VI Russian Conference on Lightning Protection

17th – 19th April, 2018
Saint Petersburg

Cost-Benefit Analysis of Lightning Protection Systems in Distribution Networks

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Outline

- ✓ Introduction
- ✓ Description of the Model
- ✓ Application and Results
- ✓ Conclusions

Introduction

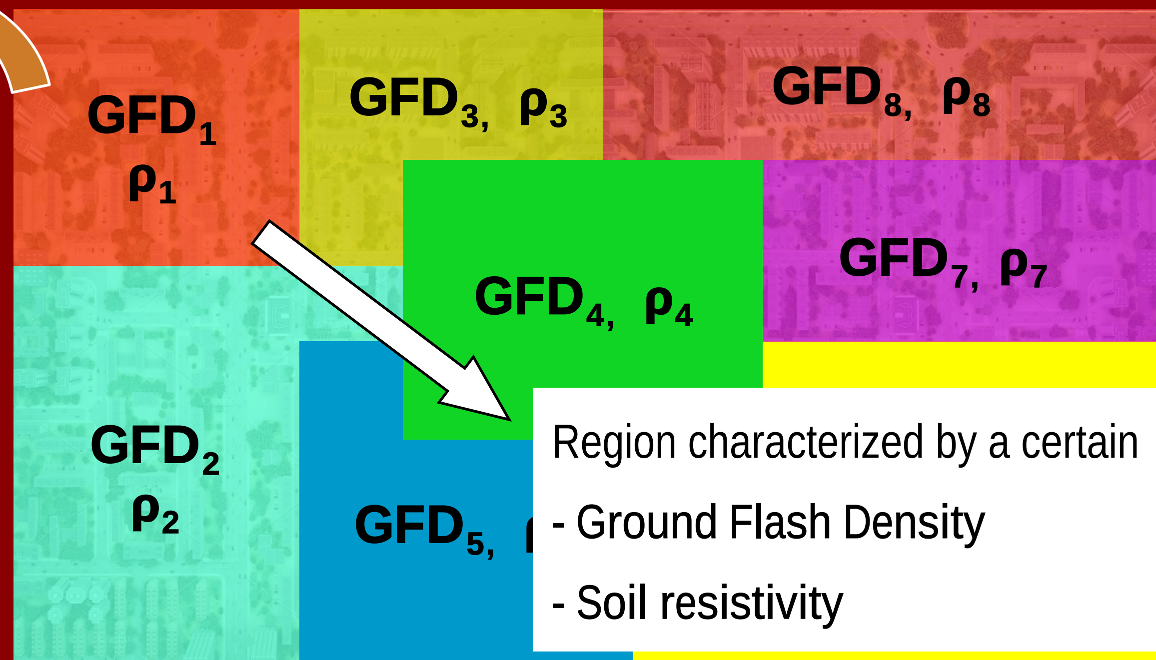
- ✓ Lightning is one of the most important sources of power quality problems in distribution networks
- ✓ Different power protection systems can be used to improve the performance of a particular network
- ✓ But the selection of the most appropriate one requires the knowledge of their effectiveness
- ✓ And this effectiveness depends on the region (soil characteristics) where the system is to be implemented
- ✓ So, how can one choose the most cost-effective system?

Let's consider that this is the concession area of a power utility

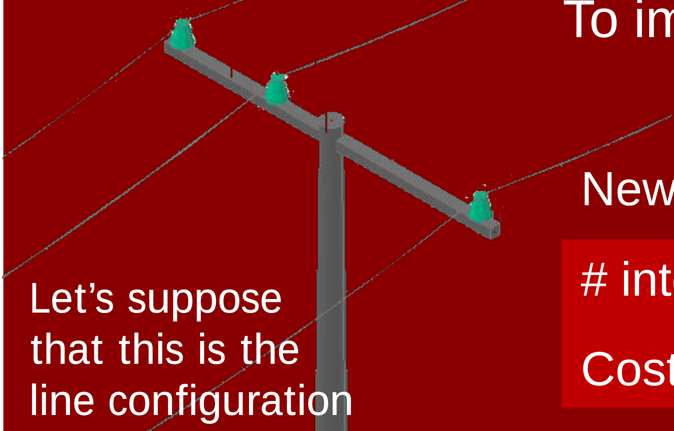
- **Is it worth the investment?**
- **How should it be made?**
- **Where and how to invest?**

Lightning is responsible for:

- high # of supply interruptions
- damages to power equipment
- indemnifications paid to consumers



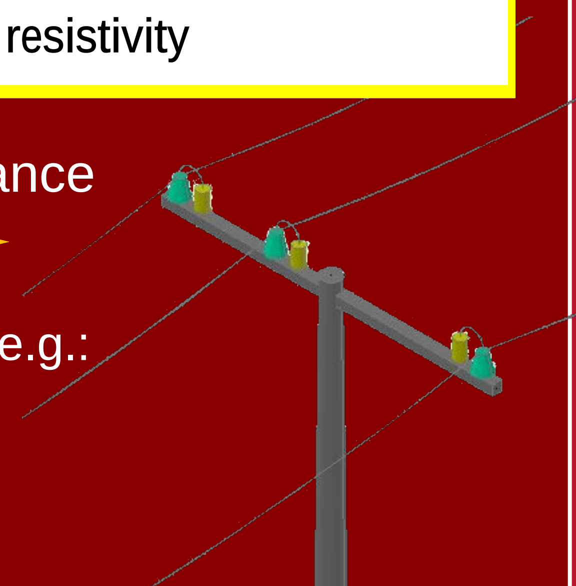
Region characterized by a certain
- Ground Flash Density
- Soil resistivity



Let's suppose that this is the line configuration

To improve the lightning performance

New line configuration is proposed, e.g.:



# interruptions:	X → X / 4
Cost / km of the line:	Y → 2 Y

So, this paper is about decision-making

The objective is to present a model to analyze the economic viability of protection systems with different effectivenesses in terms of avoided lightning-caused interruptions

To account for the benefits in monetary terms, we need to calculate the losses

The losses of the power utility has four components:

$$L_{Utility} = L_{Rev} + L_{Fines} + L_{Reinburse} + L_{Transf}$$

L_{Rev} = Losses of revenue as function of the energy not supplied

L_{Fines} = Losses due to fines applied by the regulator

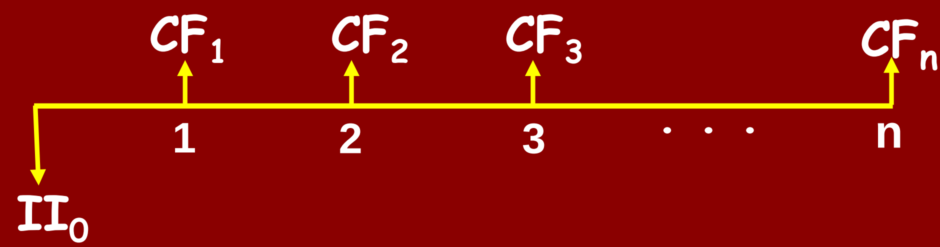
$L_{Reinburse}$ = Losses due to reimbursement of claims coming from consumers who had damaged equipment

L_{Transf} = Losses due to lightning-caused transformers' damages

The Model assumes that each system requires a certain initial investment (II_0) & each one has its own projected benefits

- ✓ Projected benefits correspond to avoided losses (future Cash Flows or CF_t)
- ✓ The Present Value of each CF_t is a function of the discount rate “r” and “t”
- ✓ The Net Present Value (NPV) is a function of “r” and “t”

$$PV_{CF_t} = \frac{CF_t}{(1 + r)^t}$$



$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1 + r)^t} - II_0 \;\; \begin{matrix} > \\ = \\ < \end{matrix} \;\; 0$$

NPV = Net Present Value

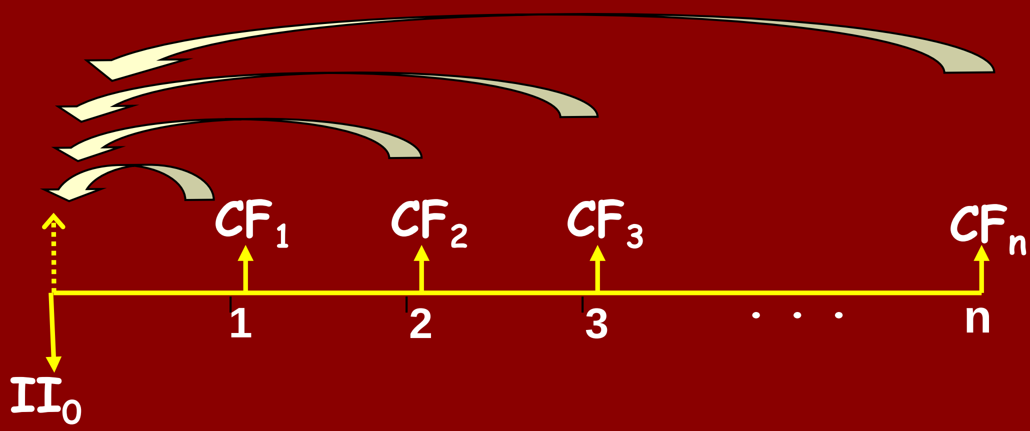
CF_t = Cash Flow in time t (Flow of benefits or avoided losses)

II_0 = Initial Investment in the LPS that is made t = 0

r = Discount Rate (when NPV = 0 → r = IRR)

The Model calculates the Discount Rate for each system that makes the NPV = 0, which is the IRR

The IRR is the rate that balances all Present Values of the "n" CFs, making them equal to the Initial Investment.



IRR is the Discount Rate that makes NPV = 0.

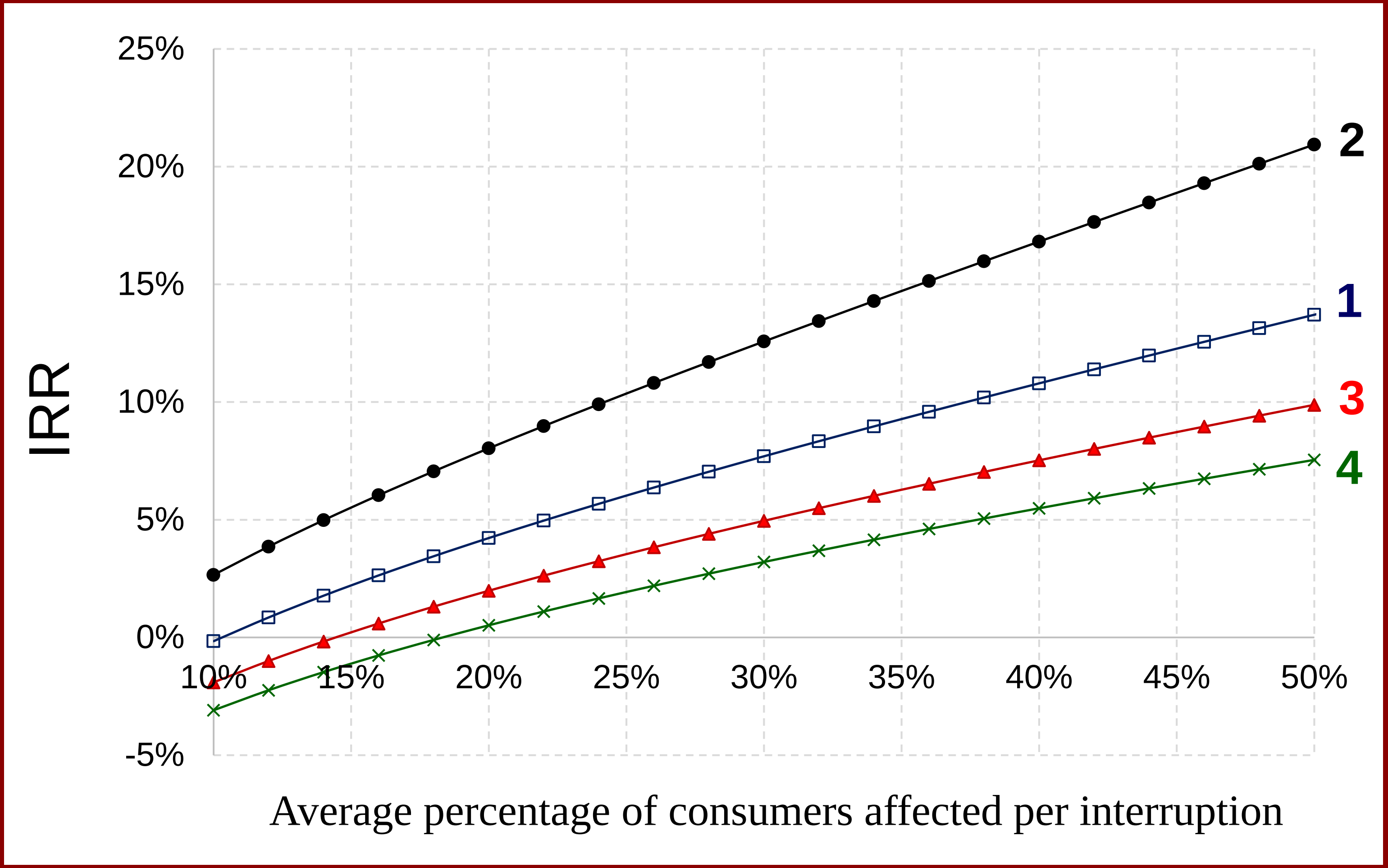
$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1 + r)^t} - II_0 = 0 \Rightarrow \sum_{t=1}^{n} \frac{CF_t}{(1 + IRR)^t} = II_0$$

NPV	=	Net Present Value
CF_t	=	Cash Flow in time t (Flow of benefits or avoided losses)
II_0	=	Initial Investment in the LPS that is made t = 0
r	=	Discount Rate (when NPV = 0 → r = IRR)

Let us consider 4 hypothetical Lightning Protection Systems with different effectivenesses and costs

Lightning Protection System	Effectiveness of the Protection System in reducing lightning interruptions	Cost (BR$)
1	10 %	2,000,000
2	30 %	4,000,000
3	60 %	16,000,000
4	85 %	28,000,000

Each System has its own IRR and this IRR varies according to the % of consumer affected



➔ This approach does not include social losses

There are also damages which are incurred by consumers (social losses), besides those of the P.U.

The social losses have two components:

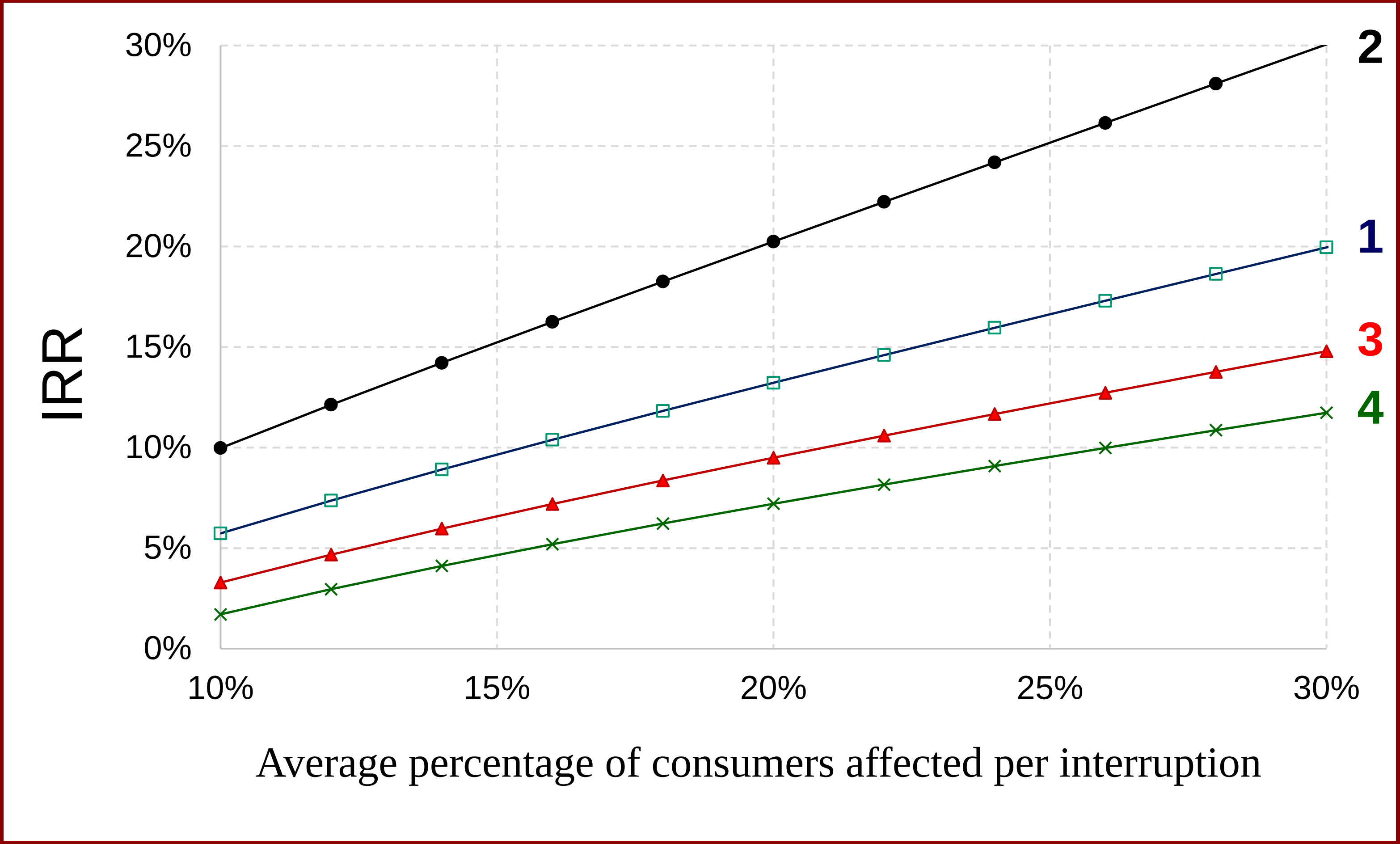
$$L_{Social} = L_{Services} + L_{GDP}$$

$L_{Services}$ = Losses incurred by consumers who pay for internet and cable TV and were prevented from profiting from these services

L_{GDP} = Losses in the annual Gross Domestic Product of the region due to lightning-caused interruptions

When we recalculate the IRR including the avoided social losses as benefits, all curves shift up

As a consequence, there is an increase in the IRR of all four systems considered



Conclusions

- The proposed model enables the analysis of the economic feasibility of lightning protection systems in distribution networks taking into account social aspects that go beyond those commonly considered

- The inclusion of avoided social losses as part of the benefits obtained by the investment ↑ the model's adherence to reality and proved to be important in the process of feasibility analysis

- The application of the model, with the use of accurate data provided by the distribution company, enables important information to be obtained in support of investment decision-making

And finally…

- The average number of consumers affected by interruption stood up as an importance variable to determine economic viability

- Developing countries such as Brazil, where the cost of capital is very high, should face more difficulties in enabling investments in protection systems, especially in regions with: (i) large network extensions; (ii) low population density; and (iii) low local income

THANK YOU FOR YOUR ATTENTION!

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We start by defining the effectiveness of a Lightning Protection System...

$$\text{Effectiveness of a Lightning Protection System} = \frac{\text{\# lightning-caused interruptions before the System implementation} - \text{\# lightning-caused interruptions } \underline{\text{after}} \text{ the System implementation}}{\text{\# lightning-caused interruptions before the System implementation}}$$

Now let's recalculate the IRR including the avoided social losses as benefits