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Flexibility assessment from a balanced technical and economic point of view

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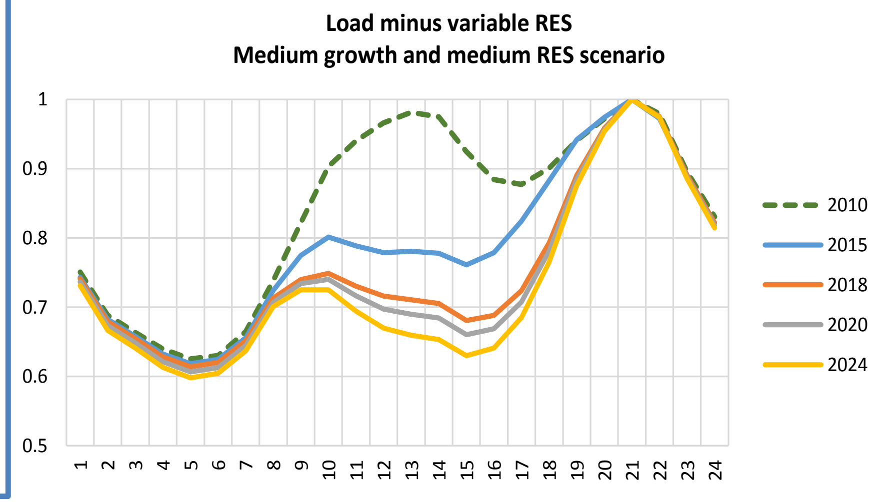
Introduction

- Flexibility is emerging as an essential feature of power systems in the transition towards low carbon emissions
- Flexibility is enabled by dispatchable resources which can either highly ramp to address load variability or can decrease load variability, both due to variable RES
- Reserve for flexibility is availability of flexible resources at different time scales
- **Example**: solar PV cause multi-hour flexibility requirements (the so called duck curve); unpredictable wind variability cause minute-by-minute flexibility requirements
- Power plants qualified as flexible do not provide only fast ramping but also frequent startups/shut downs and operation at minimum stable generation power over long time daily

Key Issues

- Can markets alone deliver sufficient flexibility?
- Has flexibility reserves features of public good?
- Assess ways of remunerating flexibility services as a reserve



Broadening the scope of Capacity Adequacy Methodology to Resource Adequacy

- **Traditional approaches to capacity adequacy** assess only meeting load **at peak load times**
- Rapid penetration of vRES can stress system reliability also at times when high ramping capabilities are required and at times of risk of over-generation
- **Resource Adequacy Methodology** is developed on a twofold basis:
  - Adequate available Capacity
  - Adequate resources with high ramping rates and strong cyclic capabilities
- **Proposed Methodology**:
  - Use of a unit commitment algorithm with running resolution for all 8760 hours
  - Test cases/Simulations over several future years and over a range of scenarios covering a wide spectrum of future system evolution cases
  - Combination of adequacy metrics (flexibility metrics and more “traditional” ones such as reserve margin)

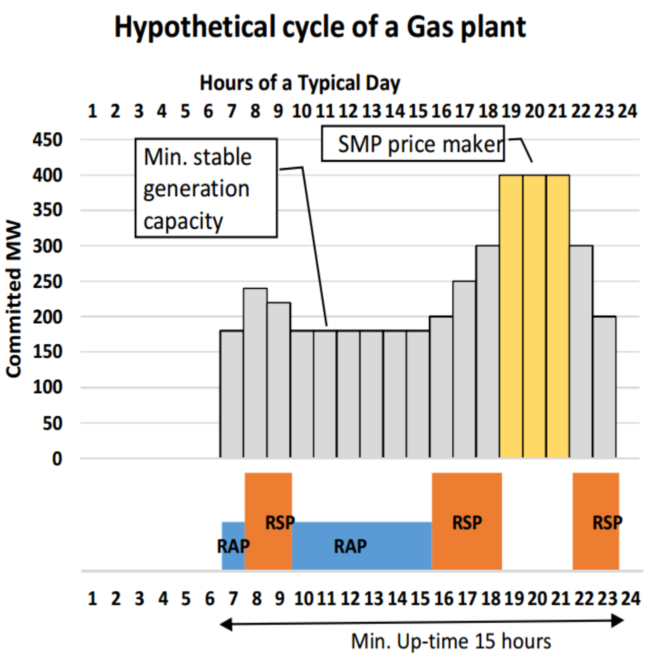
Resource Adequacy/ Flexibility Metrics (1/2)

- Reserve Margin Indicator (RM_h) : *available capacity (C_g) over and above the needed capacity for satisfying load (L_h) at peak times*
  - *From a risk averse perspective*: $RM_h = \frac{\sum_g (1 - FOR_g) * C_g + H_h}{L_h} - 1, \ \ \forall h$
  - *From a less risk averse perspective*: $RM_h = \frac{\sum_g (1 - FOR_g) * C_g + H_h + cf_{NI} \cdot NI_h + cf_{RES} \cdot RES_h}{L_h} - 1, \ \ \forall h$

- Ramping Reserve Margin Indicator (RRM_h): evaluation of the system-wide available ramping capability to follow the net load variations
  - $RRM_h = \frac{\sum_g (1 - FOR_g) * min(Pmax_g - Q_{g,h}, 60 * Ramp_g)}{|NetL_h - NetL_{h-1}|} - 1, \forall h \ if \ g \ is \ commited$

- Over-Generation Margin Indicator:
  - $\sum_{h=1}^{8760} 1, \ if \ \sum_g vUC_{g,h} < 3$

Resource Adequacy/ Flexibility Metrics (2/2)



- Mid-merit power plants (gas-fired) are characterized by a load following generation profile, providing the needed ramping services
- Due to minimum up time constraint gas plants have to remain at minimum stable generation level over a long period of time (RAP hours)
- Ramping Available Power (RAP) denotes the amount of energy provided by gas-plants dispatched for ramping purpose, when generating at minimum stable output level
- Ramping Service Production (RSP) is calculated as the amount of energy supplied by gas-plants offering multi-hours flexibility service
- $$RSP_{g,h} = \begin{cases} Q_{g,h}, [(Q_{g,h} \neq Q_{g,h-1}) \cup (Q_{g,h} \neq Q_{g,h+1})] \cap (h > 1) \\ Q_{g,h}, \ (Q_{g,h} \neq Q_{g,h+1}) \cap (h = 1) \\ 0, otherwise \end{cases}$$

- During the RAP and RSP time periods the baseload plants are the SMP makers, as their economic bids are lower than the CCGT marginal costs
- However, the CCGT plants need to operate at minimum stable generation capacity to be able to provide the fast ramping later on
- At peak load times, the CCGT may become SMP makers, hence no RAP or RSP label applies

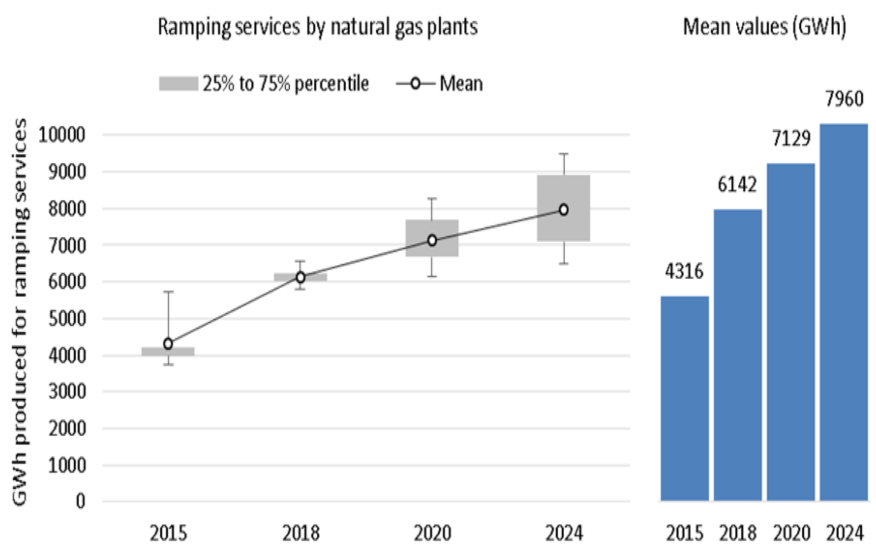
Results of Resource Adequacy Methodology
Case study: Greece

- Using a unit commitment and wholesale market simulator, we simulated the Greek power system in the context of a wide range of scenarios covering different assumptions about demand, level of RES penetration, level of net imports and the decommissioning of old lignite units
- As expected, the most intense flexibility requirements were found in scenarios with high RES penetration, low demand and high lignite capacity
- The average rates of ramping services (RSP) as provided by gas plants in the simulations tend to increase over time in scenarios complying with environmental targets of the European Union

Uncertainty analysis based on the scenarios indicate that investing in gas plants is risky, mainly because:

- The gas plants, being the last on the merit order, have to take the risk of price making to earn above variable costs
- Long-term contracting in markets for futures is difficult for gas plants, as they increasingly operate with frequent shut downs and high ramping to provide the flexibility services
- The system requirements to be covered by gas plants are uncertain and cannot be anticipated, as they depend on other deployments, mainly of variable RES, demand, storage and demand response
- Investing in gas plants expecting capital earnings from flexibility and peak services involves high risk; the same risk can also lead to mothballing of existing gas plants.

Summary of simulations for the Greek system



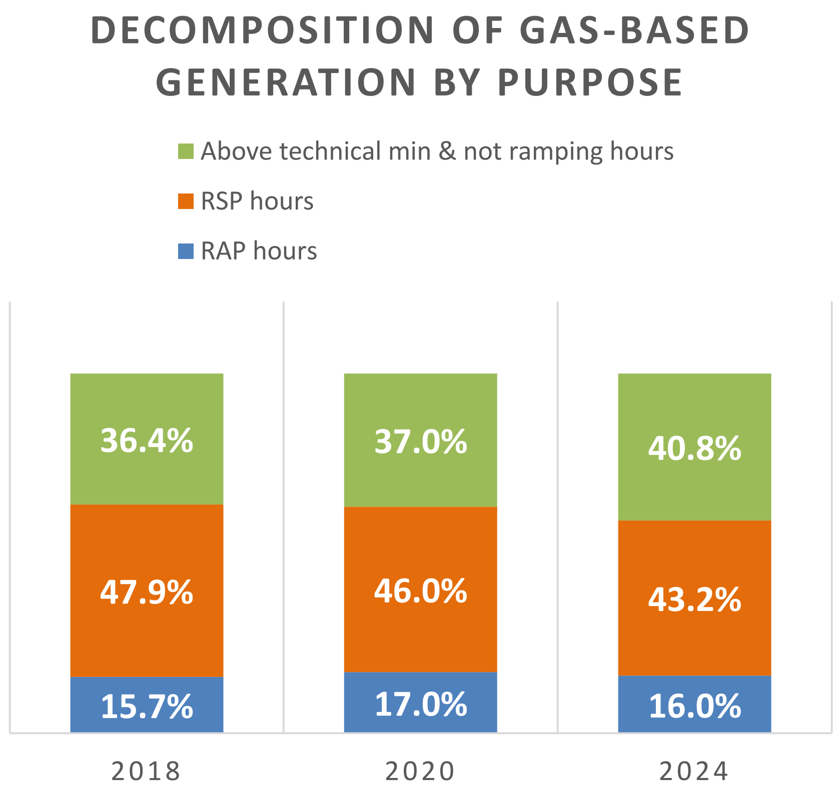
Results of Resource Adequacy Methodology
Case study: Greece

The simulations show that for gas plants

- Generation for energy purposes is inversely related to the provision of ramping services
- The amount of Ramping Service Production shows a decreasing trend over time, although the ramping services increase in total

The simulations show that

- As the merit order in the wholesale market is defined by co-optimizing ancillary services, the CCGT plants receive orders of commitment at minimum stable generation capacity only for providing ramping services later on, without having been selected in the merit order for economic reasons.
- In the majority of operating hours at RAP or RSP, the gas plants cannot recuperate their fixed and capital costs, not entirely even the entire amount of variable costs
- The intense cyclic profile entails high operational and maintenance costs, due to the unit stressing
- Until today, flexibility is not remunerated as such and not even included in the ancillary services



Conclusions

- Flexibility resources will be increasingly needed and in particular fast ramping gas plants, as the system evolves towards lower carbon emissions
- Co-optimization of energy costs and ancillary services in a wholesale market (as in Greece) implies that gas plants are committed often only for providing the flexibility services without being selected as economic in the merit order.
- Over a long period every day, the gas plants get revenues even below variable costs and cannot recuperate the increasing O&M costs due to the unit stressing for providing flexibility
- The only opportunity for earning above variable costs is at peak load times which is surrounded by uncertainty due to the rest of flexibility resources, namely hydro, storage and demand response
- Therefore, the simulations find that investing in gas plants as much as the system requires to ensure adequacy of flexibility resources is risky
- A supplier investing in gas plants incur costs while other suppliers get benefits for free in terms of improved system reliability, hence the free-riding risk discourages investment
- Remunerating flexibility services outside the wholesale market seems unavoidable. Two ways to explore: a) capacity payment focusing on resources able to deliver flexibility, b) improve and extend the arrangements for provision of ancillary services.
- Based on this analysis, Greece has introduced the first approach for a transitory period of one year. The capacity remuneration is given only to gas and hydro plants based on extra costs of gas plants due to the stressing of the units estimated between 40 and 45 EUR/kW-year.