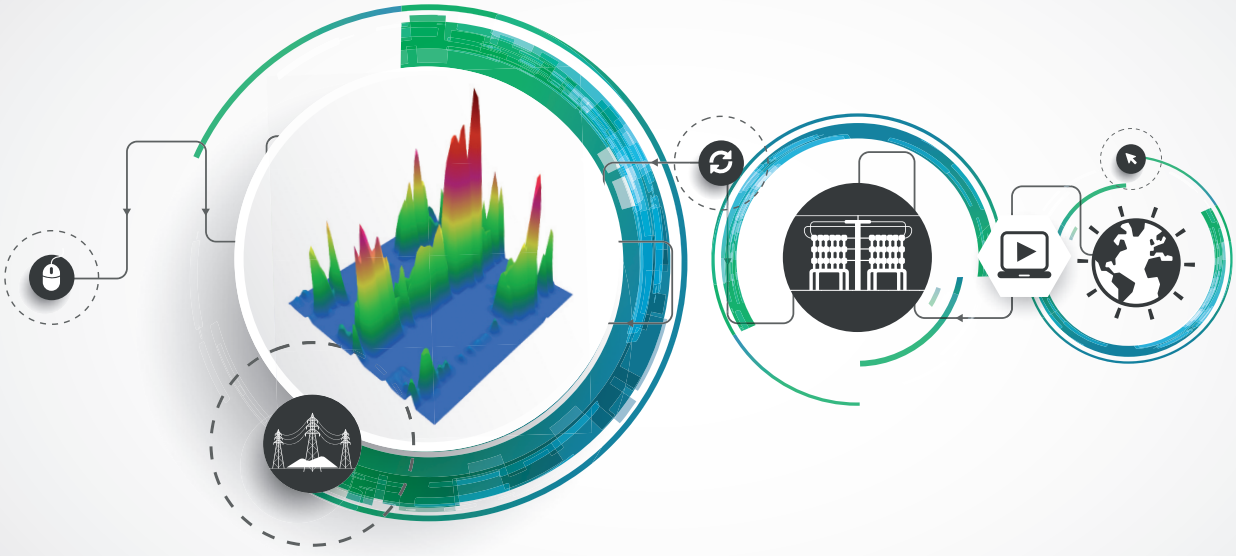


GRARE

GRID RELIABILITY AND ADEQUACY RISK EVALUATOR

DEVELOPED BY

CESI

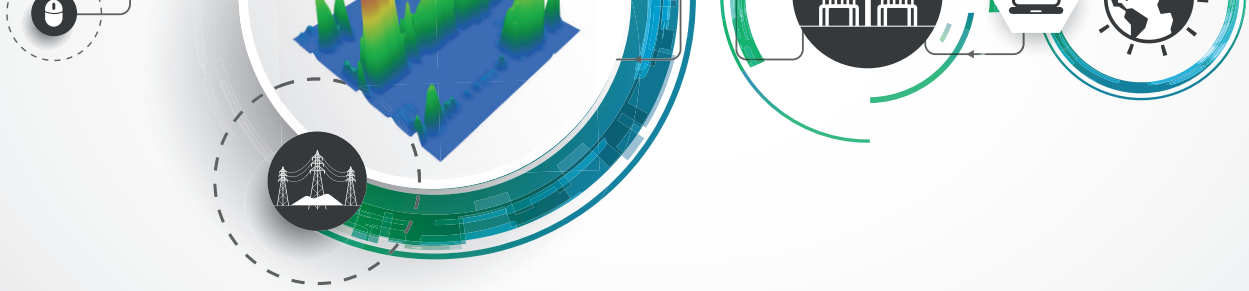
Shaping a Better Energy Future

Terna

TERNA GROUP

MAKE IT SIMPLE AS POSSIBLE, BUT NOT ANY SIMPLER.

Albert Einstein

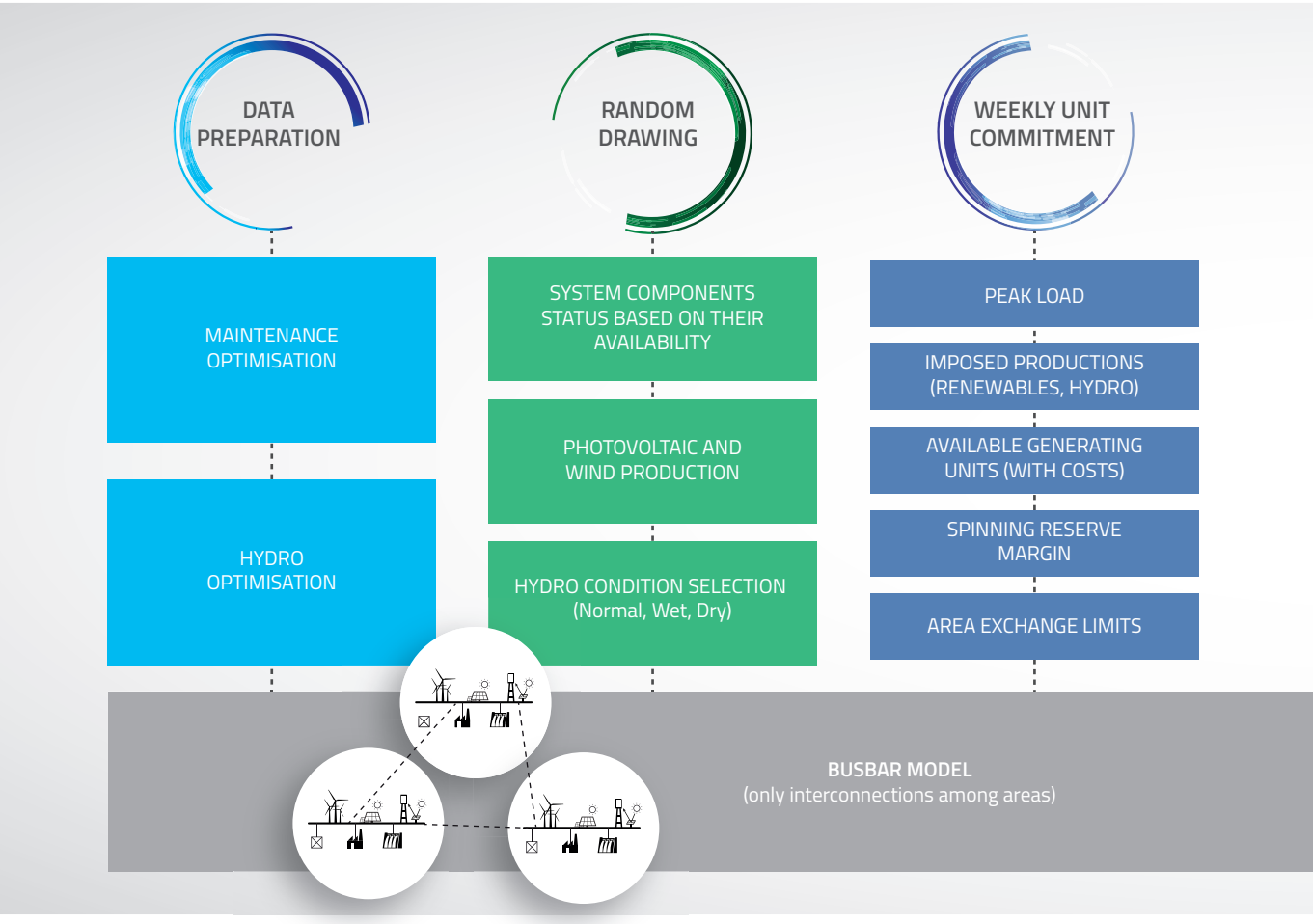


GRARE

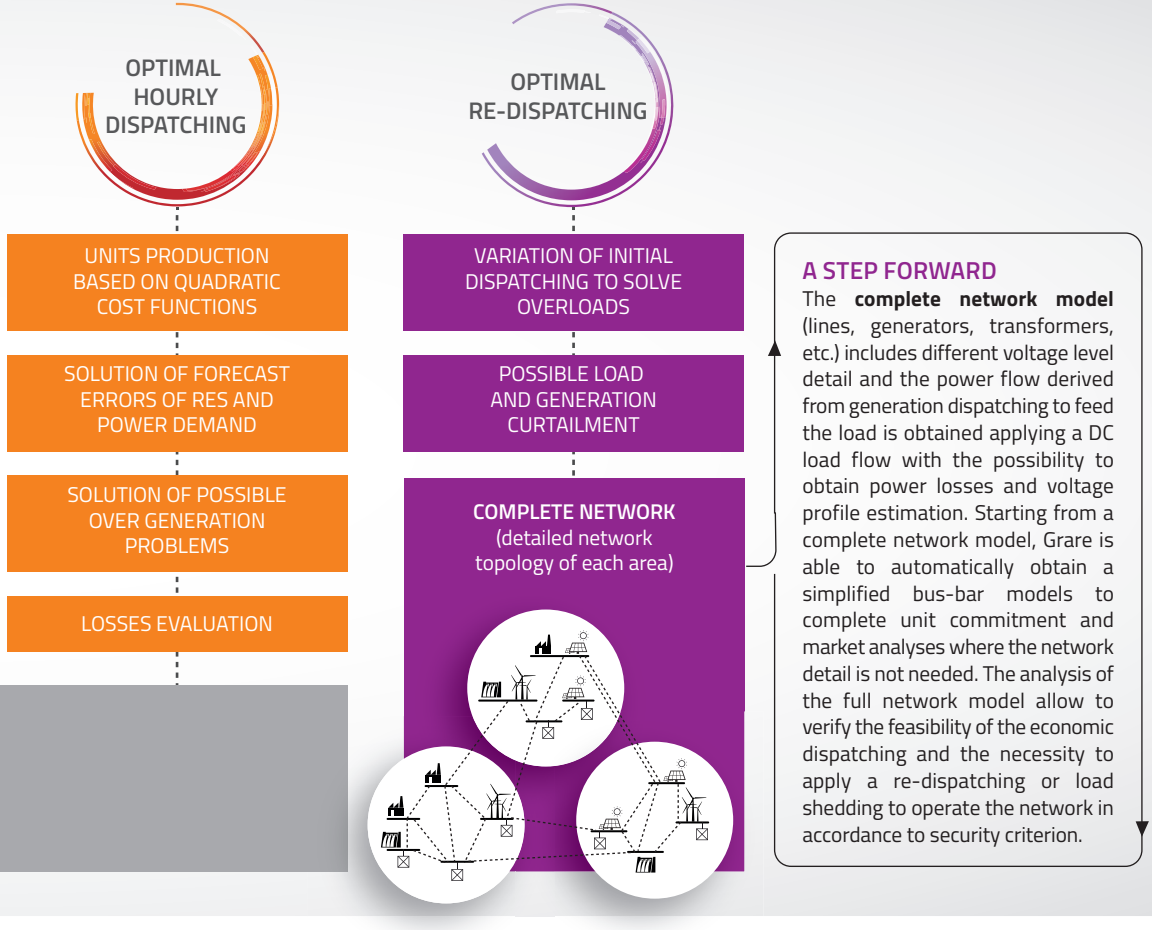
GRID RELIABILITY AND ADEQUACY RISK EVALUATOR

GRARE is a powerful computer-based tool of Terna, developed by CESI, that evaluates reliability and economic operational capability using probabilistic Monte Carlo analysis. GRARE has been developed to support medium and long-term planning studies and is particularly useful for evaluating the reliability of large power systems, modeling in detail the transmission networks. GRARE is developed taking advantage of a high performance multi-threaded code. GRARE is integrated in SPIRA application, that is designed to perform steady-state analyses (e.g. load-flow, short-circuits, OPF, power quality) and is based on a network Data Base of the system being analysed.

The calculation process is performed as a series of sequential steps starting from a high-level system representation and drilling down to low-level network details.



Thanks to the ability to couple the economic dispatch of the generation with the complete structure of the electrical network, GRARE is able to offer a unique support for the planning and evaluation of the benefits related to network investments.



MAIN FEATURES

ALGORITHM AND MAIN OPTIMIZATION PROCESS

- The **time horizon** is a single year with a minimum time unit of one hour. Many Monte Carlo Years (MCYs) can be simulated, each one being split into 52 weeks with each week independently optimized.
- **Probabilistic Monte Carlo method** uses statistical sampling based on a "Sequential" or "Non Sequential" approach.
- **Monte Carlo convergence analysis** to verify the accuracy of results obtained.
- **Optimised Maintenance schedule** based on residual load distribution over the year.
- Reservoir and pumping **Hydro optimisation** mindful of water value as an opportunity cost for water in respect to other generation sources.
- **Different hydro conditions** managed (dry, normal, wet).

MCY – MONTE CARLO YEAR
A mix of Monte Carlo variables are simulated to obtain a MCY. Typically these are: Load conditions (due to economic scenarios and temperature dependence) + Hydro availability + Forced Outage Rate of Generation Fleet and Network Elements + Transfer Capacity availability + Wind and Solar stochastic behavior.

SYSTEM MODEL

- **Network detail** to represent each single area (grid dimension up to 5,000 buses). A DC load flow is calculated and an estimate of voltage level can be obtained using the Sauer algorithm.
- **Area modelling** to optimize Unit commitment and Dispatching consistent with transfer capacities.
- **Unit Commitment and Dispatching** with Flow or ATC based approach

COMPLETE NETWORK MODEL
Simulation of the whole Network including each element (eg. Lines, transformers generation units, etc.). Flexible network devices (PST, HVDC) to control power flows also after fault conditions.

AVAILABLE TRANSFER CAPACITY
Power flows are distributed only on the basis of available capacity.

FLOW BASED
Power flows are distributed on the basis of network representation (GRARE can manage a full network representation or simplified ones such as PTDF matrix or equivalent impedances).

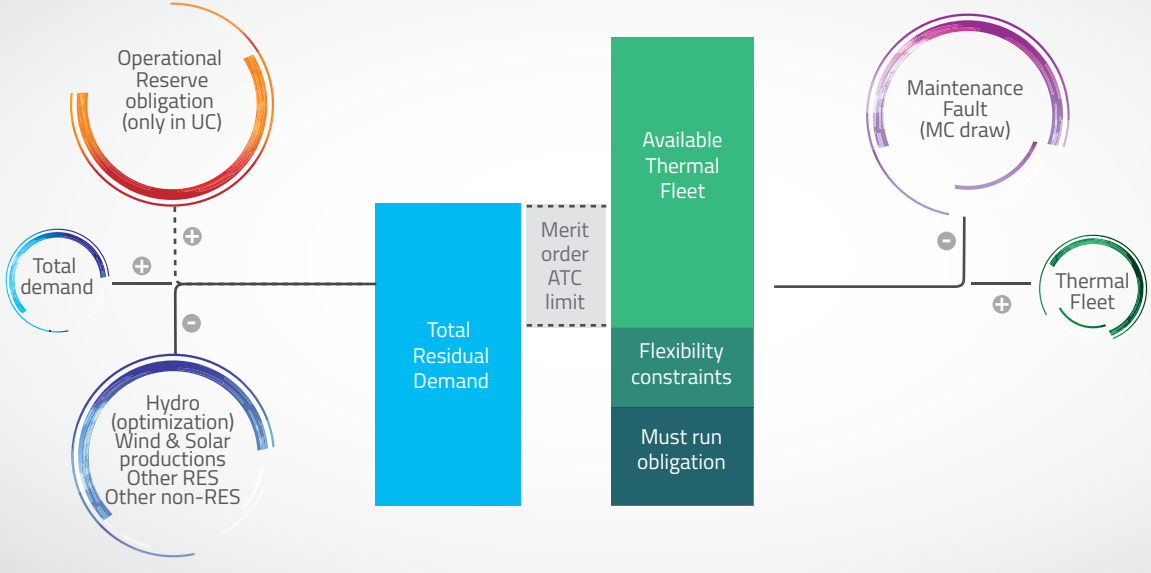
MARKET ANALYSES

- Single year day-ahead **Market analysis** with area modelling detail, but with no Monte Carlo drawings.
- The general restrictions of the **Unit Commitment** like minimal uptime and downtime of generation units are taken into account for each optimization period.
- **Dispatchable units** characterised by power limits, costs, must-run or dispatching priority, power plants configurations, start-up and shut-down flexibility and CO2 emissions.

ADEQUACY ANALYSES

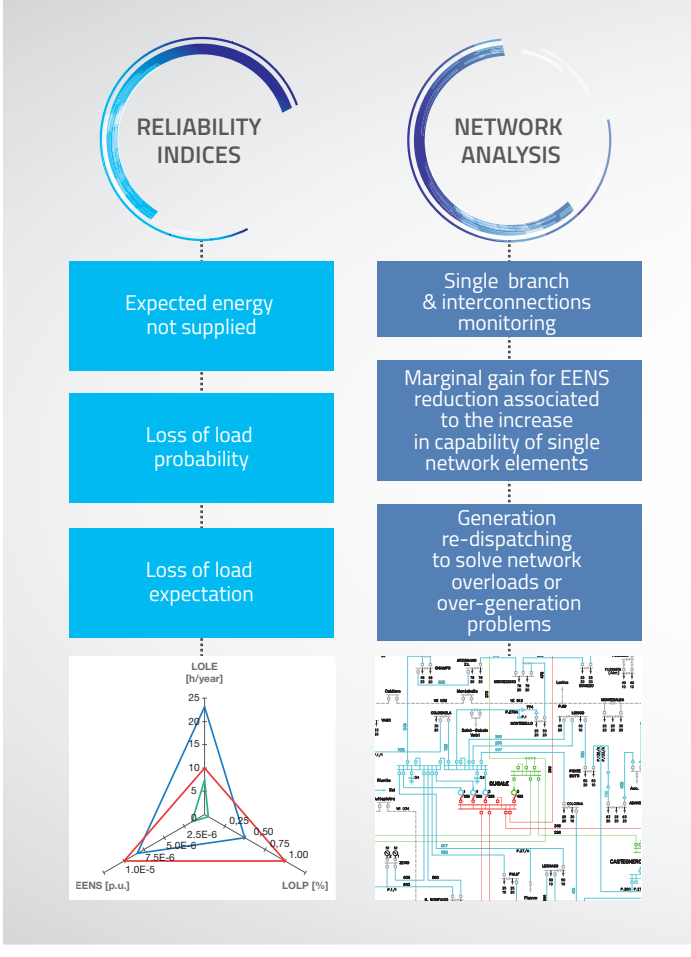
- **System adequacy level** measured with Reliability Indexes (EENS, LOLE, LOLP).
- **Renewable production** calculated by a random drawing starting from producibility figures.
- **Operational reserve level** evaluation taking account of largest generating unit, uncertainty of load and RES forecast, possible aggregation of Area and fixed % of load.
- **Demand side management** as rewarded load to be shed with priority without impact on adequacy.
- **Over-generation management** with possible priority on generation to be reduced.

GENERATION ADEQUACY EVALUATION



MAIN APPLICATIONS

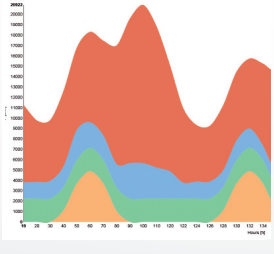
- Designed for technical analyses of large electric systems.
- Evaluation of electric systems Generation & Transmission adequacy.
- Optimal level of RES integration.
- Cost Benefits Analysis for network reinforcements and storage which factors in Security of Supply, network overloads, RES integration, network losses, CO2 emissions and over-generation.
- Calculation of Total Transfer Capacity of interconnections.
- Generation reward evaluation for Capacity Remuneration Mechanism.
- Point Of Connection and sizing for new power plants.



MAIN RESULTS

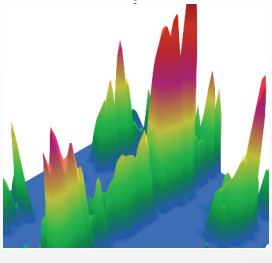
AREA & SYSTEM BALANCING

- Area & system costs
- Productions & gen. costs for each unit
- Area & system electrical losses
- Energy exchanges among areas



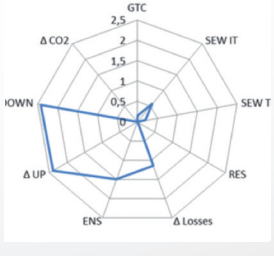
AREA & GRID ANALYSES

- RES curtailment
- EENS distribution due to lack of power, lack of interconnection, overloads



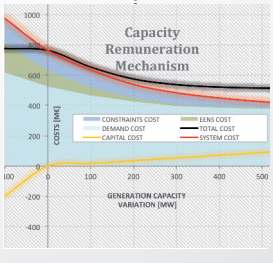
COST BENEFIT ANALYSIS

- Social Economic Welfare (SEW) and Variation of CO2 emissions
- Energy not supplied (EENS) reduction
- Integration of renewable resources
- Savings in the ancillary services market
- Grid transmission capacity increase (GTC) and Energy losses variation related to the network flows
- Avoided investments



CAPACITY REMUNERATION MECHANISM

- Reliability Options Model
- Estimation of option premium based on system costs, value of lost load, interconnection capacity



WORLD CLIENT REFERENCE

The high level of versatility and flexibility of the GRARE tool has been appreciated in Europe first and then in several countries all around the world. The program has been developed to be applied in the design phase for the Italian framework and it is now used for Entso-E adequacy studies. Various TSO/Institutions have benefited from the potentiality of the tool by using it directly or through specialist consultancy services.

GREAT THINGS ARE DONE
BY A SERIES OF SMALL THINGS
BROUGHT TOGETHER.

Vincent Van Gogh

The top independent grid operator in Europe for kilometres of lines managed,
Terna is a company of Italian excellence composed of more than 3,700 professionals.
Terna Group works everyday to make the National Transmission Grid safer, more efficient,
more sustainable and increasingly interconnected, also in view of continental electrical development.

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