21, rue d'Artois, F-75008 PARIS
http://www.cigre.org

C5-213

CIGRE 2016

Capacity Mechanisms: Results from a World Wide Survey

H. HÖSCHLE (BE), G. DOORMAN (NO)
on behalf of the Cigré Working Group C5.17:
"Capacity Mechanisms: Needs, Solutions and State of Affairs"

SUMMARY

Capacity mechanisms are defined as an arrangement that is part of the market design, meant to provide revenues to capacity providers (generation and demand resources) in addition to the revenues from selling energy in the day-ahead, intraday and possibly other physical markets. As part of its work, the working group C5.17, *"Capacity Mechanisms: Needs, Solutions and State of Affairs"*[1], conducted a survey.

The purpose of the survey is to get an up-to-date overview of capacity mechanisms all over the world. This includes the status and description of currently installed mechanisms as well as planned implementations in the future. A set of contributions is received from 31 countries respectively regions or operating zones (grouped under jurisdictions) from all over the world. Major covered topics of the survey are characteristics of the power system and the power market, possible concerns about system reliability presently and in the near future, and the inclusion of a capacity mechanism in the present market design, as well as the possible future implementations of such mechanisms. In the present paper, we report the results from this survey, which gives an insight over the use and perceived future needs of capacity mechanisms worldwide. The paper presents an excerpt of the full evaluation which is part of the technical brochure covering the work of the working group C5.17.

Thanks to the 31 received contributions, the survey gives a good landscape of currently existing and developed capacity mechanisms around the world. The power systems surveyed present a full range of characteristics. There was a large spread in the size of the systems, ranging from a few 1000 MW to more than 160 GW annual peak load in countries with different fuel supply mixes – ranging from single-fuel to multi-fuel (coal, nuclear, hydro), different market structures and consumption patterns ranging from peak capacity-constrained to energy-constrained systems. By capturing these characteristics, the survey could then empirically check a possible link with an implementation of a capacity mechanism.

The integration of capacity mechanisms in the market design is independent from the market/system size. Capacity mechanisms are identified in both very large (PJM) and very small (Ireland) systems. Capacity mechanisms occur more often in system with large seasonal differences and where respondents indicate doubts about the generation adequacy in the long run. Countries that use capacity mechanisms reside on all continents. Three of the countries that do not have a capacity mechanism today, have decided to introduce one or are currently implementing one. Two other countries have serious discussions about capacity mechanisms. An additional four countries are changing their designs. This shows that market design is dynamic and continuously evolving.

In general, the large variety and combination of capacity mechanisms in place indicates that country specific characteristics lead to individual designs. Based on the survey however, it was not possible to identify objective power system characteristics that distinguish between the need or not for a capacity mechanism.

KEYWORDS

Capacity mechanism, Overview, State of affairs, Survey results, Working group C5.17

Corresponding author H. Höschle: hanspeter.hoschle@energyville.be

1 INTRODUCTION

The underlying work of this paper was conducted in the framework of the Cigré Working Group C5.17 *"Capacity Mechanisms: Needs, Solutions and State of Affairs"*[1]. The scope of the working group is to draft the need for capacity mechanisms, describe and compare relevant market models, describe present solutions in various countries and to document current plans and developments. As part of the work, a survey is conducted to assess the current state of affairs. The survey covers countries respectively regions or operating zones (referred to as jurisdictions) from all over the world. The purpose of the survey is to get an up-to-date overview of capacity mechanisms. This includes the status and description of currently installed mechanisms as well as planned implementations in the future. Moreover, the presence of relationships between the implementation and power system and market characteristics is assessed.

The objective of the survey is threefold. Firstly, an overview of the current implementation is given. The results reveal the types of mechanisms that are at the time of the survey in place and also indicate the market framework in which the capacity mechanism is embedded. Secondly, a detailed lookout on ongoing discussions and planned implementation indicates the development of capacity mechanism in market frameworks world wide. It shows that market designs are dynamic and continuously evolving. Thirdly, an analysis is done that tries to assess if certain observable characteristics exist that trigger the discussion and implementation of capacity mechanisms in a given market area. The points of interests are characteristics of a power system, expectations about system reliability, renewable energy sources (RES) shares and interconnection capacity of a jurisdiction.

As approach to reach the targets of the survey, questionnaires were sent out in 2014 to all jurisdictions around the world through the Cigré network. A total of 31 jurisdictions responded giving the status of current implementations, given an available data basis of 2012 / 2013, and an outlook up to 6 to 10 years ahead. The answers have been evaluated and assessed with a coherent methodology. Statistical overviews, graphical representations and discussions of the findings are reported in the technical brochure of the working group. The purpose of this paper is to give a condensed summary of the survey results. The full discussion of the survey results can be found in technical brochure of the working group [1]. This paper highlights the most significant findings of the evaluation. Next to the state of implementation or ongoing discussions in the individual jurisdictions, the focus is on the relationship of capacity mechanisms with the power system size, expectations about system reliability, RES shares, and available interconnection capacity.

The paper is organized as follows. Section 2 outlines the data baseline and gives an overview on the power systems' characteristics. Section 3 lists an overview on the capacity mechanisms world wide, both present and planned. Section 4, 5 and 6 describes the findings on the relationship of capacity mechanism with system reliability, embedded power markets, RES shares and available interconnection capacity. The last section concludes the work of the survey and the presented results in the paper.

2 REPRESENTED POWER SYSTEMS AND DATA BASELINE

The purpose of the survey is to get an up-to-date overview of capacity mechanisms implemented all over the world. This includes the status and description of currently installed mechanisms, as well as planned implementations in the near future. With the help of data about the individual power systems, triggers can be identified that lead to the discussion towards the implementation of certain mechanisms. To further facilitate this discussion, a questionnaire is used to gather information of multiple power systems. Besides general country information, the questions are structured by means of five categories, namely power system characteristics, power market characteristics, system reliability and capacity mechanisms.

The data baseline is a set of contributions received from 31 countries respectively regions or operating

zones (jurisdictions) from all over the world (Figure 1). A list of submissions can be found in Table III in the appendix. Grouped by continents, the contributions originate from North America (5), South America (3), Europe (15), Asia (5), Africa (1) and Australia (2). In terms of embedded market systems, the contributions originate from both regulated (6) and liberalized (25) power market systems. With respect to capacity mechanisms, the jurisdictions represent both systems with present capacity mechanisms (16) and without capacity mechanisms (15). In 8 of the jurisdictions, implementations or redesigns of a capacity mechanism are currently taking place[1]. In what follows, a more detailed evaluation of the power system characteristics is done.

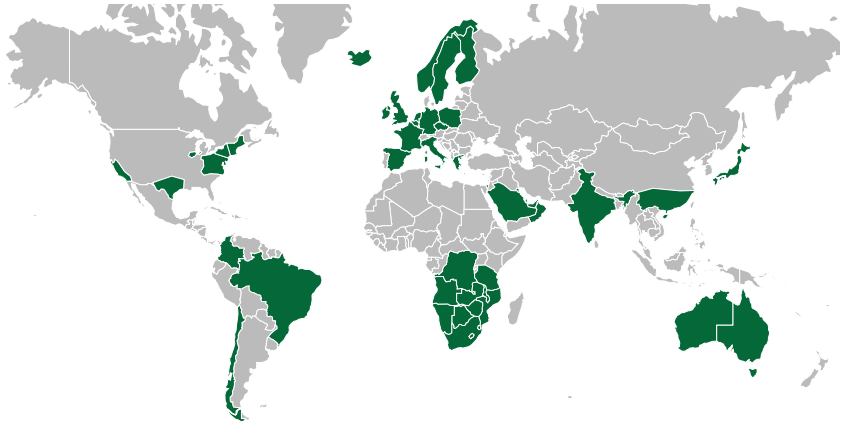


Figure 1: Map showing origin of submissions

Figure 2 gives a visual overview of the jurisdictions in terms of annual peak demand (in GW) and total annual consumption (in TWh) given for the years 2012 respectively 2013. Both winter (❄) and summer (☼) peak systems are represented. A direct link to the existence to capacity mechanisms is not present. System with and without capacity mechanisms exist both in systems with summer or winter peak. Also the size of system cannot be seen as a direct indicator for or against the need of a capacity mechanism.

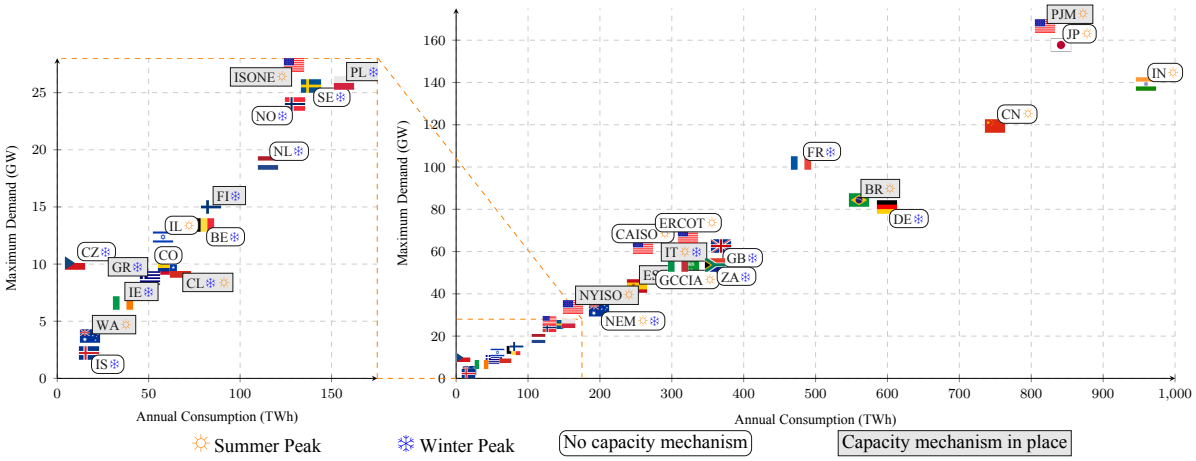


Figure 2: System size of contributions (based on data from 2012/2013)(Abbrev. see Table III)

Similarly, the ratios between day/night and winter/summer are compared. The ratios represent a rough estimate of the daily respectively seasonal demand volatility. These indicators are valid for categorizing the power system but similar to the peak demand and annual consumption, a direct link cannot

[1]This information was collected in 2014 with respect to capacity mechanisms in place (CM (present)) as well as planned or discussed capacity mechanisms (CM (planned i.e. up to 6 to 10 years ahead) which can either be plans for the introduction or the revise of an existing mechanism. In the following, *present* will always refer to a period 2012/2013 for observed data or 2014 for present market systems in place, and *planned* refers to "from 2014 on".

be drawn. However for the winter/summer ratio, the bigger the deviation from 1, the more seasonal a system is, which might lead to less operating hours of peaking units and an (emerging) need for a capacity mechanism (France, Finland, Sweden). On the other side, this is not the case for example for Norway. Therefore, the extended assessment in the technical brochure of the working group also includes the share of installed capacities respectively generated energy per fuel type. Interesting for the evaluation are systems that are dominated by one resource, i.e. nuclear-, fossil fuel-, and hydro- or RES-based systems. Also for the generation mix no direct connection between system specification and the existence of capacity mechanism cannot be drawn, e.g. hydro-based systems exists both with (Brazil, Colombia) and without capacity mechanism (Norway).

3 CAPACITY MECHANISMS WORLD WIDE

3.1 PRESENT IMPLEMENTATIONS

The evaluation of present capacity mechanisms is limited to the jurisdictions with a history of capacity mechanism for several years. In total, 16 out of 31 market areas have implemented capacity mechanism as part of their market design. Strategic reserves or operating reserves are implemented in 7 markets (AU NEM, FI, PL, SE, US PJM, US NYISO)[2]. They are intended to cope with seasonal extremes ("cold reserve") or as "safety net" if demand cannot be met at the market. In case of US PJM and US NYISO, the reserves are part of a combination with other market based capacity mechanisms. Capacity payments are represented by 5 markets (ES, GR, IE, IT, CL). In AU WA, CL, US NYISO and US PJM capacity payments are also part of a combined capacity mechanism. US ISONE has implemented a capacity auction. Capacity auctions are also part of the market design in US NYISO and US PJM. A capacity mechanism based on reliability options is implemented in Colombia. A visual overview is given in Figure 3.

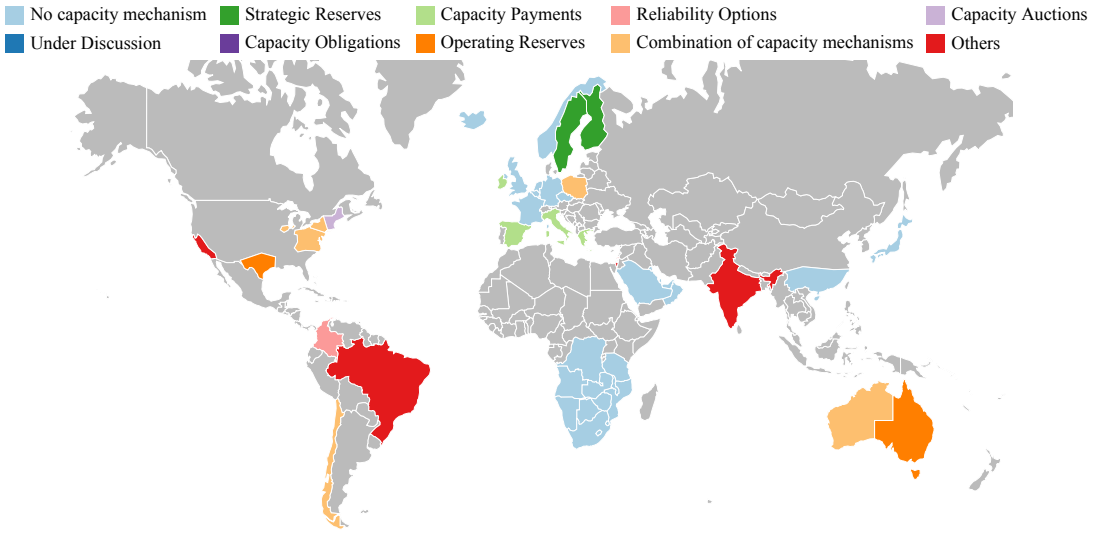


Figure 3: Map of present capacity mechanisms in jurisdictions

3.2 PLANNED IMPLEMENTATIONS

In 10 of the 31 jurisdictions a discussion is ongoing about the redesign, introduction or abolition of a mechanism. BE, FR and GB are in the process of introducing a capacity mechanism coming from a market design based on a day-ahead market only. BE introduces a strategic reserve to cope with seasonal shortages in the winter. GB and FR both chose for a market-based approach, namely capacity auction

[2] Abbreviations for jurisdictions are listed in Table III in the appendix.

respectively ex-post capacity obligation. Discussions in DE and JP have not yet reached consensus about a possible introduction not to speak of a type of mechanism. CL, IE and IT are in the process of changing their existing capacity mechanism design. In all the 3 jurisdictions the transition is made towards a reliability options design. SE has fixed a time line to phase out the strategic reserve until 2020 again. This is illustrated in Figure 4.

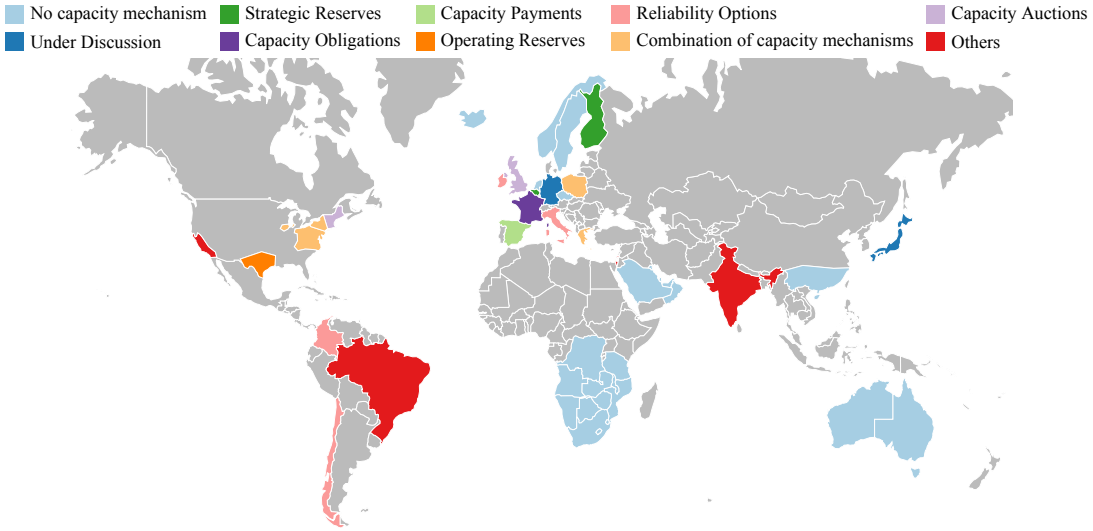


Figure 4: Map of planned capacity mechanisms in jurisdictions

4 SYSTEM RELIABILITY

In all answers, the responsibility for the long-term generation adequacy and short-term security of supply is allocated with the government, the system operator or a panel that have at least one of the two parties as member. It clearly shows that the long-term responsibility also in liberalized market design is not only left to the outcome of the market decisions. The system operator has hereby the role of an approved expert and counsellor on future capacity demand expectations while the final responsibility and authority to set rules is with the government. In most cases, the system operators conduct a certain monitoring. However, the answers indicate that there are hardly procedures that are found in all jurisdictions. Common predefined measures that are repeatedly used are for example the Loss of Load Expectation (LOLE), accompanied by e.g. simulations of severe weather conditions such as dry years or cold spells. Mostly, such simulations and calculations lead to annual or multi-annual adequacy / security of supply reports that form baseline for policy making.

If applicable for the jurisdictions, interconnections are taken into account for the assessment of security of supply. Especially in case of system simulations and scenario calculations, the impact of the interconnections is considered. Vice versa, next to the generation adequacy assessment, also the sizing of interconnections and internal network planning is part of the security of supply studies.

The result for the system reliability is given below in Table I. The table shows the information received for present and expected system reliability together with the existence of capacity mechanisms. In all jurisdictions with concerns on the system reliability, this concern is connected with the generation adequacy. Only in three jurisdictions the network adequacy causes concerns about the system reliability. On the long-term perspective, the concerns increase with the unpredictability of the system development.

Jurisdictions with a capacity mechanism in place tend to have a positive expectation about their system reliability in the future. Jurisdictions that are discussing or implementing a capacity mechanism at

the moment have been woken up by concerns about the generation adequacy in the near future.

Table I: Overview of system reliability and present / planned capacity mechanism

Country	AU NEM	AU WA	BE	BR	CL	CN	CO	CZ	DE	ES	FI	FR	GB	GCCIA	GR	IE
System reliability																
Present	++	++	+	-	-	++	++	++	++	++	++	++	++	-	++	++
3 years ahead	++	++	-	-	-	++	-	++	++	+	+/-	++	++	-	+	
6 years ahead	?	++	-	?	?	?	-	++	++	-	-	+	++	++	+/-	
Capacity mechanism																
Present	(✓)	✓		✓	✓		✓			✓	✓				✓	✓
Planned/Discussed			✓						✓			✓	✓			
None						✓		✓						✓		
Main reason																
Generation	•	•	•	•/-	•	•	-	-	•	-	-	•/-	-	-	-	-
Network	-		-	-	•	•	-	-	•	-	-	-	-	-	-	-
Other	•/-		-	-	-	-	-	-	-	-	-	-	-	-	•	-

Country	IL	IN	IS	IT	JP	NL	NO	PL	SAPP	SE	US CAISO	US ERCOT	US ISONE	US NY-ISO	US PJM
System reliability															
Present	++	+	+	+	+/-	++	+	++	-	++	+	+	++	++	++
3 years ahead	++	++	++	+		++	++	-	-	++	-	-	+	++	++
6 years ahead	++	++	++	+		-/+	++	+	++	+	-	-	+	?	++
Capacity mechanism															
Present		✓		✓				✓		✓			✓	✓	✓
Planned/Discussed															
None	✓		✓		✓	✓	✓		✓		✓	✓			
Main reason															
Generation	-	-	-	-	-	•/-	-	•/-	•	•	•	-	•	-	-
Network		-	-	•	-	-	-	•	-	-	-	-	-	-	-
Other		-	-	-	-	-	-	-	-	-	-	-	-	-	-

5 POWER MARKETS AND EXPECTED PROFITABILITY

Part of a comprehensive description of a power system is the design of the power market. Main distinction in power markets is made between liberalized and regulated markets. In addition, the market design can be split up based on the mechanisms and market platforms within the market zone. The received answers are for the greater part from liberalized markets (25 out of 31).

Out of the 31 answers, 16 markets have implemented a capacity mechanism before 2014. All capacity mechanisms are part of a liberalized market design. Combinations of capacity mechanisms with power pools (5), with day-ahead market designs (8) or both (3) exist (Table II). The regulated markets do not show a need for an explicit capacity mechanism.

Figure 5 illustrates the expected development of profitability for different generation types, namely base, mid and peak units. Note, the values represent a general impression and may vary for certain plants or installed units. It shows that there is a general trend towards less profitability of peaking units which are mostly situated in the low state and are likely to stay there. For the mid and base units the situation is improved and for most jurisdictions the units are located in the reasonable profitability state.

6 IMPACT OF RENEWABLES & INTERCONNECTION CAPACITY

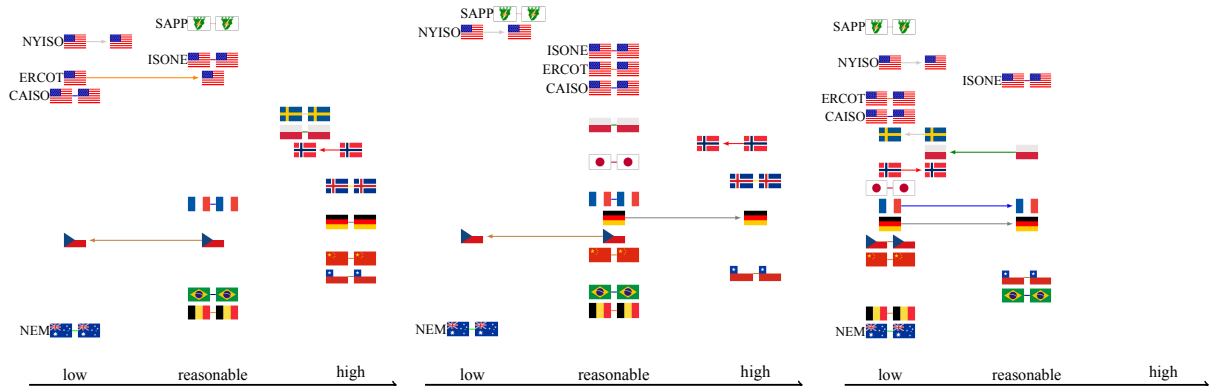
Next to the description of the individual system characteristics, the correlation of power system characteristics and the implementation of capacity mechanisms is analysed, more precise, if there is an observable connection between the share of RES on the total generation and the presence of a capacity mechanism, as well as the level of interconnection capacity with neighbouring markets and a capacity mechanism. Figure 6a and 6b are used to illustrate the relationships based on the received data.

Capacity mechanisms are more often present in jurisdictions with a high share (right part of Figure 6a) of intermittent RES (wind, solar) with low marginal costs is a first assumption. However, the data does

Table II: Overview of existing markets

Country	AU NEM	AU WA	BE	BR	CL	CN	CO	CZ	DE	ES	FI	FR	GB	GCCIA	GR	IE
Liberalized	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓
Power pool	✓	✓		✓	✓		✓						✓		✓	✓
Bilateral contracts		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Day-Ahead market		✓	✓				✓	✓	✓	✓	✓	✓	✓			
Real time/Balancing		✓	✓	✓				✓	✓	✓	✓	✓				
Ancillary service	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Capacity mechanism	(✓)	✓		✓	✓		✓			✓	✓				✓	✓

Country	IL	IN	IS	IT	JP	NL	NO	PL	SAPP	SE	US CAISO	US ERCOT	US ISONE	US NY-ISO	US PJM
Liberalized		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓
Power pool														✓	
Bilateral contracts	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓	✓
Day-Ahead market		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Real time/Balancing		✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓
Ancillary service			✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓
Capacity mechanism		✓		✓				✓		✓			✓	✓	✓



(a) Base (b) Mid (c) Peaker

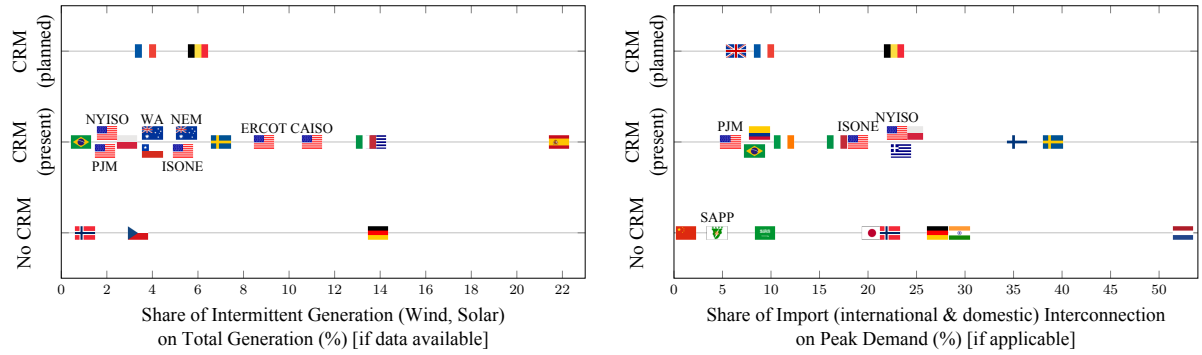
Figure 5: Expected development of profitability for generation types (current → up to 6 to 10 years)

not confirm the assumption. Both, systems with a high share and capacity mechanism like Spain and a high share without capacity mechanism like Germany can be observed. Obviously, the data only shows a snapshot of the data from 2012 and 2013. A time line showing the growth of share of RES and the start of the capacity mechanism could reveal a clearer relationship. Also at the other end of the spectrum, i.e. system with low shares of intermittent RES, both systems with capacity mechanism (Brazil, US PJM) and without capacity mechanism (Norway) can be observed.

Isolated and less interconnected (left part of Figure 6b) are more dependent on domestic capacity and might therefore earlier decide to implement a mechanism to remunerate domestic capacity. Similar, to Figure 6a, a coherent link between interconnection and capacity mechanism can not be observed. Strongly interconnected jurisdictions like Finland and Sweden still opt for a capacity mechanism to cover seasonal peaks. France, GB and Belgium with a low interconnection capacity for European jurisdictions are in the process to implement a capacity mechanism. However, a direct link to the interconnection is not stated as reason for implementation.

7 CONCLUSIONS

The evaluation based on the questionnaires gives a good overview of currently existing and developed capacity mechanisms around the world. Thanks to the 31 received contribution, a world wide overview



(a) RES share

(b) Interconnection capacity

Figure 6: Relationship of the presence of capacity mechanisms and RES share or interconnection capacity

could be established. This paper presents the results from the survey, which gives an insight over the use and perceived future needs of capacity mechanisms worldwide. It includes an excerpt of the full evaluation which is part of the technical brochure covering the work of the working group C5.17 *"Capacity Mechanisms: Needs, Solutions and State of Affairs"*[1].

The surveys were sent out in 2014. A total of 31 jurisdictions responded giving the status of current implementations, given an available data basis of 2012 / 2013, and an outlook up to 6 to 10 years ahead. The contributions originate also from both regulated (6) and liberalized (25) power market systems. With respect to capacity mechanisms, the jurisdictions represent both systems with present capacity mechanisms (16) and without capacity mechanisms (15). In 8 of the jurisdictions, an implementation or a redesign of capacity mechanism is currently taking place.

The integration of capacity mechanisms in the market design is independent from the market / system size. Both capacity mechanisms in large and smaller systems are identified. Capacity mechanisms occur more often in system with large seasonal differences and in system with doubts about the generation adequacy in the long run. The large variety and combination of capacity mechanisms in place indicates that country specific characteristics lead to individual designs.

The ongoing discussion in multiple European countries leading to new implementations of capacity mechanisms and the reported redesign of existing capacity mechanism show the dynamic nature of power markets. While a direct link of the existing of a capacity mechanism to a certain power system criteria could not be observed, the assessed system criteria contribute to some extent to the decision for or against the implementation of a capacity mechanism. But, it also shows that the decisions are mostly taken due to very country-specific constellations of the described criteria.

BIBLIOGRAPHY

[1] G. Doorman, J. Barquin, L. Barroso, C. Batlle, A. Cruickshank, C. Dervieux, R. Flanagan, J. Gilmore, J. Greenhalg, H. Höschle, P. Mastropietro, A. Keech, M. Krupa, J. Riesz, B. LaRose, S. Schwenen, G. Thorpe, K. De Vos, L. de Vries, and J. Wright. *Capacity Mechanisms: Needs, Solutions and State of Affairs*. Technical Brochure, Cigré Working Group C5.17, 2016.

APPENDIX

Table III: List of submissions

#		Code	Country/ Market area
1	South America	BR	Brazil
2		CL	Chile
3		CO	Colombia
4	North America	US CAISO	California Independent System Operator
5		US ERCOT	Electric Reliability Council of Texas
6		US ISONE	ISO New England Reliability Coordinator
7		US NYISO	New York ISO
8		US PJM	PJM Interconnection
9	Europe	CZ	Czech Republic
10		BE	Belgium
11		ES	Spain
12		FI	Finland
13		FR	France
14		DE	Germany
15		GB	Great Britain
16		GR	Greece
17	Europe	IE	Ireland & Northern Ireland (SEMO)
18		IS	Island
19		IL	Israel
20		IT	Italy
21		NL	The Netherlands
22		NO	Norway
23		PL	Poland
24		SE	Sweden
25	Asia	CN CSG	China Southern Grid, CSG
26		GCCIA	GCCIA (Kuwait, Saudi Arabia Eastern Operating area, Bahrain, Qatar, Abu Dhabi, Oman)
27		IN	India
28		JP	Japan
29	Africa	SAPP	South African Power Pool
30	Australia	AU NEM	Australia National Electricity Market
31		AU WA	Western Australia