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Applying Operations Research Algorithms to optimize Field Service on High-Voltage Networks

High-voltage networks are technological infrastructures of vital importance for energy transmission. Safety, continuity, and quality of service are ensured by a wide range of recurring and extraordinary maintenance activities. These activities are performed by numerous and heterogeneous teams covering very large areas, where the traditional decision-making approach based on the sole human expertise is not always enough.

What is Operations Research?

Operations research is a sub-field of applied mathematical sciences aiming at **analyzing and solving complex problems** through **mathematical models**

and **advanced quantitative methods** to develop specific approaches to **support** both **decision-making** and strategic processes.

Its importance is shown in contexts where there are **too many possible solutions** to a problem to evaluate. Therefore, the number of acceptable solutions grows exponentially or factorially compared to the input size of the problem.

The case described encompasses all those situations where it is essential to **decide how to engage and coordinate limited resources and activities complying with the constraints set and**, at the same time, **maximize the benefits** deriving from the correct resource allocation.

On a practical level, operations research focuses on constructing a mathematical model to describe the problem and elaborate an optimal or near-optimal solution, by considering all stages of the decision-making process, that is:

- Problem definition;
- Analysis of the reality and data collection;
- Model construction;
- Identification of one or more solutions;
- Analysis of the outcomes.

Operations research has strong ties with other disciplines, like mathematics, computer science, economics, and engineering, and has become common practice in several fields. Recently, it has experienced a growing applicability in business activities as it enables organizations to **make better decisions and reach the goals set**, always respecting the constraints imposed from outside which can be barely controlled by the decision-maker.

The Complexity of Maintenance on Power Lines

A power line is a network infrastructure to transmit high-voltage electrical energy consisting of overhead, underground, or submarine lines.

High-voltage lines (220 kV - 132 kV) are generally overhead and have two or more conductors hanging between two metal towers and properly insulated from them. High-voltage three-phase current is transmitted to urban areas where dedicated substations firstly step it down to values between 5 and 20 kV and secondly transform it to single-phase current, which is commonly required by home appliances.

Maintenance activities on installations like these are critical to ensure both **continuity** and **quality of service**. They mainly consist in:

- Visual **monitoring** of infrastructures and ground clearance between conductors;
- Periodically **planned activities** (e.g. cleaning and replacement of insulators, cleaning of foundations, bush clearing so as to avoid any possible ground discharges);
- **Extraordinary activities** to **remove anomalies detected** (e.g. replacement of spacers or marking spheres, repairing of failures on conductor strands or guard cables, creation of joints);
- **Emergencies** following alerts or accidents;
- Network **demolition and modernization.**

The complexity lies in managing both recurring and extraordinary operations, whose **heterogeneous** nature requires the intervention of **numerous teams** composed by considering **various operational constraints and the resources' skills**. Moreover, to ensure continuity of service, activities should be carried out **within a set time** and all through the territory where the network is installed, with the consequent need to **optimize travel** to intervention sites over extremely large areas.

How Operations Research Supports Field Service on High-Voltage Networks

The applicability and the impact of operations research on the organization of business activities are meeting a growing success. With **enterprise systems** becoming increasingly **complex** and the consequent need to **manage considerable amounts of data**, automatic decision-making tools have seen their rise as essential solutions to tackle large-scale problems through algorithmic processing, thus outclassing the old decision-making approach based on the sole human expertise, which proves to be suitable only when the information provided and the complexity of systems were lower.
When applied to Field Service activities to be performed on high-voltage networks, operations research algorithms can be broken down into three steps of evolutionary generations:

- **Task planning algorithms**. As mentioned before, maintaining an extensive network such as in the case of high voltage, requires the management and the organization of a variety of interventions, with different timings and features, including planning over time and emergencies.

When “fed” with the activities to be performed on the network (scheduled operations, warnings, emergencies, and anomalies detected during monitoring) and constraints for their execution (time, duration and priority of interventions, working timetable, lunch break, overtime work, skills and availability of resources, travel time, compliance with Service Level Agreements, materials and equipment stocked), operations research algorithms can efficiently support planners during the organization stage, creating the optimized route for resources as to maximize the useful working hours dedicated to operational activities and minimize any possible periods of inactivity and losses of time traveling over a large area.

To obtain the best possible schedule of activities, several operations research algorithms can be adopted, such as: greedy replenishment, local optimization, random improvement, and minimum spanning tree.

- **Team creation and task assignment algorithms**. The second evolutionary step consists of automating the team creation, taking into consideration the complexity of the activities to be performed on a high-voltage network, and the consequent need to deploy heterogeneous teams.

  In this case too, operations research provides the best solution taking into account various constraints, such as the resources’ compatibility, the correspondence of their working hours, and the complementarity of their skills.

  In this case, in order to obtain better results and an optimal ranking of teams among which to choose the most performing one to deploy, several algorithms available in literature can be adopted, such as: weight optimization, best ranking, heuristic, and combinatorial approaches.

- **Applying Artificial Intelligence to team creation algorithms**. The third evolutionary step through which operations research can support Field Service on high-voltage networks consists in feeding algorithms with experience-based suggestions, to improve the creation of teams in a proactive way.

  AI, and specifically all Machine Learning branches, provide algorithms that autonomously optimize performance both by analyzing historical-statistical data and by learning from human experience, thus processing all possible future situations the planner may face over time. This way, even the most complex scenario characterized by maintenance problems on a power line can be predicted and assigned to teams adequately and correctly composed.

Why Optimize Activities Applying Operations Research Algorithms?

Many and varied are the benefits deriving from the use of operations research algorithms to manage maintenance procedures on high-voltage networks, paving the way for the **rationalization of the overall process for scheduling activities**, from their **assignment** to field teams to a **boost in efficiency** when actually performing them.

- **Improved capacity to manage interventions**. A more effective engagement of human resources results in an improved optimization which means greater availability of operators and therefore the management of a higher number of field activities, without the need for overtime work or outsourced teams.

- **Better management of complex intervention plans**. By optimizing the scheduling and assignment of activities to resources on the basis of various parameters (e.g. emergencies, skills, and geolocation of plants), operations research can face even the most complex yet typical work calendar for maintenance activities on power lines, thus simplifying the general management and reducing the planner's workload.

- **Higher efficiency of operational resources**. When creating optimal teams considering an endless number of combinations of resources according to their skills and past performance, field interventions are concluded more quickly and efficiently, thus leading to improved results for the company.

- **Forecasting**. By analyzing large amounts of data from past interventions on the network, operations research algorithms can predict future activities and the required resources, providing the planner with a comprehensive and long-term overview of the workload, to make improvements in time in case any corrective actions should be performed.