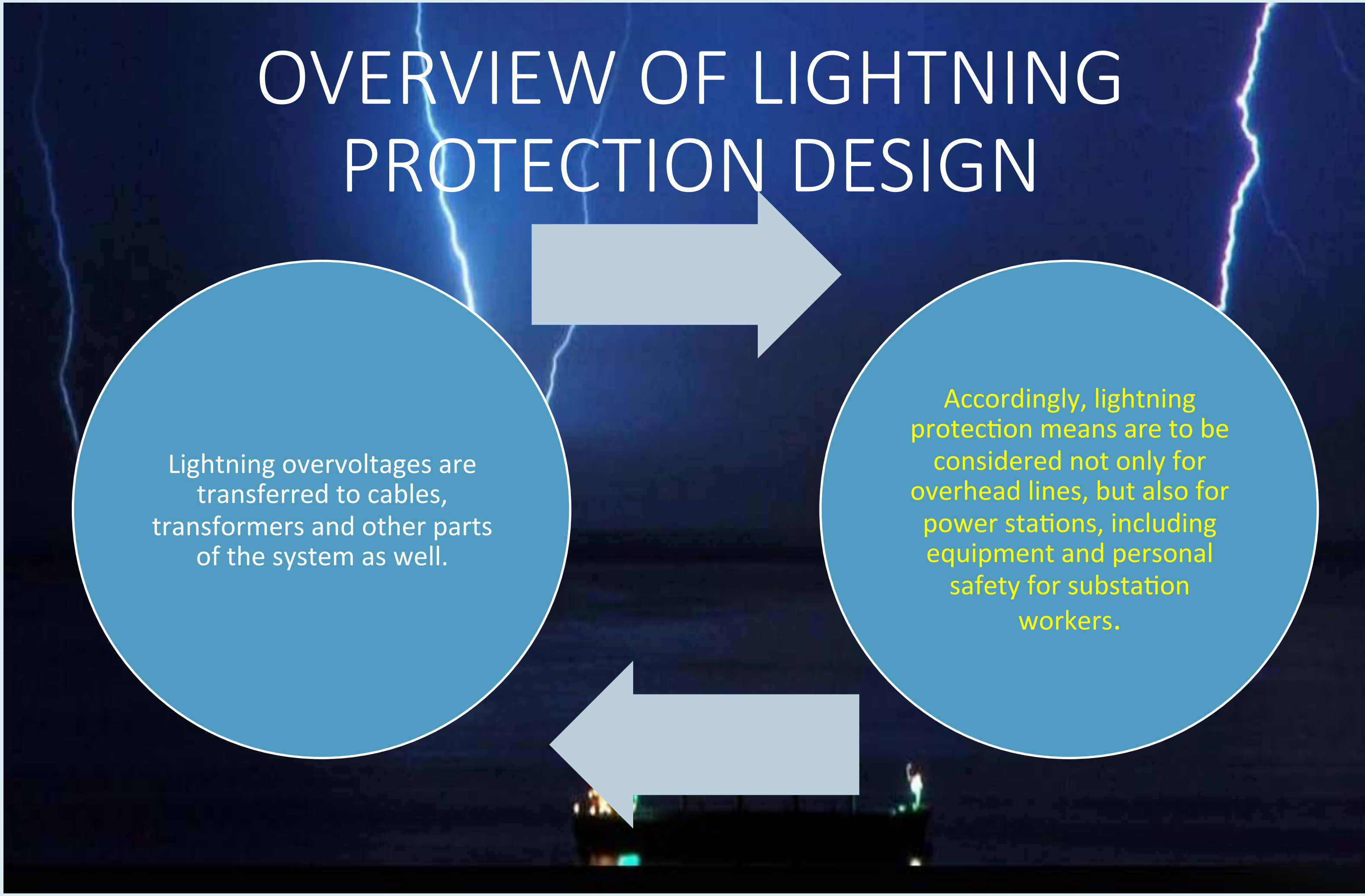
Polymeric housed arresters are expected to drastically reduce this problem due to their tight construction, which minimizes air space inside the arrester.



MULTI-PULSE EFFECTS

While other mechanisms (varistor surface flashover) were found during the reported tests conducted, it was clear that thermal energy from multi-pulses was playing an important role in the results.

An important aspect not to ignore, is that 30 to 50 % of negative flashes contain continuing currents lasting 40 ms or longer and that virtually all positive flashes have continuing current components in the order of 100A that can affect surge arresters.


OVERVIEW OF LIGHTNING PROTECTION DESIGN
Lightning overvoltages are transferred to cables, transformers and other parts of the system as well.
Accordingly, lightning protection means are to be considered not only for overhead lines, but also for power stations, including equipment and personal safety for substation workers.

SUMMARY OF EXISTING GUIDELINES

Lightning protection in power systems may be divided in two parts:

Station and Equipment protection.

Overhead line protection

Lightning is a major cause of transmission and distribution line outages, and in order to reduce this number to an acceptable rate, effective protection means have to be implemented. In this regard, shield wires and surge arresters are used.

SHIELD WIRES

Ideally, all lightning flashes should terminate on the shield wires and be able to discharge the current to earth through the towers without creating excessive overvoltages compared to the line insulation level.

In reality, due to practical design limitations and costs, a (low) probability of shielding failures and backflashovers will always exist.

These probabilities should in general be calculated in the line design process. Guidelines in this regard are presented in CIGRE Brochure 63 (1991).

SHIELD WIRES

By using the Electro Geometric Model (EGM), it is possible to design the shielding wires to protect against shielding failures involving flash currents below a few kA.

However, since the EGM is only an estimate, such predictions are an approximation. Nonetheless for a given shielding angle, the probability distribution of lightning peak current values determines the probability of shielding failure, and is therefore important in this regard.

SHIELD WIRES

On the other hand, the probability of flashover is determined by the insulation level (BIL) of the line, tower footing resistance, tower height, coupling factors between shield wire and phase conductors, tower separation and lightning current waveshape.

In order to make analyses of backflashover probabilities with reasonable accuracy, an advanced computation model and reliable input data are necessary. Main difficulties are the insulation withstand for irregular impulses of short duration, and ionization processes in the earth, which depend on soil and impulse characteristics (CIGRE Brochure 63, 1991)

SHIELD WIRES

Since the probability of flashover depends on the line insulation level, this implies that in the UHV range, outages caused by this kind of failures can be eliminated.

Due to this reason, shield wires on MV distribution lines to avoid direct flashes are not sufficient to prevent lightning-caused faults.

For lower system voltages, however, backflashover is the major cause of line outages.

In addition, for these voltage levels (11 - 33 kV system voltage) induced voltages due to flashes near the line are also of concern.

LINE SURGE ARRESTERS

Surge protective devices (surge arresters) across the line insulation have been introduced. Preliminary operational experiences in this regard are promising, (CIGRE Report WG33.11 TF-3, 1997), and further studies are underway.

Major concerns in this regard are the current and energy stresses on the arresters in relation to their withstand capacity.

Theoretical calculations based on recommended lightning current statistical distributions (including stroke multiplicity) have indicated a relatively high risk of arrester failures, especially for lines without earth wires.

However, these results seem not to fit with the preliminary experience. More studies are therefore needed.

LINE SURGE ARRESTERS

It is clear that reliable input data (statistical probability distributions) of lightning incidence (Ng, etc.) and lightning current characteristics are essential for analyses of overhead line protection.

In order to make meaningful analyses of the protective effects of shield wires as well as line surge arresters, such data are necessary.

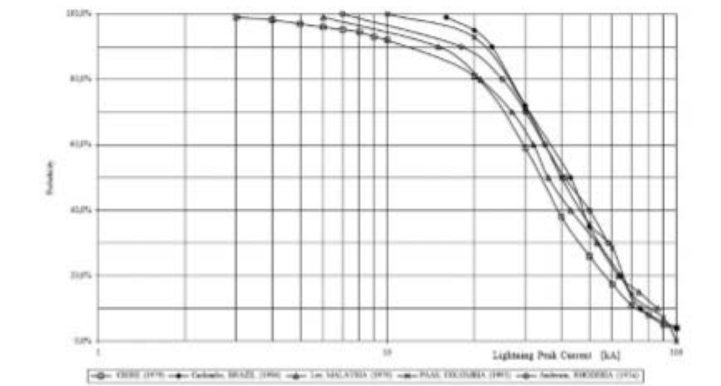


Figure 1. Comparison of Cumulative Distribution of Lightning Peak Current Distribution between CIGRE and four Tropical Sites (Malaysia. Rhodesia, Brazil and Colombia)

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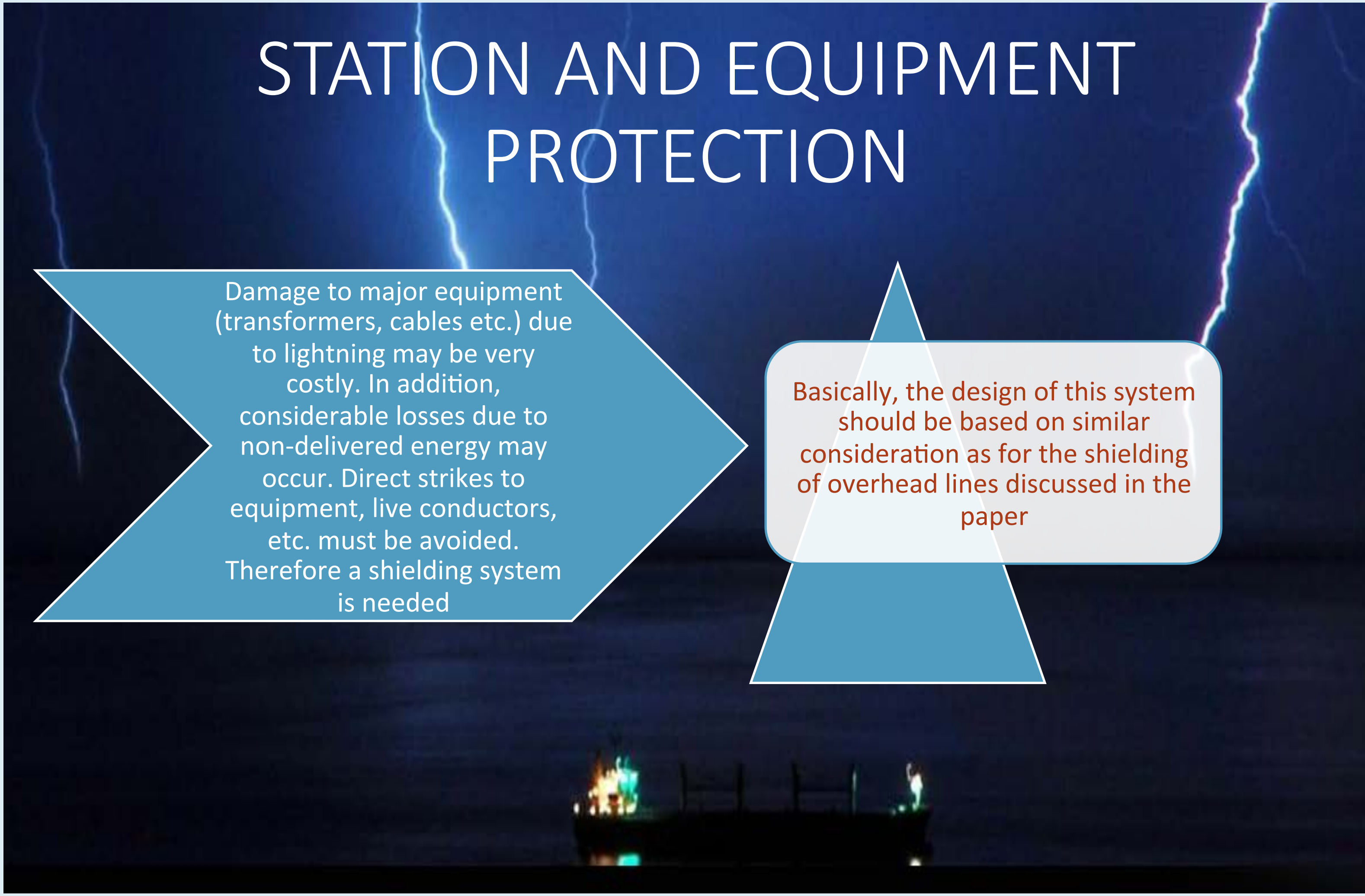
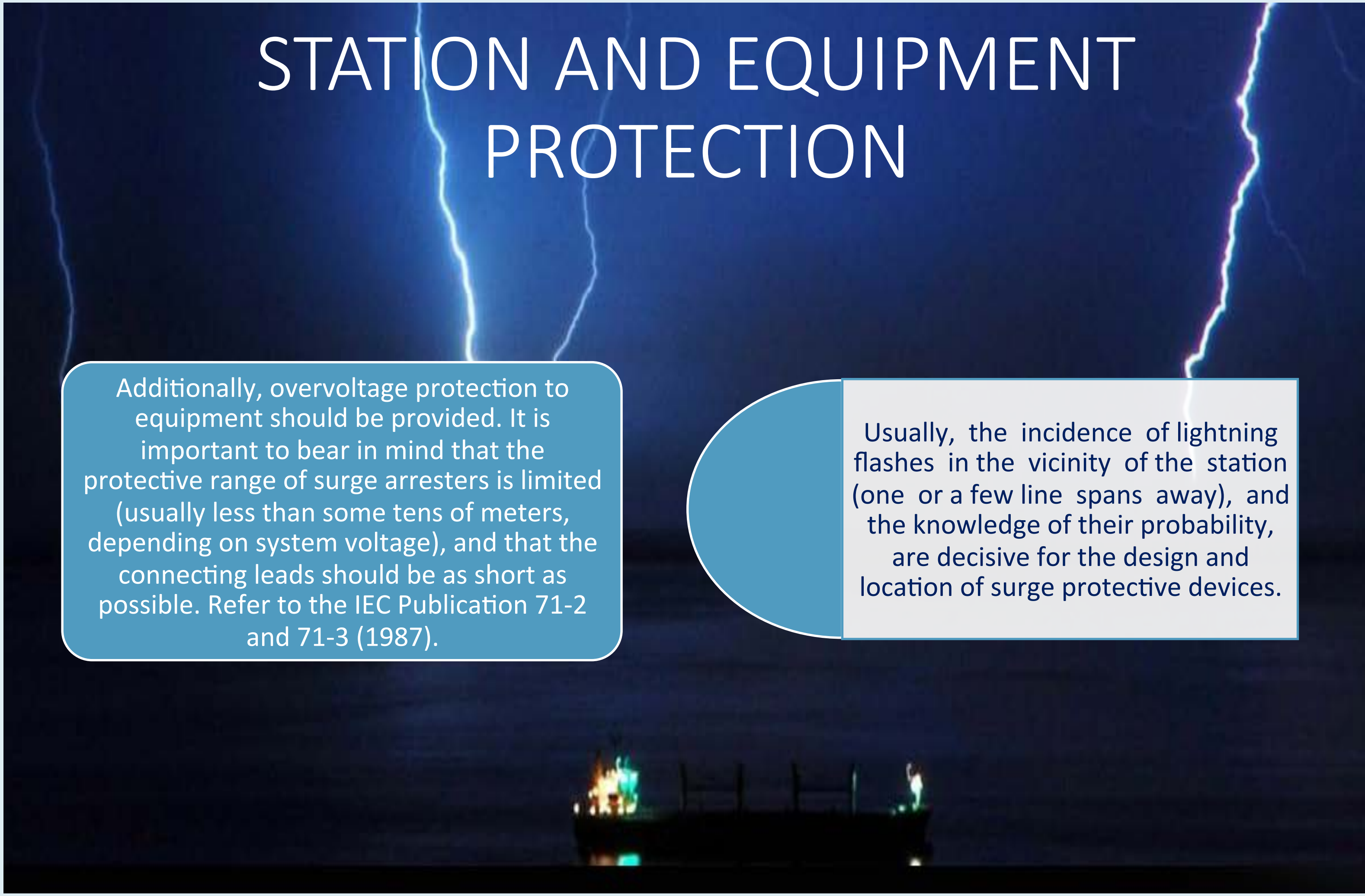


STATION AND EQUIPMENT PROTECTION

Damage to major equipment (transformers, cables etc.) due to lightning may be very costly. In addition, considerable losses due to non-delivered energy may occur. Direct strikes to equipment, live conductors, etc. must be avoided. Therefore a shielding system is needed

Basically, the design of this system should be based on similar consideration as for the shielding of overhead lines discussed in the paper

STATION AND EQUIPMENT PROTECTION



Additionally, overvoltage protection to equipment should be provided. It is important to bear in mind that the protective range of surge arresters is limited (usually less than some tens of meters, depending on system voltage), and that the connecting leads should be as short as possible. Refer to the IEC Publication 71-2 and 71-3 (1987).

Usually, the incidence of lightning flashes in the vicinity of the station (one or a few line spans away), and the knowledge of their probability, are decisive for the design and location of surge protective devices.

LIGHTNING COUPLING TO NEARBY POWER LINES - Mexican Study

De la Rosa et al. (1988) provided input on the coupling between lightning electromagnetic fields and the voltage induced in nearby power lines over a finitely conducting ground i.e. considering the effect of the voltage developed on the line due to the horizontal component of the electric field.

This was done based on extensive measurements on an experimental line in Mexico, where a 13.8 kV, 10 m high, 2.8 km distribution line was equipped with instrumentation at both ends and lightning electric fields and the associated induced voltages along with location of lightning relative to the line were recorded simultaneously.

This work was carried out with the cooperation of the Mexican Institute of Electrical Research (IIE), the Institute of High Voltage Research of Uppsala University (IfH), the Norwegian Research Institute of Electricity Supply (EFI) and ASEA Research (Sweden).

Measurements included the voltage at one or the two ends of an experimental line and the corresponding electric field produced by close lightning.

LIGHTNING COUPLING TO NEARBY POWER LINES – Mexican study

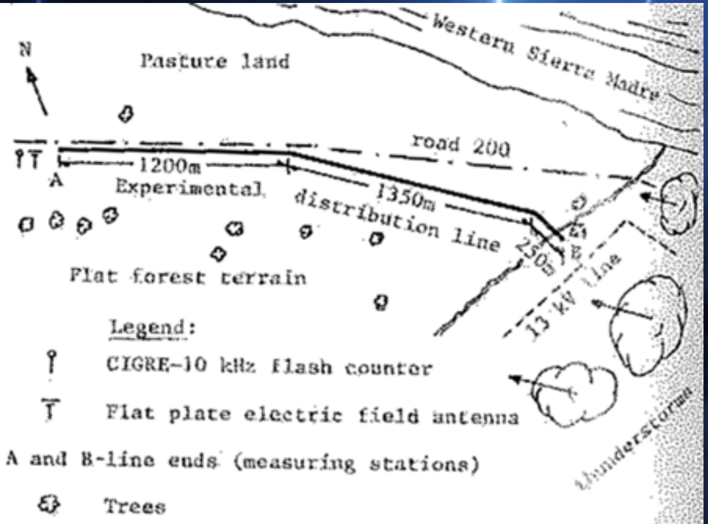
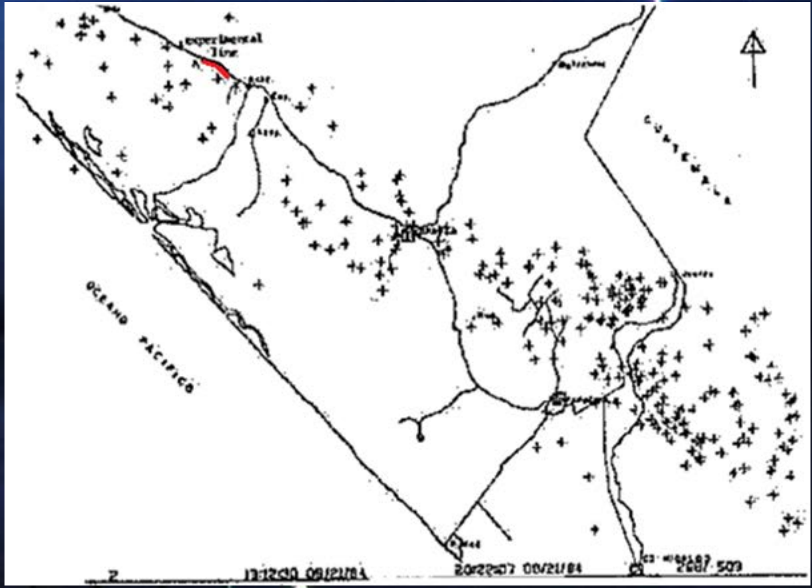


FIGURE 1 The 13 kV experimental distribution line in Southern Mexico.



LIGHTNING COUPLING TO NEARBY POWER LINES - Mexican Study

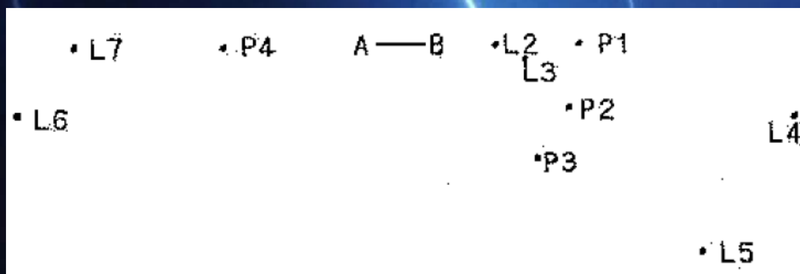
Results included induced voltage waveform variations in the sub- microsecond region and a voltage waveform and polarity clearly related to the position of lightning relative to the line.

It was also found that lightning strokes terminating on ground close to distribution lines can create large overvoltages capable of producing insulation flashover.

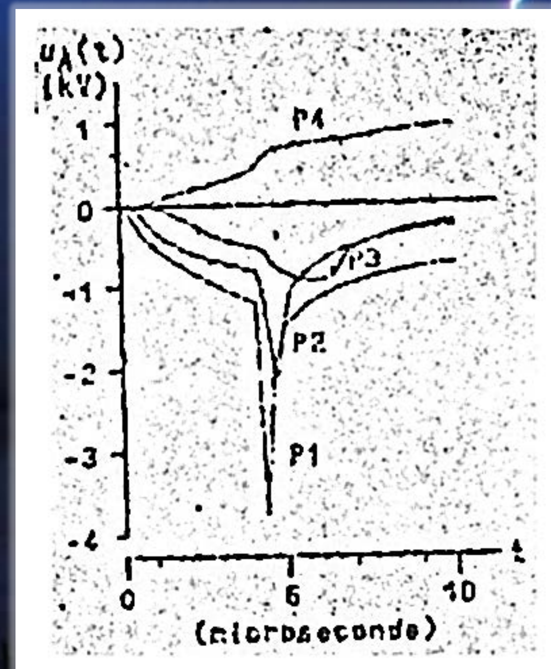
It was shown that waveforms and peak values of lightning induced voltage at the ends of the line were greatly affected by the ground conductivity and the lightning striking points.

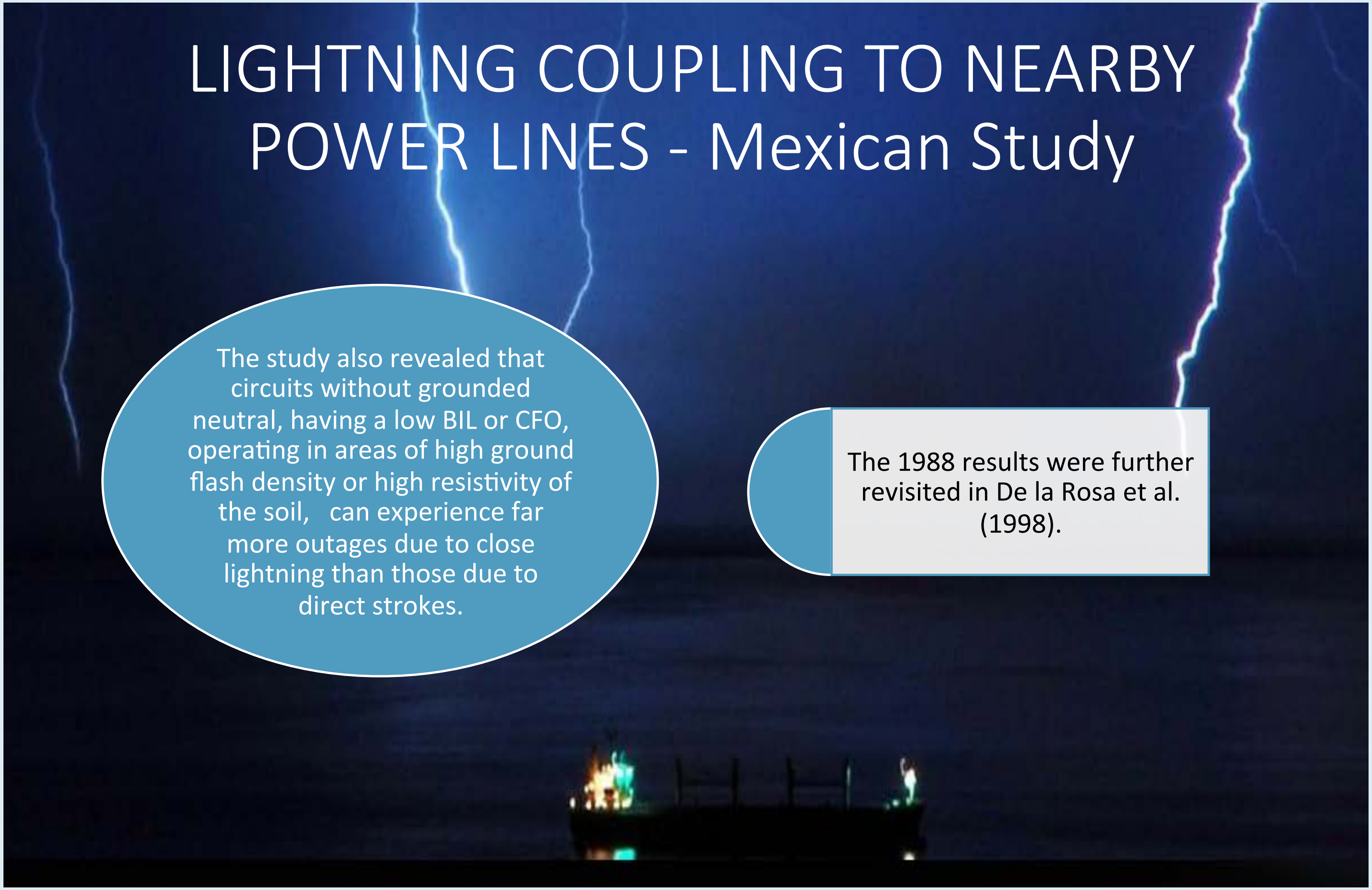
This confirmed that the coupling of lightning electromagnetic fields had to include the contribution of the soil resistivity, and a close agreement was found between the adapted transmission line model and the experimental measurements.

LIGHTNING COUPLING TO NEARBY POWER LINES – Mexican Study



Lightning position in Fig. 10	Calculated Peak Voltage (kV) for ground conductivity:		Measured Voltage (kV)
	10^{-2} Si/m	10^{-3} Si/m	
L1	− 1.5	− 8.0	− 1.4
L2	−12.0	−46.7	−11.6
L3	− 5.8	−14.8	− 4.0
L4	− 9.6	−27.9	− 5.8
L5	− 3.8	−15.5	− 2.9
L6	+ 2.7	+ 7.7	+ 3.0
L7	+ 3.0	+ 7.4	+ 2.9




LIGHTNING COUPLING TO NEARBY POWER LINES - Mexican Study
The study also revealed that circuits without grounded neutral, having a low BIL or CFO, operating in areas of high ground flash density or high resistivity of the soil, can experience far more outages due to close lightning than those due to direct strokes.
The 1988 results were further revisited in De la Rosa et al. (1998).

FUTURE DIRECTIONS

New directions in this area are expected to include more statistical correlations between lightning parameters, aimed at improving the assessment of lightning-related outages and damage to electric power installations in different world regions.

It will be important to have additional studies of spatial and temporal variations of lightning

Likewise, new research on improving lightning protection of distribution lines should be pursued.

Finally, there is a need for more guidance and improved models to evaluate the effect of multi-pulse lightning and continuing currents on lightning surge arresters and other protective devices in electric power installations and industry.


And that's all for now
Thank you!
Muchas Gracias!