Capacity Remuneration Mechanisms Delivering Flexibility to Integrate Renewables in Europe

Prof. Pantelis CAPROS, National Technical University of Athens, E3MLab

12th International Conference in the European Energy Market
Lisbon, 19-22 May 2015

E3M - Lab

Capacity adequacy concerns

- Revenue adequacy concerns seem to emerge in the EU power generation market
- Several difficulties in raising funds for large power projects, early retirement of existing plants, cancelling of clean coal projects and difficulties for gas plants to break-even constitute potential threats to reliable supply
- Public and system authorities raised concerns about future capacity adequacy and discuss out-of-market actions including unilateral policies to remunerate capacity
- The European Commission questions unilateral actions from an Internal Energy Market perspective

Possible causes

- The financial crisis having adverse effects on availability or conditions of financing
- The slowdown of growth causing electricity demand growing below expectations
- Over-capacity because of past practices and trends
- Rapid penetration of renewables and flaws in market design and operation
- Reduced operating hours of conventional plants (especially gas) due to low demand and RES
- Consequently, low prices in wholesale markets (mostly power exchanges) and shift from bilateral contracts to wholesale market purchasing of electricity
- The possible structural inability of energy – only markets to solve the missing money problem as demand responses are inadequately operating

Role of traditional capacity remuneration mechanisms (CRM)

- Traditionally, Capacity Remuneration Mechanisms reward power capacity availability, especially at peak loads, irrespective of other capabilities of the power plants (e.g. ancillary services, fast ramping capabilities at system level)
- Hence, they are conceived as complements to energy markets aiming at stabilizing investment cycles and delivering high reliability performance at reasonable cost and under manageable uncertainty rates.
- Types of conventional capacity remuneration mechanisms:
  a) direct payments
  b) obligations of load serving entities implying a decentralized market for procurement of capacity availability guarantees
  c) centralized auctions for procurement of capacity availability guarantees (e.g. reliability options)
- Nowadays, reliability concerns are also driven by high deployment of variable renewables. Traditional capacity mechanisms do not address them.

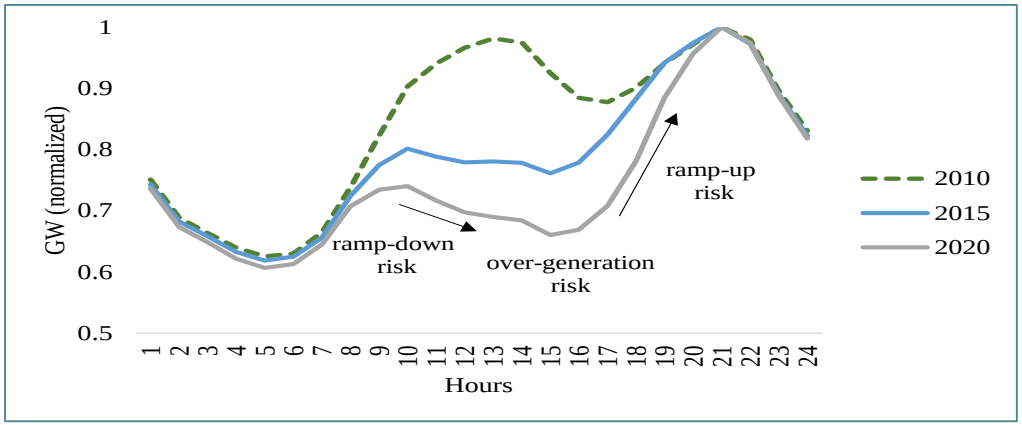
Emerging system requirements that CRMs have to address

- We identify that the transformation of system load driven by large penetration of variable RES generation create new types of reliability concerns, such as lack of fast ramping resources, risk of over-generation and insufficient resources to balance in real time.
- The variable RES fluctuate over multi-hour and sub-hourly time-scales
- Flexibility as an emerging system requirement: Resources with fast ramping and short cycling operation
- Flexibility applies both on a minute-by-minute (e.g. wind) and a multi-hour (e.g. solar) time-scale of operation
- Types of flexibility resources:
  - Gas-firing plants with different operation cycling constraints (e.g. CCGT versus GT)
  - Hydro-lakes and Storage (hydro-pumping and new storage technologies)
  - Interconnectors depending on possible complementarities between control areas

Illustration in the case of solar plants

- Solar PV has naturally a systematic daily pattern following sunlight

Duck effect:



- Multi-hour ramping requirement at sunset implies maintaining gas-firing plants in synchronisation significant time before requiring them to ramp.
- The gas plants operate as must-run system plants to deliver the flexibility services and wholesale prices are often lower than their bidding or their variable costs. This implies monetary losses unless remunerated for flexibility services.
- Risk of over-generation during low load times as sum of minimum stable power levels of thermal plants (incl. base-load and gas plants) may exceed net load (e.g. negative prices or RES curtailment)

A modern CRM should address multiple reliability threats, also due to variable RES

System flexibility cases shown on a typical daily load variation where net load includes the contribution of variable renewables

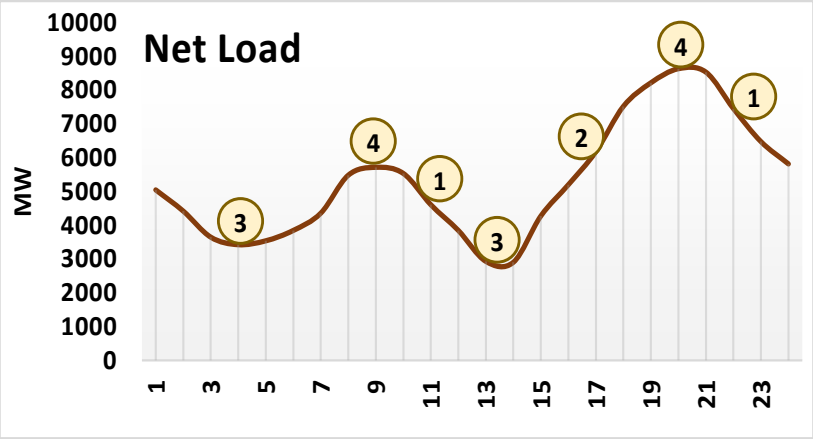
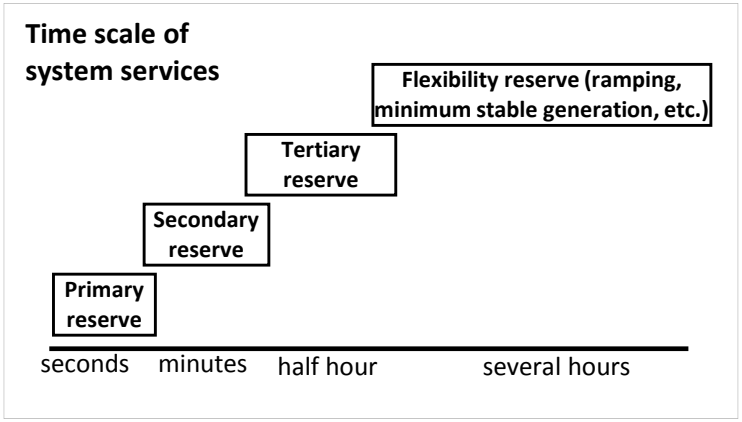


Illustration of time scheduling of system services for managing reliability



1 : Downward ramping capability
2 : Upward ramping flexibility
3 : Minimum stable generation flexibility (over-generation risk)
4 : Peaking capability

"Missing money" problem

- The missing money problem is due to the impossibility to set system prices at levels allowing comfortable earning above marginal costs for peaking and load following units (e.g. gas plants) which can not recover capital costs in retail markets
- In view of the increasing share of must-take generation over time (mainly renewables), wholesale marginal prices are likely to be low in a high number of hours per year.
- The system requires increasingly higher ramping and reserve services and require gas-plants to synchronise over multiple hour timescales while they are not system price makers.
- In real time operation, the system requires increasingly higher reserve capacities of gas plants to perform fluctuations for secondary reserve purposes.
- Consequently, gas-plants although conceived as merchant plants when built are used and will more used in the future as system plants.

Simulation results

- Using the PRIMES model we performed simulation analysis for all EU countries focusing on CRM requirements.
- The model simulated the entire market, including wholesale and contract markets, projecting trends towards higher variable RES
- The analysis identified which plant categories may face "missing money" problems under different market competition regimes, namely perfect competition, supply function equilibrium and Cournot competition.
- See https://ec.europa.eu/energy/sites/ener/files/documents/20130207_generation_adequacy_study.pdf

Capital cost recovery ratio of new dispatchable plants commissioned before 2030 (earnings from energy-only markets over 2015-2050, discount rates WACC 9%)

Red color indicates a missing money issue

		Marg. Cost	SFE	Cournot	(blue above 1, red below 1)
Central-western	nuclear & coal	1.03	1.13	1.22	
	GTCC	0.55	0.71	1.24	
	simple cycle and CHP	0.27	0.19	0.31	
Central-south	nuclear & coal	1.34	1.35	1.47	
	GTCC	1.03	1.03	1.39	
	simple cycle and CHP	0.91	0.88	0.99	
Eastern	nuclear & coal	1.22	1.40	1.80	
	GTCC	0.42	0.56	0.65	
	simple cycle and CHP	0.36	0.48	0.60	
Iberian	nuclear & coal	1.05	1.10	1.14	
	GTCC	0.52	0.62	0.74	
	simple cycle and CHP	0.26	0.10	0.24	
British isles	nuclear & coal	1.11	1.15	1.19	
	GTCC	0.30	0.34	0.54	
	simple cycle and CHP	0.10	0.10	0.10	
Nordic and Baltic	nuclear & coal	1.07	1.18	1.47	
	GTCC	0.75	0.81	1.09	
	simple cycle and CHP	0.35	0.49	0.81	
South-east	nuclear & coal	1.10	1.18	1.40	
	GTCC	0.24	0.94	1.50	
	simple cycle and CHP	0.20	0.25	0.35	
EU	nuclear & coal	1.13	1.22	1.42	
	GTCC	0.57	0.76	1.11	
	simple cycle and CHP	0.35	0.38	0.53	

Capital recovery by plant category

Nuclear and coal plants are found comfortably recovering capital costs

CCGT fail to recover capital costs (roughly by 30% in SFE) except under Cournot competition

Simple cycle plants have in all cases trouble in recovering capital costs

However, recovery of capital costs under SFE would be possible if considering economics for the entire portfolios of plants

Calculation of capacity remuneration focusing on flexibility

- Estimated at 40-50 k€/MW-year on EU average on top of earnings from energy-only markets
- Conceived to focus only plants providing flexibility, excluding base-load plants, and implemented in a coordination manner
- Remuneration is roughly 3% of total generation costs
- Can be implemented through complementary market arrangements:
  - Auctioned reliability options for flexibility services
  - Intra-day mechanisms
  - TSO contracts for ancillary and reserve services

Capital cost recovery ratio over plant lifetime including new and retrofitted plants	Perfect competition			SFE		
	GTCC	Simple cycle gas	Plant port-folio	GTCC	Simple cycle gas	Plant port-folio
Energy only market	0.2	0.1	0.8	0.7	0.2	1.0
With Capacity payment	0.8	0.6	1.0	1.0	0.9	1.1

Capital cost recovery ratio of new dispatchable plants commissioned before 2030 (earnings from energy-only markets over 2015-2050, discount rates WACC 9%)

		Marg. Cost	SFE	Cournot	(blue above 1, red below 1)
Central-western	nuclear & coal	1.05	1.09	1.14	
	GTCC	1.17	1.36	2.12	
	simple cycle and CHP	0.34	0.31	0.47	
Central-south	nuclear & coal	1.22	1.36	1.48	
	GTCC	0.79	1.10	1.48	
	simple cycle and CHP	0.91	1.02	1.19	
Eastern	nuclear & coal	1.29	1.53	1.78	
	GTCC	0.43	0.67	0.91	
	simple cycle and CHP	0.98	1.13	1.55	
Iberian	nuclear & coal	1.05	1.10	1.12	
	GTCC	0.58	0.66	0.72	
	simple cycle and CHP	0.30	0.36	0.41	
British isles	nuclear & coal	1.10	1.16	1.20	
	GTCC	0.47	0.72	0.97	
	simple cycle and CHP	0.10	0.14	0.33	
Nordic and Baltic	nuclear & coal	0.78	0.89	1.14	
	GTCC	0.81	0.86	1.17	
	simple cycle and CHP	0.04	0.24	0.62	
South-east	nuclear & coal	1.52	1.17	1.49	
	GTCC	1.25	1.47	2.34	
	simple cycle and CHP	0.65	0.45	0.78	
EU	nuclear & coal	1.14	1.17	1.34	
	GTCC	0.85	1.04	1.51	
	simple cycle and CHP	0.48	0.53	0.80	

Capital recovery under low XB-trade

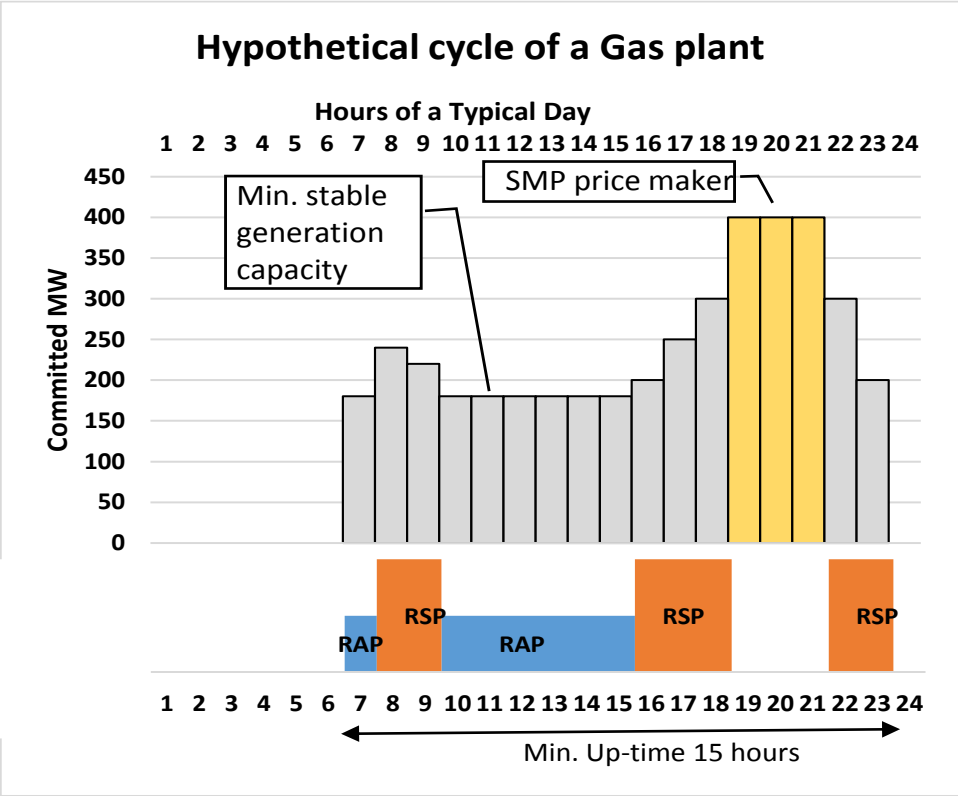
Sensitivity analysis assuming strong Net Transfer Capacity constraints and poor market coupling

Low cross-border trade implies higher use of GTCC and simple cycle plants as balancing is more concentrated nationally

This eases capital recovery of GTCC and simple cycle plants but increases overall cost of balancing and flexibility

Main conclusions of simulations

- The main issue is capacity adequacy for flexibility and reserve in supporting growing RES, rather than capacity adequacy in general
- Complementary measures exist for flexibility and reserve.
  - Long-term markets: auctioned reliability options for flexibility, strategic procurement
  - Short-term markets: intra-day bidding
- Capacity remuneration targeted only to simple and combined cycle cycle gas plants would represent a small fraction of total generation costs.
- If CRM applies asymmetrically across the EU countries, the analysis shows:
  - Significant distortion of investment by country as well as of cross-border trade compared to optimal solution
  - Higher wholesale prices in the country that applies capacity remuneration and small decreases in prices in neighbouring countries (free riding effect)
  - Higher generation costs for the entire EU, and in particular for the country which applies capacity remuneration
- Strong market coupling and flow-based allocation of interconnecting capacities (as opposed to administrative restrictions, such as the NTC) reduces overall cost of flexibility and balancing. The simulations found cost savings of more than 40 billion over 5-years periods just from well functioning cross-border trade.



The plant is committed to synchronize on a mini-mum stable generation level at 7th hour, and perform a sequence of ramping and commitment at minimum stable generation level, except at hours 19 to 21 when the plant (or another gas plant) is system marginal price maker. Except over these latter few hours, the plant delivers flexibility services but cannot recover even variable costs from energy-only market.

The plant delivers ramping at RSP times (ramping service power) and for this purpose it has to operate also over RAP times (ramping availability power)

Remunerating flexibility services

Due to cycling operation constraints a gas plant has to operate while not being a system price maker

In addition the daily cycling stresses a CCGT plant and increases fixed maintenance costs

Operation costs also increase due to the need to contract flexible gas resources

Capital costs cannot be recovered as illustrated.

As all reliability services, "public good" situations prevent market-based solutions (due to free riding)

All the above justify a CRM focusing on flexibility services

Conclusions

- Reliability measurements reflecting flexibility (i.e. sufficient fast ramping, avoidance of renewable curtailment, avoidance of risk of over-generation) have to be adopted in addition to traditional loss of energy probability measurements
- Flexibility is not only a real time operation issue but mostly a multi-hour system need to maintain fast ramping resources as must-run
- Multi-hour flexibility resources, such as CCGTs, as well as storage systems cannot recover fixed and capital costs from energy-only markets. Intra-day markets are useful but, due to volatility, do not provide stable long-term signals for investment (or avoidance of mothballing) of flexible resources.
- Our model-based analysis for all EU MS found that missing money is mainly challenging the gas-firing plants, and less the base-load plants.
- We argue in favor of new design capacity remuneration mechanisms focusing on flexibility resources. Such CRM would remunerate fixed/capital costs of plants requiring to follow fast ramping and fast cycling operation. Auctions of reliability options for flexibility resources is probably the best method.
- Harmonizing the CRMs across the EU MS and exploiting unobstructed trade over the interconnectors save on reliability and flexibility costs.