Study Committee C1

Power System Development and Economics

Paper C1-ID10785-2022

KAIROS, an Innovative Tool for Planning Renewable Energies in the MENA Region: a case study on the KSA Power System

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Justification of transmission investments

- Need for environmentally friendly solutions
- Benefits for the society must be clearly highlighted, quantified and monetized

Power system decarbonization and market design

- Though the share of RES generation is still moderate in Europe (36%), there are occurrences where the ratio RES generation to demand is attaining values close to 100%, as shown in Fig. 1 related to Italy.
- Such situation was dramatically amplified in Spring 2020 due to the lockdown measures caused by the pandemic that pushed upward the ratio RES generation to demand to 44% compared to 31% in the same period of 2019.
- Growing share of V-RES entails growing volumes of reserves that shall be made available in the various time windows at the minimum cost. Fig. 2 shows the evolution of Ancillary Services Market disbursement related to reserve requirements in Italy

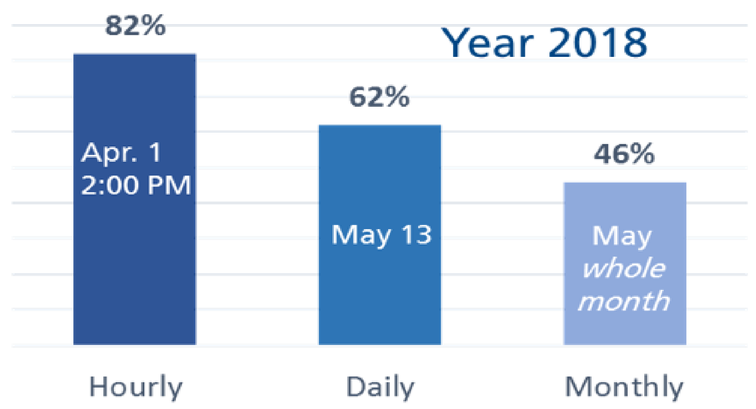

Fig1: Penetration of RES generation in Italy in Spring 2018 (source: Terna)

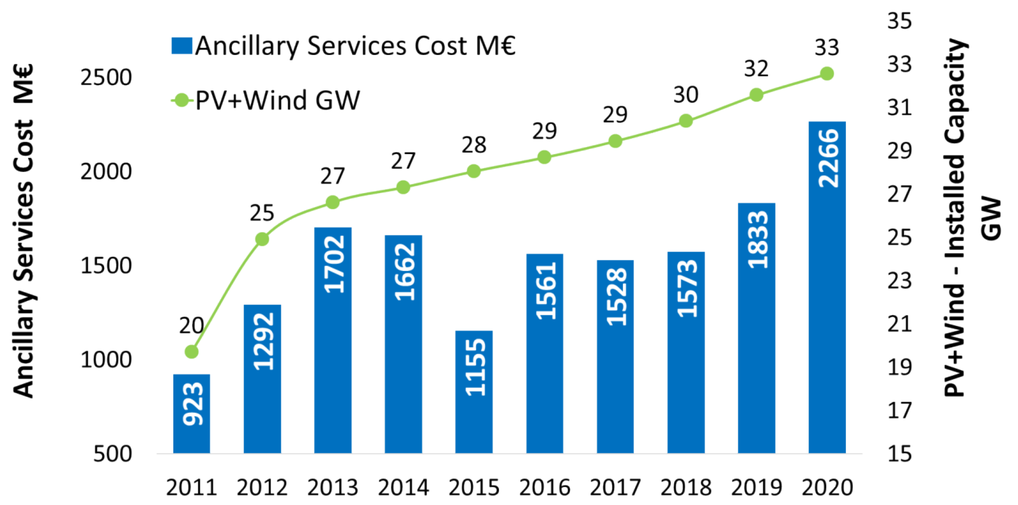

Fig2: Evolution of reserve requirements in Italy at the beginning of V-RES deployment boom

How to procure reserves at minimum costs in systems with high V-RES penetration ?

KAIROS

TOOL FOR POWER MARKET ANALYSIS AND RESERVE PROCUREMENT

CESI

Kairos is an innovative **CESI's proprietary dispatching simulation tool** for power market analysis, specifically built for modeling hydro-thermal coordination scheduling on annual basis, **with a detailed focus on reserve procurement mechanism**.

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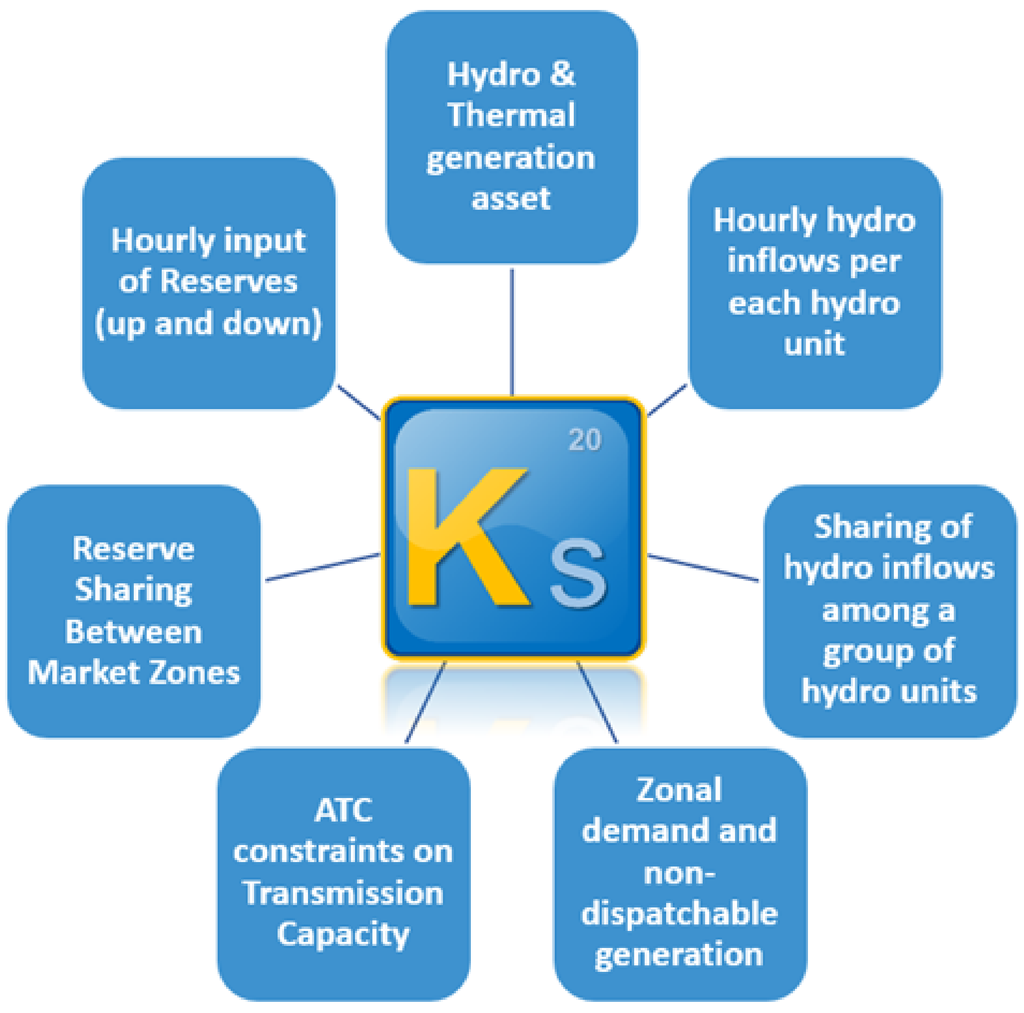
KAIROS

TOOL FOR POWER MARKET ANALYSIS AND RESERVE PROCUREMENT

- Deterministic model belonging to the class of "security constrained unit commitment problems"
- Mixed Integer Programming (MIP) problem
- Timeframe: 1 year with hourly discretization

Multi-zonal Main Features



Market model

- Kairos implements a multi-area optimization procedure which performs an optimal coordinated hydrothermal hourly scheduling of the generation set, with the aim of **minimizing the overall generation cost**, but managing all the generation set constraints and **satisfying the reserve requirement**.
- The power system constraints handled in the solution approach are the integral limitations on the water reservoirs of the hydro plants and the transfer capacity of the equivalent lines of the interconnection corridors among market zones in addition to the technical characteristics of generation units.

Constraints

- load and generation balance equation;
- primary, secondary and tertiary reserve demand;
- power unit technical constraints, such as minimum start-up and shutdown times, operative costs and min./max. capacity;
- start-up costs;
- constraints on transmission capacity in terms of the Available Transmission Capacity (ATC) margins;
- must-run obligation contracts;
- network integrity constraints, that is must-run constraints necessary for network security issues.

Tailored for Reserve Cost Assessment

- PRIMARY RESERVE (Frequency Containment Reserve, FCR): to contain the system frequency after the occurrence of an incident or imbalance. It has been estimated on the basis of the potential out of service of the biggest unit.
- SECONDARY RESERVE (Automatic Frequency Restoration Reserve, aFRR): with an activation time of less than 15 minutes and used to restore the frequency deviation to zero. It has been estimated to compensate potential fluctuations of load on 15-minute intervals.
- TERTIARY RESERVE (Replacement Reserve, RR): to restore the secondary and primary reserve margins. It can be provided both by units in operation and units that are switched off but can be put in operation quickly, like gas turbines. The tertiary reserve has been calculated to compensate typical forecast errors from day ahead in the estimation of load, solar and wind generation.

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Application of the KAIROS simulator

The day ahead unit commitment and the economic dispatch allow to choose the production facilities to be run to fulfil the demand of electricity at the lowest production costs without violating the technical constraints of the system and of the production facilities and to have enough flexibility to compensate unbalances during real time.

The perimeter of the simulations includes 11 operating areas (KSA + the Gulf Region perimeter)

Scenario

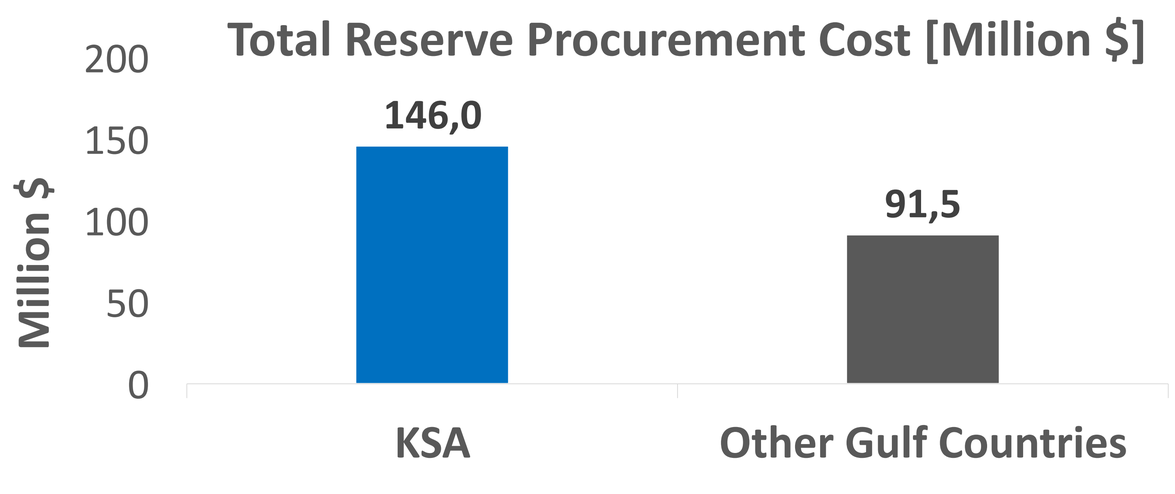
Target year: **2030**

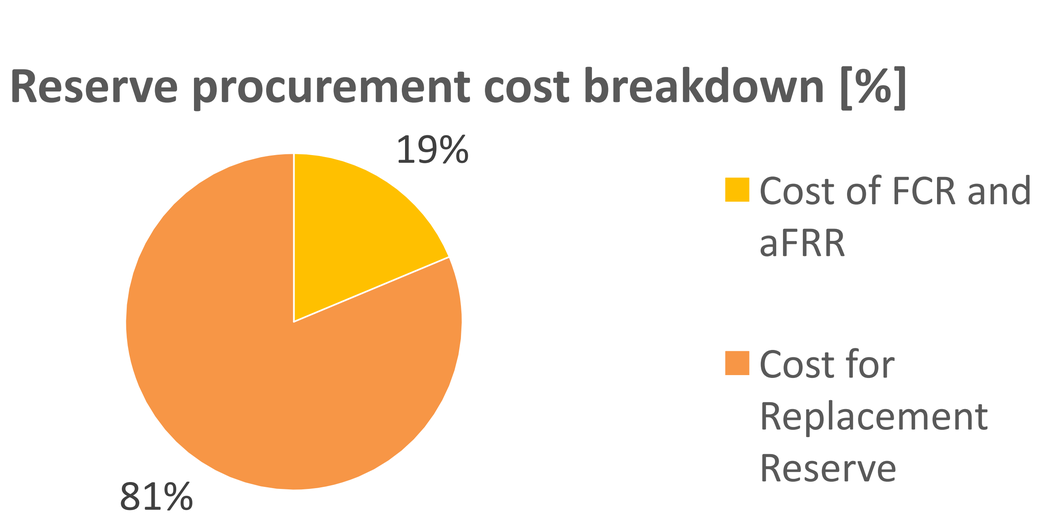
RES penetration in KSA: **30.2 %**
Total Installed RES in KSA: **49.7 GW**

RES penetration in other Gulf Countries: **3.2 %**
Total Installed RES in other Gulf Countries: **5.8 GW**

Results: Reserve procurement costs

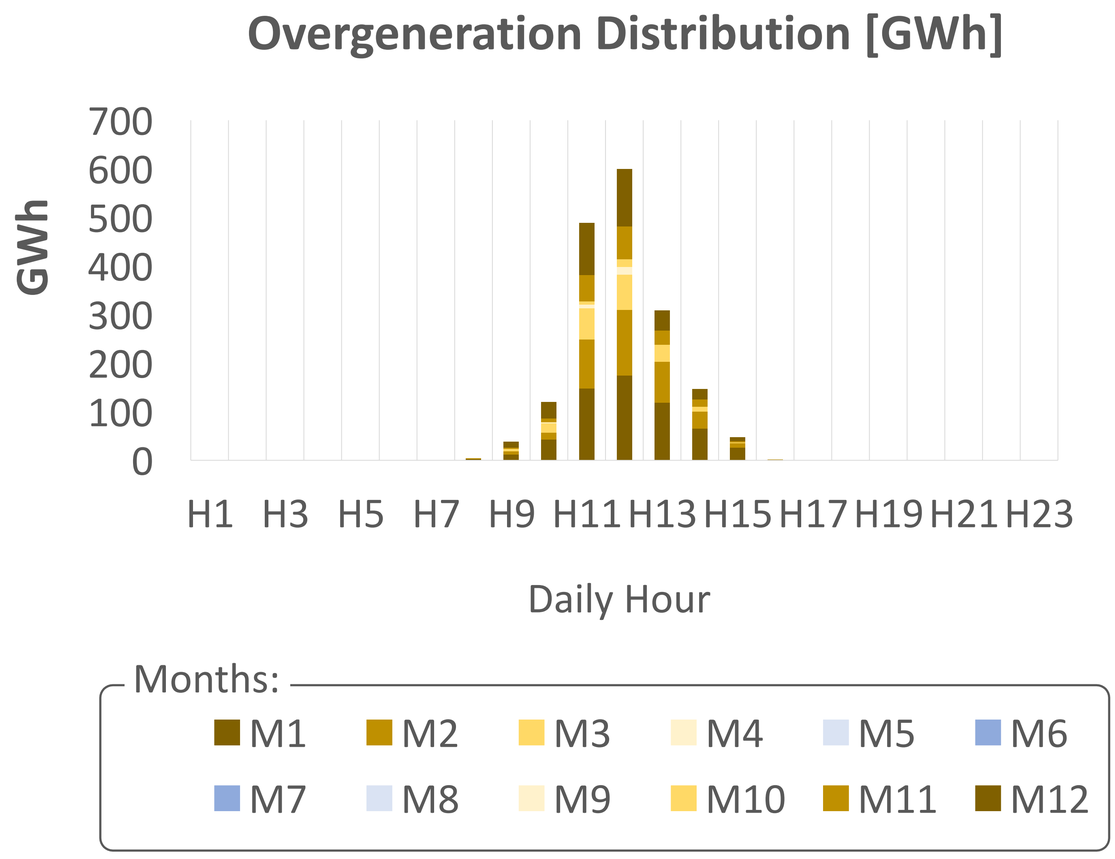
The **cost of procuring** reserves **is about $ 238 million** for the whole perimeter, whereas the **cost for the KSA region is about $ 146 million**, as detailed in the following figures.





Distribution of the Overgeneration in the KSA region

The bar diagram in figure below represents the distribution of the overgeneration located in KSA region.



Conclusion

- The results obtained thanks to the simulations carried out by using KAIROS computational tool, allow to highlight the extra costs related to reserve procurement, costs usually overlooked in power market analyses that do not properly simulate the ancillary market phase.
- the "Reserve" scenario where the demand of reserves is considered in each operating area delivers higher costs (respect to a plain day-ahead market scheduling), because reserve margins, in order to be provided, require more thermoelectric units committed, consequently increasing the number of units not dispatched at their maximum capacity, and increasing the number of start-ups.
- In this context, flexibility is a key factor to offer fast services to system operators and to facilitate daily network management and network development planning, assuring adequate reserve margins.