cigre | PARIS 2022

ipto
INDEPENDENT POWER TRANSMISSION OPERATOR

Study Committee C5 –
Electricity Markets & Regulation

Paper ID_10705_2022

A Methodology to Estimate the Reserve Capacity Needs in Balancing Markets-Application to the Greek Balancing Market

Yannis Kampouris[1], Panos Mandoulidis[1], Giorgos Prionistis[1], Vassilios Ziogas[1]

[1]Independent Power Transmission Operator, IPTO, Greece

MOTIVATION

- The continuous development of the markets harmonization in EU has concluded to the application of the so called “target model” all over the European Continent. This model includes the operation of a balancing market that ensures the system security. System security faces significant challenges due to the uncertainties of the (ever-increasing) intermittent RES and the increasing volume of power exchanges among control areas. Balancing markets, operated by TSOs, deal with the procurement and provision of reserves to ensure system secure operation. The assessment is of high importance since over-estimation could lead to unneeded high balancing costs while underestimation may lead to insufficient system security and unwanted risks.
- IPTO has proposed a methodology developed for and applied to the Greek Balancing market since the target model being applied in November 2020 providing satisfactory results.

BACKGROUND

Balancing Market Principles in Greece

The balancing market procedures follow the energy market results provided by the Greek power exchange. The participating entities are the Balancing Services Providers (BSPs), i.e. the generators and the Balancing Services Receivers (BSRs), i.e. TSOs, suppliers, non-dispatchable RES, non-dispatchable loads, etc.

Greek balancing market is designed on unit based / central dispatch model, i.e. the TSO is the only BSR and the bids of the BSPs are provided by each available generator (not of portfolios).

TSO executes every 30min (dispatching period) the balancing market procedures to continuously adjust the generation to the load under the minimum cost.

A mixed-integer optimization algorithm (called “Integrated Scheduling Process” - ISP) is executed for each dispatching day on a 30 min time-step to determine the commitment of the generators to provide balancing energy within each dispatching period. Execution takes place regularly three times per day, as well as on an ad-hoc (on demand) basis. The regular execution times are at 16:45 EET and 24:00 EET of day D-1 and as well as at 12:00 EET of the dispatch day D.

ISP is followed by Real Time Balancing Market (RTBM) procedure that determines the optimal set-points for each committed BSP committed by the ISP. RTBM is executed close to real-time (every 15-minutes) issuing the corresponding FRR instructions to BSPs, placed on top of the ISP half-hour base points.

In order for the BSPs to appropriately prepare their balancing energy offers, several hours before the ISP and RTBM executions, a pre-process takes place in order to estimate a number of parameters and factors which have to be considered for the solution of the Greek balancing market. Such factors include:

- *Non-dispatchable load forecast*
- *Non-dispatchable RES generation forecast*
- *Mandatory hydro generation injections*
- *Transmission system constraints*
- *Transmission system losses forecast*
- *Reserves’ requirements estimation*

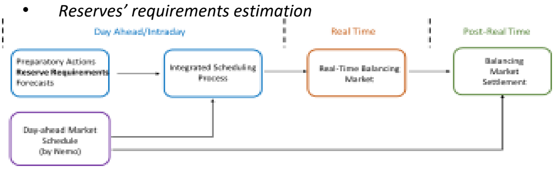


Figure 1: Procedures in the Greek Balancing Market

Balancing Capacity Products

The Greek Balancing Market utilizes the following Balancing Capacity Products (upward and downward):

- *Frequency Containment Reserve (FCR), with instant physical activation.*
- *Automatic Frequency Restoration Reserve (aFRR).*
- *Manual Frequency Restoration Reserve (mFRR) with 15’ activation time requirement.*

The aFRR balancing product corresponds to the AGC process, thus its activation time is restricted to a 10-seconds time frame, aiming to keep the Area Control Error (ACE) close to zero

CIGRE PARIS 2022

ipto

INDEPENDENT POWER TRANSMISSION OPERATOR

Study Committee C5 –

Electricity Markets & Regulation

Paper ID_10705_2022

A Methodology to Estimate the Reserve Capacity Needs in Balancing Markets-Application to the Greek Balancing Market

Yannis Kampouris[1], Panos Mandoulidis[1], Giorgos Prionistis[1], Vassilios Ziogas[1]

[1]Independent Power Transmission Operator, IPTO, Greece

The mFRR product serves a twofold main purpose. The first is to restore the aFRR that has been utilized in the current dispatching period, through slow balancing energy activations aiming to redispatch the BSPs, so that sufficient aFRR is maintained on all of them. mFRR covers also the slow deviations that may occur from forecast errors either on system consumption or renewable production, as well as other external factors such as the realization of the exchange programs, or system extreme conditions. The activation time of mFRR is extended to a 15-minute period.

No Replacement Reserves (RR) are foreseen in the Greek balancing market, thereby increasing the significance of aFRR and mFRR balancing products.

FRR REQUIREMENT METHODOLOGY

Balancing capacity products aFRR and mFRR are estimated for the complete control area of IPTO but separately by the proposed methodology due to different characteristics and purposes.

Calculation of aFRR

Factors that may bring abrupt changes to the ACE have to be incorporated in the calculations of aFRR:

- *Generator outages*
- *Connection-disconnection of large loads*
- *Deviations or/and delayed realization of exchange schedules*

$$P_{aFRR^{up}}(t_k) = \sqrt{P^2_{aFRR_{min}} + \left(c_1 P_{g.out}(t_k)\right)^2 + \left(c_2 \Delta P_{int.up}(t_k)\right)^2 + P^2_{Load.up}}$$

$$P_{aFRR^{dn}}(t_k) = max\left\{P_{aFRR_{min}}, d_1 \Delta P_{g.dev}, d_2 \Delta P_{int.dn}(t_k), P_{Load.dn}\right\}$$

$P_{aFRR_{min}}$ is the minimum guaranteed amount of aFRR for the control area, $P_{g.out}(t_k)$ accounts for the estimated generating unit production that may be abruptly disconnected from the grid and is the average dispatch period production as it resulted from the previous week's thermal and hydro units' ISP solution base points. $\Delta P_{int.up}(t_k)$/ $\Delta P_{int.dn}(t_k)$ account for the incremental changes of the scheduled interchange programs between two consecutive dispatching periods requiring either upward or downward reserve accordingly. Since the tie-line schedules are not known at the time the reserve requirements are calculated, historical data from the previous week are utilized. $P_{load.up}$/$P_{load.dn}$ are constant values representing an estimated amount of large load that may be suddenly connected/disconnected in/from the transmission grid and $\Delta P_{g.dev}$, also a constant value, accounts for a relative amount of dispatchable generation that delays to follow power setpoint orders.

Calculation of mFRR

Factors that affect mFRR belong to a slower time frame:

- *aFRR restoration*
- *Load and RES forecast errors*
- *Deviations or/and delayed realization of exchange schedules*
- *Delayed setpoint change of generators*

$$P_{mFRR^{up}} = \sqrt{P^2_{aFRR^{up}} + \left(k_1 P_{RES}\right)^2 + P^2_{L_{forecast}.up} + \left(k_3 \Delta P_{int.up}\right)^2 + P^2_{energ.up}}$$

$$P_{mFRR^{dn}} = max\left\{P_{aFRR^{dn}}, r_1 P_{RES}, P_{L_{forecast}.dn}, r_3 \Delta P_{int.dn}, P_{energ.dn}\right\}$$

P_{RES} is the forecasted transmission-connected RES production in the control area. Multiplication factors account for the average annual forecast error of the corresponding term and are of the order of 10%. $P_{L_{forecast}.up}$/ $P_{L_{forecast}.dn}$ account for the transmission system load forecasts ("net load"). $\Delta P_{int.up}(t_k)$/$\Delta P_{int.dn}(t_k)$account for the incremental changes of the scheduled interchange programs between two consecutive dispatching periods. A 40% portion of the tie-line increment value is allocated to the aFRR requirement and a 60% percentage to the mFRR requirement.

Study Committee C5 –
Electricity Markets & Regulation

Paper ID_10705_2022

A Methodology to Estimate the Reserve Capacity Needs in Balancing Markets-Application to the Greek Balancing Market

Yannis Kampouris[1], Panos Mandoulidis[1], Giorgios Prionistis[1], Vassilios Ziogas[1]

[1]Independent Power Transmission Operator, IPTO, Greece

INDICATIVE RESULTS

Aggregated curves from November 2020 to October 2021

System Characteristics:

- *Net load ranged from 1650 to 9400 MW, total energy consumption is 45 TWh*
- *Upward reserve volumes follow in general the load variation and adapt to system's requirements. aFRR^{dn} maintains a constant profile for the majority of hours due to load rejection terms. mFRR^{dn} exhibits a small portion with high reserves when transmission-connected renewable production is large.*

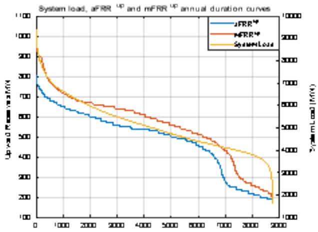


Figure 2: Net Load, aFRR^{up} , mFRR^{up} duration curves

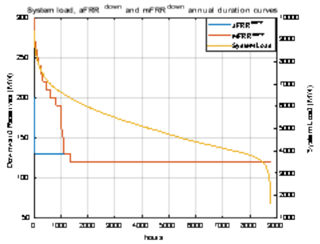
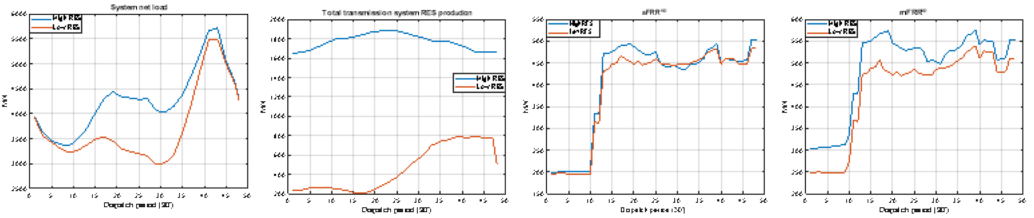
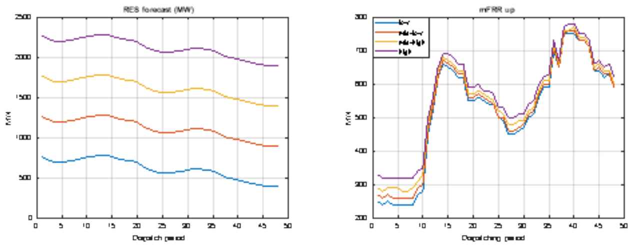


Figure 3: Net load, aFRR^{dn} ,mFRR^{dn} duration curves

Typical cases: Low/High Transmission RES production



Impact of Transmission RES generation on mFRR



Conclusions:

- *System reserves adapt to system's needs (load or renewables variations) and system uncertainties*
- *No shortage of system reserves were recorded during the investigated period*
- *Methodology may easily be adjusted to future system needs, as it allows the consideration of any new rules in the calculations*