FLORENCE SCHOOL OF REGULATION

ROBERT SCHUMAN CENTRE

Distributed energy resources and electricity balancing: visions for future organisation
Appendices

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APPENDIX 1

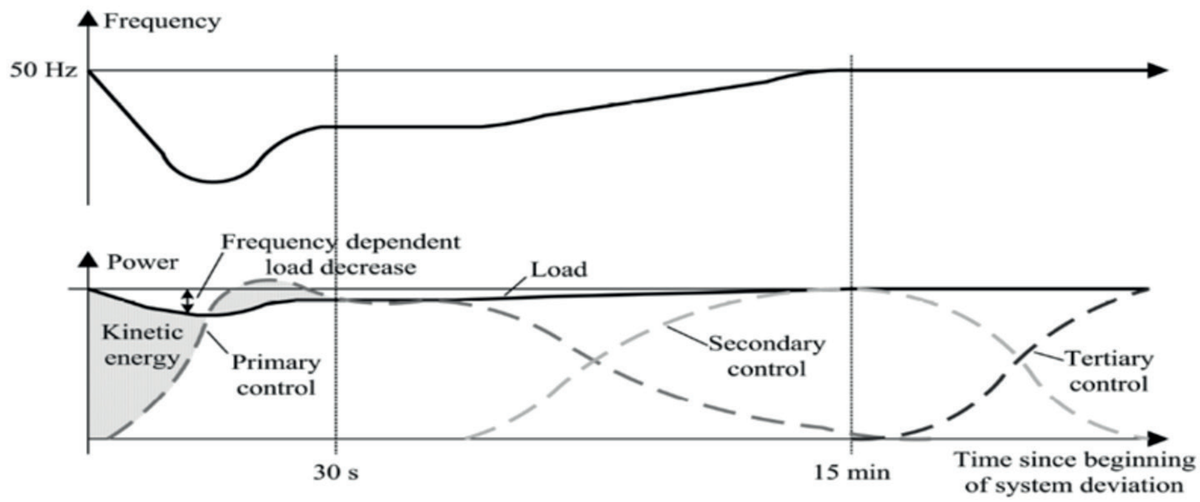
Terms of Reference: Decentralised, Inclusive and Resilient Energy Market

Introduction

Electrical power systems are characterised by voltage and frequency and the flow of electricity is a continuous process. Buffering or storing electrical energy at each node is still not feasible, therefore electrical energy needs to be generated exactly at the time of consumption. Differences in supply and demand causes the nominal frequency (50Hz in EU) to deviate. Consequently, supply and demand need to be monitored in real time to implement adjustments to maintain equilibrium and nominal frequency. Significant deviation from the nominal leads to cascading effect culminating in a blackout [7]. Transmission system operators (TSOs) oversee fast, flexible, fossil fuel-based generation units and demand response service from large consumers, ensuring the continuation of operation during significant transient faults in the energy system. These generators form the basis of frequency control strategies used in balancing these electrical systems. Each control strategy has specific purposes and features and can be categorised in three groups:

1. Primary Control (Frequency Containment Reserve - FCR)
2. Secondary Control (Automatic Frequency Restoration Reserves - aFRR)
3. Tertiary Control (Manual Frequency Restoration Reserves - mFRR)

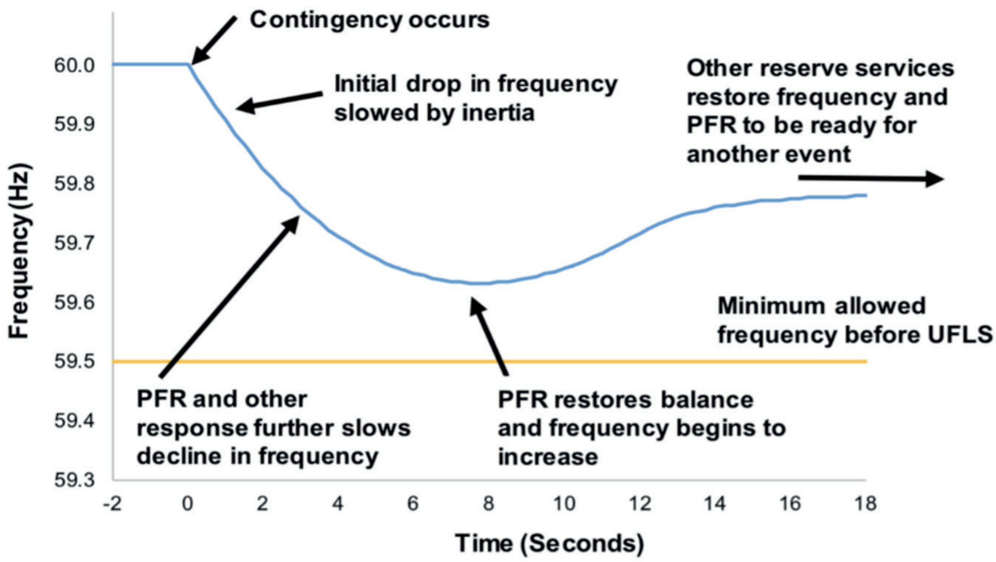
Figure 1: The three tiers of grid control and its activation structure [1]



In conventional grid structures:

Primary control is an automatic function that is almost instantaneously activated to stabilise the frequency drops/spikes. It is the fastest type of frequency control with a response time of a few seconds and operates using a joint process involving all TSOs of the synchronous area. This is shown in Fig. 2 below. For example, if there is an increase in demand, the energy used to compensate for this demand comes from the kinetic energy stored in large rotating synchronous generators that start decreasing its velocity. This is referred to as Inertial response [2]. For the generators to recover the speed, the speed controller of each generator acts to increase the generator power to clear the imbalance. Within a period of 30 seconds, each generating unit is able to generate the required power and stabilise this production for at least 15 minutes or depending on the requirements of the TSO within the synchronous region. Primary control is done using generation plants that are connected to the high voltage power supply with the exception of renewable energy sources which are non-schedulable due to its intermittent nature.

Figure 2: Recovery of the system from a contingency event and action by primary frequency control (PFR) [3]



Secondary control is performed automatically by all the generators to restore the nominal frequency, the power exchanges and reserve of the generators used in primary control. The generators involved in this regulation function through dedicated reserve power that are set in conjunction with central controllers. The reserve control power is negotiated in a contract conjunction with the TSO and is a percentage of the maximum available power with a predefined minimum value to ensure that it can be dispatched whenever needed. This service is remunerated according to the set contracts.

Tertiary control is not an automatic function and is executed upon request by the grid operator. The reserve margins used for the secondary control are restored through tertiary control.

The differences between the primary, secondary and tertiary frequency control is the time the production and response can be activated, and the remuneration for each. Primary frequency control is symmetrical as the capacity for control has been scheduled and usually balances between ramping up and down the production and therefore not remunerated. Secondary and tertiary control are not symmetrical as the capacity can be used only for ramping up or down the production to restore the frequency and are remunerated.

2. Review of the three levels of regulation

Table 1. Main features of frequency control strategies [2]

	Response Time	**Duration Time**	**Operation**	**Purpose**
Primary Control	10-30 Seconds	15 Minutes	Automatic	Act in case of frequency variation in order to stabilise frequency value
Secondary Control	200 Seconds	120 minutes	Automatic	Act to bring back frequency value to the nominal value and restore the power reserve of the generators used for the primary frequency control
Tertiary Control	15 Minutes	Indicated by TSO	Upon Request	Act to restore power reserves of the generators used for the secondary frequency control

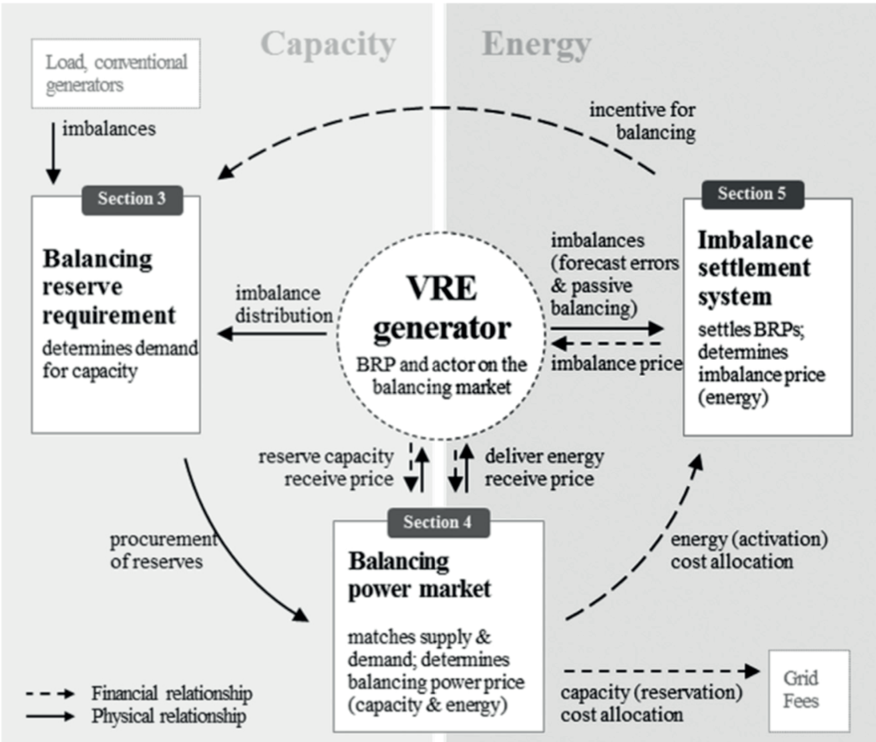
3. Research Topics and Open Questions

Research Topic 1: Balancing solutions for grids with a very high share of renewables

With the increase of distributed renewable resources (DER) in the grid, the type of energy flow changes as there is less influence of synchronous generators and inertial response on the grid frequency (solar PV plants do not provide any inertia response, [2]). Deviation of the grid frequency from the nominal value might require different balancing mechanisms.

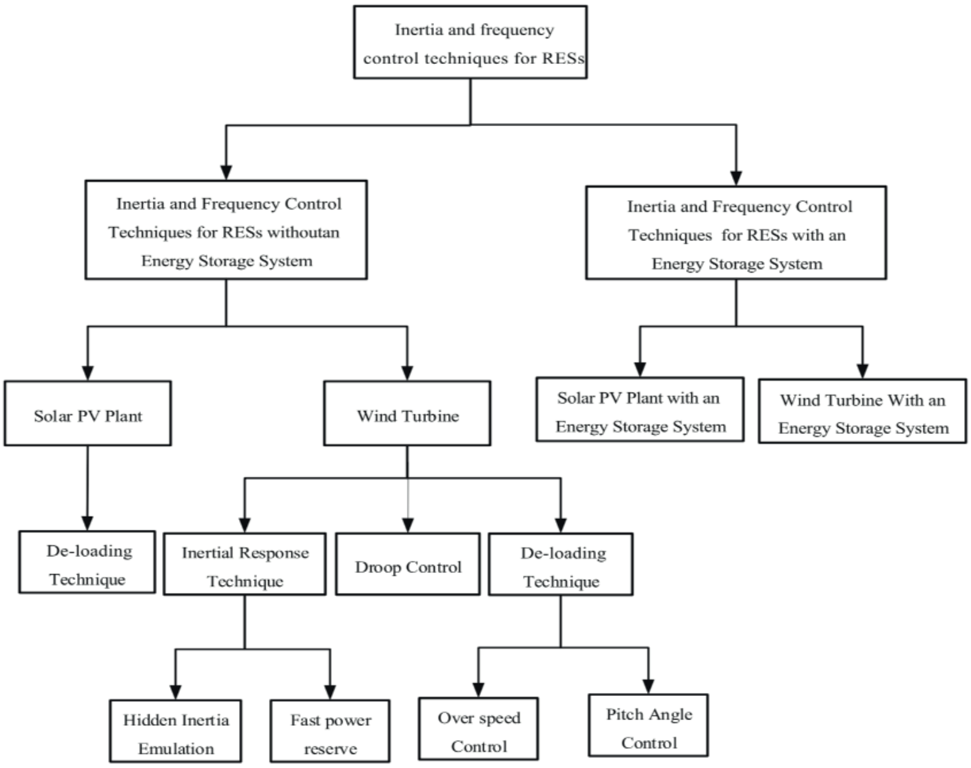
As discussed by Hirth, Ziegenhagen in Figure 3 below, a design taking into account the building blocks of the balancing mechanism in the case of high DER share can be implemented.

Figure 3. Four building blocks of the balancing mechanism in case of high share of DER [4]



In solar PV power plants, energy storage and deloading techniques can be used for frequency control. In wind power plants, energy storage, deloading techniques and inertial response techniques are used. Deloading techniques utilise pitch and over speed control of the turbine as shown in Figure 4 below.

Figure 4: Inertia and frequency control techniques for wind and solar [5]



New digital technologies have demonstrated the efficiency of a hierarchical bottom-up market design and the potential it has for local energy communities and to enable wider individual choice when it comes to energy use (as shown in Figure 5 below). The challenge is to interpret how balancing markets would function in that market design.

Figure 5. Grid-aware local energy markets

Research Questions:

- How can a balancing market be designed that follows a bottom-up, hierarchical market approach in which an energy system is powered by a high share of renewable energy? Do the roles of current market actors change and, If yes, how?
- Which specific regulatory changes are required to reduce entry barriers for smart consumers/prosumers and allow for a bottom-up hierarchical market design?
- Can this design already be implemented in energy communities in Europe?

Research Topic 2: Aligning physical balancing and/or penalty costs

Two objectives for implementation of balancing markets with high shares of DER:

1. To maintain physical aspects of the grid (frequency, stability, congestion management)
2. To provide a mechanism for penalising strong deviations in consumption and production from the scheduled trades. (e.g. when the asset agent trades based on a poor forecast or decides to consume or produce unscheduled kWh).

Research Questions:

- How does the balancing market design account for physical grid balancing along with trade settlement and penalties?
- Can the two objectives outlined above be met in the same balancing market design or is more than one market mechanism needed?
- How do balancing exchanges interact with each other in different hierarchies?
- Should all assets be penalised if they do not match their trade schedule? It might be the case that consumers should not be penalised for not consuming the energy they bought. But, traders should be dis-incentivised to withdraw more from the grid or inject more into the grid than their schedules based on their trading.

Research Topic 3: Integration of Balancing Market with DSOs, TSOs, Aggregators and Local Market Operators

A design implementation could allow an aggregator who acquires flexible end-users' resources to offer them to the balancing stakeholders (DSOs, TSOs and BRPs). Balancing services can be categorised according to the physical grid and geographical location. For instance, flexibility resources sourced from participants in a physical grid location could be traded by DSOs for localised balancing. Under large synchronous areas, the BRP aggregator could sell the flexibility that has been sourced from a large geographical location to TSOs for balancing purposes. Since flexibility sourcing in this case is from low voltage DERs, the design should put emphasis on ensuring that the relationship between all stakeholders avoids localised grid constraints while procuring flexibility [6].

Research Questions:

- Should there be local flexibility markets and how would they work? (Consider the DSO's approach to do some type of restructuring of trades after the spot market, as well as the role of recent digital platform innovations)
- What is the minimum bid volume (5MW in Norway, 1MW in the Netherlands - providing an entry barrier)? Can it be solved through aggregation i.e. symmetric balancing capacity product [7]
- What role do the aggregators play? If a DSO needs balancing reserves for its grid area, would an aggregator be the point of contact for the demand? How should different reserve types (primary, secondary and tertiary reserves) be treated?

- Should we differentiate between flexibility and services/balancing as a grid service and balancing as a system service, especially with a view of reducing the market entry barrier for individual households/assets? While grid services aim at the local DSO grid, the pan European balancing reserve works on TSO level.
- Consider BRP as a service – how should it be implemented in hierarchical bottom-up markets?
- How will the DSO handle the challenge of reinforcing the distribution network for low voltage grids? [6]

Research Topic 4: Financial basis for determining penalties and costs

Penalties and costs discussed in Research Topic 2 should be determined so that the grid system is optimised and imbalances are reduced, while offering fair prices to smart agents and customers.

Research Questions:

- What should the penalty level be for consuming or producing more/less than a scheduled trade? Is it similar to the regulated utility cost (market maker) or wholesale cost, assuming most assets will not have perfect prediction?
- What is the reward paid to balancing assets participating in the balancing market? How is this currently calculated? Would that be different in a bottom-up market design?
- How to ensure that the “energy cost” of microtransactions does not exceed associated optimisation benefits to the system?
- Should balancing prices be set per local energy market, or is there a network model constraint that defines prices based on a customer’s location in the grid? Prices are unique per customer or set per local energy market?
- What is the relationship between DSO grid tariffs in the spot market and balancing market prices? How do the balancing market prices factor into a consumer’s final energy bill? How can this be optimised so that smart customers are rewarded even though they might not have perfect forecasts?

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APPENDIX 2

Ethics conditions for the performance of studies by the FSR

1. The client requests the Florence School of Regulation ('FSR'), which accepts, to conduct a study on Decentralised, Inclusive and Resilient Energy Market (the 'Study'), as further detailed in the attached Appendix 1: Terms of Reference ('ToR'), which represent the sole contractual basis for the content of the Study.

2. The FSR is solely responsible for the performance of the Study and the client acknowledges that the FSR has the widest possible discretion on how to conduct the Study, in accordance with the ToR. In no way shall the client condition the performance of the Study, beyond its purpose as defined in the ToR, or the Study's results.

3. The FSR aims to conduct the Study according to the highest academic standards and impartially. In conducting the Study, the FSR might, at its own discretion, consult or engage the client and other stakeholders.

4. The Study and its results, together with the ToR, an acknowledgment of the commissioning of the Study by the client and these provisions, will be published by the FSR, except for any data or other information which, because of its nature, should be considered as confidential. In any event, no part of the Study will be confidential to the client.

5. The intellectual property right on the results of the Study will be vested in the FSR.

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