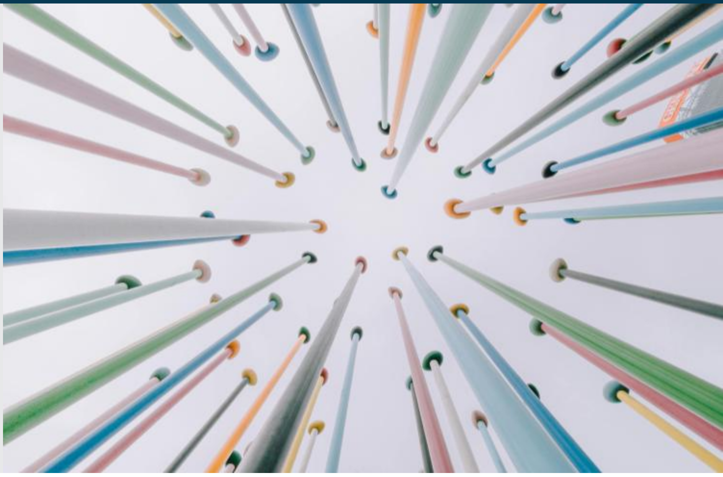
SUCCESS CASE 34.2025

Probabilistic Characterisation of Energy Flows

IDENTIFYING THE PROBABILITY OF CONSTRAINTS AND RISKS ASSOCIATED WITH NEW ENERGY FLOWS



THE CHALLENGE

The planning of the development of the electrical network has undergone significant changes. Historically, with electricity distribution unidirectionally connecting the transmission network to the consumer, planning focused on peak consumption periods to predict future investment needs. This model has changed with the energy transition and particularly with the exponential growth of distributed generation. The distribution network is now facing a **shift in the energy flow paradigm** which is introducing increasing complexity and requires the **creation of new planning methodologies and tools**.

THE SOLUTION

The digitalisation of power networks and the increase in computational capacity have fostered the development of **innovative tools for creating new planning models**. In 2015, E-REDES began developing **probabilistic planning methodologies**, resulting in new analytical models incorporated into the DPLAN, i.e. the distribution planning power flow calculation tool. These models involve processing large volumes of data, and require exercises to typify average behaviours and to probabilistically combine the dynamics of consumption/production of loads. This necessitated changing the way E-REDES characterised and projected energy flows, using data analytics techniques such as clustering and transition probability matrices, known as Markov chains. Probabilistic planning is thus supported by **network performance simulations**, based on synthetic load diagrams that reflect consumption/production behaviour according to past probabilities. Figure 1 on the next page shows the probabilistic result of a conductor overload. The same methodology is applied to all network installations, from substations and transformer stations to delivery points at high, medium, and low voltage.

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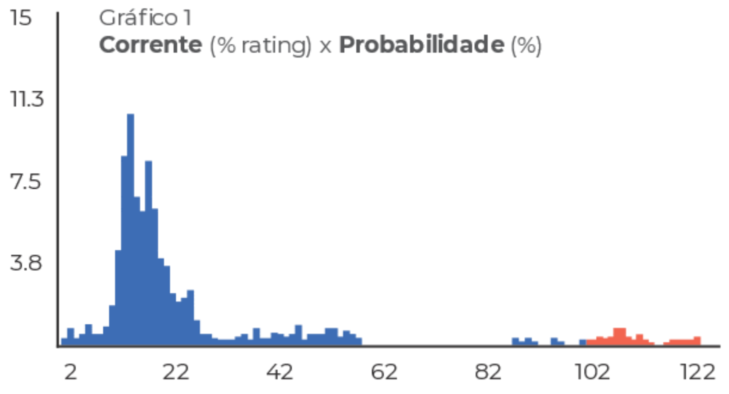

Figure 1. Probabilistic result of a conductor overload. In this case, the conductor has a low probability of being overloaded (in red). This conductor is typically operated at less than 60% of its capacity, predominantly between 10% and 25%.

The dimensions tackled by this solution are:

- **Typification of the behaviour of loads connected to the network**. Each installation is associated with a sequence of twelve most common diagrams for that installation, representing weekdays, Saturdays, and Sundays of each season – along with their respective statistical parameters: mean and standard deviation (see Figure 2). The typical diagrams are then normalised and grouped according to consumption patterns (according to the Bisecting K-Means algorithm).
- **Characterisation of the intraday dynamics of the loads of each type of installation**. Transition probability matrices between load states are constructed Using Markov Chains, allowing the subsequent generation of synthetic consumption/production diagrams.

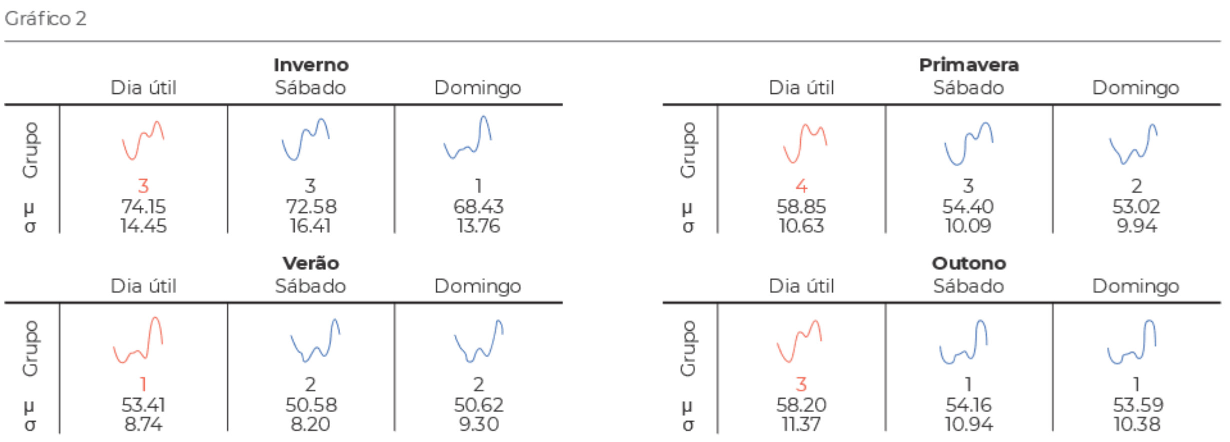

Figure 2. Example of a sequence of twelve most common diagrams for an installation used for its typification.

THE RESULTS

Identifying potential constraints and predicting the probability of occurrence of constraints not only enhances the effective and efficient use of the network but also **supports management decisions**, allowing, for example, the prioritisation or **consideration of new investments against alternative solutions**, such as contracting flexibility services. In summary, the probabilistic characterisation of loads provides:

- **Greater accuracy**, enabling studies based on the real dynamics of the network and not just peak values. The use of theoretical and static simultaneity factors is no longer necessary.
- **Greater comprehensiveness**, identifying annual constraints with quarter-hourly resolution, respecting the probabilities of historical occurrence.
- **Eased characterisation of new connections**, allowing associating load patterns with future installations, according to the typification of existing ones.