TradeRES
New Markets Design & Models for 100% Renewable Power Systems

User Guide

RESTrade

Multi-agent Trading of Renewable Energy Sources

Overview

The RESTrade module comprises the models of the traditional power and energy reserve markets under development in the TradeRES project [1, 2]. This module supports the participation of traditional dispatchable power plants, variable renewable energy, and demand players in the system balance, i.e., automatic (aFRR) and manual (mFRR) frequency restauration reserve markets [3, 4]. Also, it uses both the marginal pricing theory (MPT) and the pay-as-bid (PAB) scheme to define prices. The aFRR capacity requirements are computed considering the balancing guide-lines of the ENTSO-E [3]. It is also possible to compute the aFRR capacity as in the Portuguese (PT) system. Furthermore, it also computes the imbalance settlement based on the PT or Spanish (SP) formulations [5, 6]. The PT formulation considers that all Balance Responsible parties (BRPs) must pay the energy used to balance the system equally. So, it computes a single penalty and dual pricing. The SP formulation computes the balance direction and only the BRPs that originate those balance needs must directly pay/receive the price of energy balance of the system.

Table 1: Iberian Imbalance Prices.

BRP position	System in up-regulation	System in down-regulation
Positive (power excess)	PT: imbalance price SP: spot price	Both: imbalance price
Negative (power deficit)	Both: imbalance price	PT: imbalance price SP: spot price

Traditional aFRR capacities are computed hourly. Very fast-responsive power plants reserve a down and up capacity to participate in this market. They can be remunerated using the MPT or the PAB. In PT their energy is remunerated considering a predefined value defined by the Regulator. However, RESTrade also provides an hourly energy aFRR market. The clearing of this market can consider both the MPT and PAB schemes. The mFRR hourly energy market is also provided, where power plants can submit bids for up and down regulation as different products. RESTrade module also enables the users to run new reserve market design models. The capacity market of aFRR is divided into up and down capacities, which allows market participants to submit independent up and down capacities. The capacity and energy reserve markets implemented in this module are also capable to deal with shorter time units starting (5, 15 or 30 minutes). This module is adapted to

negotiation close-as-possible to real-time operation. These new timeframes are activated according to the data resolutions used by the users.

Inputs

The inputs to RESTrade modules are mostly from the agents' bids on reserves markets. These bids can be written to Excel files for each market. Alternatively, users can create their own input files to run the RESTrade module. Each spreadsheet of the Excel files corresponds to a period of time. All files indicated in this document are available at the root directory of the installation. All economic values are presented in monetary units (m.u.).

Table 2: Data needed to run RESTrade modules.

Agent	Variable	Unit	Description	File to edit
Supply and demand	CDsec	MW	Down capacity to offer at aFRR capacity market	Secondary.xls
	CUsec	MW	Up capacity to offer at aFRR capacity market	
	[CDsec, CUsec]	MW	Band capacity to offer at aFRR capa city market	
	PCsec	m.u ./MW	Band price to bid at aFRR capacity market	
	PDCsec	m.u /MW	Price to bid at aFRR down capacity market	
	PUCsec	m.u /MW	Price to bid at aFRR up capacity market	
	QDsec	MW	Down power to offer at aFRR energy market	SecondaryMarket.xls
	QUsec	MW	Up power to offer at aFRR energy market	
	PDEsec	m.u ./MWh	Price to bid at aFRR down energy market	
	PUEsec	€/MWh	Price to bid at aFRR up energy market	
	QDter	MW	Down power to offer at mFRR energy market	Tertiary.xls
	QUter	MW	Up power to offer at mFRR energy market	
	PDter	m.u. /MWh	Price to bid at mFRR down energy market	
	PUter	m.u ./MWh	Price to bid at mFRR up energy market	
TSO (All variables are	Dmax	MW	Maximum expected demand	SecondaryNeeds.xls
	CsecD	MW	Down capacity needs of aFRR capacity market	SecondaryOutput.xls

computed except Dmax and real-time energy needs)	CsecU	MW	Up capacity needs of aFRR capacity market	
	[CsecD, CsecU]	MW	aFRR capacity band requirements	
	EsecD, EsecU, EterD, EterU	MWh	Real-time energy requested by aFRR and mFRR reserves for up and down balances	SecondaryENeeds.xls TertiaryNeeds.xls
	EimbU, EimbD,	MWh	Total imbalanced energy	TertiaryNeeds.xls

To define the simulation behavior, a row-based binary configuration text file (*Config.txt*) is provided below. This is possible to set as follows:

Table 3: Inputs in the configuration file.

Row	Value	Description
1	0	Traditional markets
	1	Upcoming market designs
2	0	Marginal pricing
	1	Pay-as-bid
3	0	ENTSO-E aFRR procurement
	1	Portuguese aFRR procurement
4	0	Portuguese imbalance settlement
	1	Spanish imbalance settlement

This version of RESTrade module is not able to handle missing data. In case of missing data, put “0” as its respective value, and the results of that period will be “0”.

Outputs

This section presents the output of each market.

Table 4: Outputs of the RESTrade modules.

Market	Output	Unit	Description	File
Traditional aFRR capacity	[CsecDf, CsecUf]	MW	Contracted aFRR band	SecondaryOutput.xls
	PSec	m.u./MW	aFRR band strike-price	
	EsecD, EsecU	m.u./MWh	Activated aFRR up and down energy	TertiaryOutput.xls
Upcoming aFRR capacity	CsecDf	MW	Down aFRR capacity	SecondaryOutput.xls
	CsecUf	MW	Up aFRR capacity	
	PSecDf	m.u. /MW	Down aFRR capacity price	
	PSecUf	m.u. /MW	Up aFRR capacity price	
aFRR energy	CsecEf	MW	Down aFRR energy	SecondaryEOutput.xls
	CsecEf	MW	Up aFRR energy	
	PSecEf	m.u. /MW	Down aFRR energy price	
	PSecEf	m.u. /MW	Up aFRR energy price	
mFRR	EterD	MWh	Activated mFRR down energy	TertiaryOutput.xls
	EterU	MWh	Activated mFRR up energy	
	PterU	m.u./MWh	Strike-price of up mFRR reserves	
	PterD	m.u. /MWh	Strike-price of down mFRR reserves	
Imbalance settlement	Pimb	m.u./MWh	Imbalance penalty	
	PimbD	m.u./MWh	Down imbalance price	
	PimbU	m.u./MWh	Up Imbalance price	

How to run it

The RESTrade module is integrated with MASCEM in Spine Toolbox. It requires to run previously the MASCEM models as indicated in the following fluxogram:

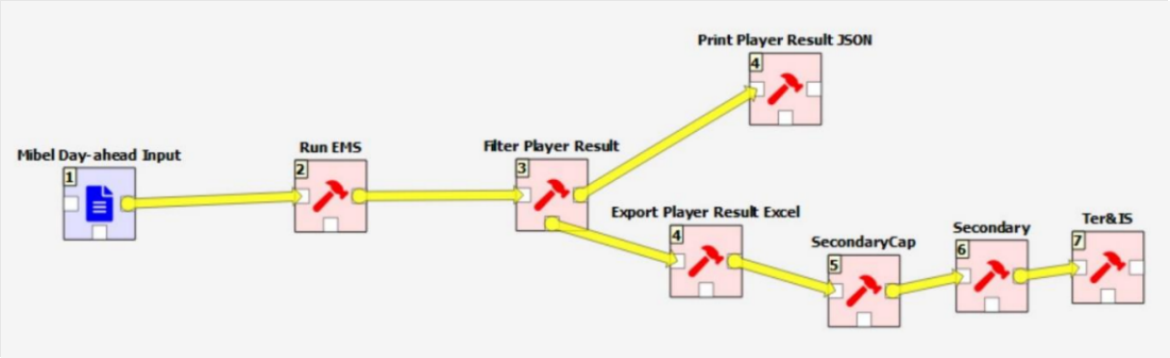

Figure 1: MASCEM and RESTrade fluxogram in Spine Toolbox.

RESTrade consists of the following blocks: “SecondaryCap”, “Secondary” and “Ter&IS”. Below is a brief explanation of these blocks and input data are provided.

SecondaryCap – This block contains both the models of the procurement of aFRR capacity and of the aFRR capacity market. To compute the aFRR procurement, it is necessary to introduce the maximum expected consumption (second column in file *SecondaryNeeds.xls*) per period under simulation (first column). The TSO submits to the market the up and down needs of the aFRR capacity and collects the agents’ bids to the market, computing the market-clearing price(s) and up and down capacities. The bids per agent and period of negotiation are inserted by the users in the *Secondary.xls* file. Each negotiation period should be introduced in the different Excel sheets. Information of each column in the *Secondary.xls* file is presented as follows:

Table 5: Description of the aFRR bids input file.

Detailed description	Supply and demand agents. Information can be inserted in ascii format	Indicate per agent the secondary capacity. This capacity has to be positive in case of traditional markets, but can be positive or negative, otherwise [MW]	Indicate per agent the price of the secondary capacity [m.u./MW]
Information needed	Indication of the agent name	CUsec/CDsec	PCsec/ PUCSec/PDCSec

Outcome: The outcomes from this market are available in the *SecondaryOutput.xls*.

Secondary – This block contains the market model for simulating the aFRR energy market. The TSO reads the secondary dispatch needs from *SecondaryENeeds.xls* file. The file needs the following information: Period, Up Needs (MW), and Down needs (MW). This agent also collects the agents' bids and computes the up and down energy prices using file *SecondaryMarket.xls.* This file has a similar format to the *Secondary.xls* file, and the same format of *Tertiary.xls*, presented as follows:

Table 6: Description of the mFRR bids input file.

Detailed description	Supply and demand agents. Information can be inserted in ascii format	Indicate per agent the secondary or tertiary power [MW]	Indicate per agent the price of the secondary or tertiary energy [m.u./MWh]
Information needed	Agent name	QDsec/ QUsec QDter/ QUter	PDEsec/ PUESec PDter/PUter

The outcomes from this market are available in the *SecondaryEOutput.xls*.

Ter&IS – This block contains both the models of the mFRR energy market and of the imbalance settlement. The TSO reads the mFRR dispatch needs from a file (*TertiaryNeeds.xls*) and collects the agents' bids (*Tertiary.xls*), and computes the up and down energy prices. This last file follows the format of the *SecondaryMarket.xls*. Tertiary energy needs and total imbalances can be edited in file *TertiaryNeeds.xls* as follows:

Table 7: Description of the TSO needs for up and down mFRR regulation.

Period number	Up needs [MWh]	Down needs [MWh]	Total Up deviations [MWh]	Total Down deviations [MWh]
1	EterU	EterD	EimbU	EimbD

In this module, the TSO also computes all energy costs with the reserve markets and the respective penalties of the imbalanced agents. The outcomes from this market, as the penalties and imbalance prices are available in the *TertiaryOutput.xls*. *SecondaryOutput.xls* and *TertiaryOutput.xls* files, contain all the capacity and energy outputs from the RESTrade modules, respectively.

TradeRES

New Markets Design & Models for 100% Renewable Power Systems

Find out more

[1] E. Rinne et al., “D4.8: Open-access tool of linked electricity market models,” TradeRES project deliverable. p. 18, 2021.

[2] L. de Vries et al., “D4.5: New market designs in electricity market simulation models,” TradeRES project deliverable. p. 44, 2021, [Online]. Available: https://traderes.eu/wp-content/uploads/2021/10/D4.5_TradeRES_NewMarketDesigns_H2020.pdf.

[3] ENTSO-E., “Appendix 1 - Load-Frequency Control and Performance. In ENTSO-E Operation Handbook”, 2009. https://www.entsoe.eu/resources/publications/system-operations/operation-handbook/.

[4] H. Algarvio, F. Lopes, A. Couto, and A. Estanqueiro, “Participation of wind power producers in day-ahead and balancing markets: An overview and a simulation-based study,” Wiley Interdiscip. Rev. Energy Environ., vol. 8, no. 5, 2019, doi: 10.1002/wene.343.

[5] Ea Energy Analyses, “Value of Forecast for a wind power plant Owner”, IEA WIND TASK 36 - FORECASTING FOR WIND POWER, December 2021.https://www.ieawindforecasting.dk/-/media/sites/iea_task_36/publications/iea_task_36_value_of_forecast_100122.pdf?la=da&hash=6C75F1A29A863E39A7D75AE2D7816D0FD0B09795.

[6] P. Frade et al., "Wind balancing costs in a power system with high wind penetration–Evidence from Portugal." Energy policy 132 (2019): 702-713.

Main contacts

Hugo Algarvio hugo.algarvio@lneg.pt

Ana Estanqueiro ana.estanqueiro@lneg.pt

Fernando Lopes fernando.lopes@lneg.pt

António Couto antonio.couto@lneg.pt

Info

The TradeRES project will develop and test innovative electricity market designs that can meet society’s needs of a (near) 100% renewable power system. The market design will be tested in a sophisticated simulation environment in which real-world characteristics such as actors’ limited foresight into the future and risk aversion are included.

Start date
1 February 2020

End date
31 January 2024

Overall budget: € 3 988 713,75

https://traderes.eu
info@TradeRES.eu

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 864276