

# Balance



## Balancing market optimization

### Overview

In several electricity markets currently worldwide generation companies dispatch their power units for each hour or half hour of the next day.

It is the responsibility of the Market Operator to send instructions to a group of market participants, also known as the Balancing Market Entities (BMEs) to assure that the forecasted load in each time period matches the aggregate supply.

Instructions are thus positive or negative energy changes that are made to the self-scheduled energy of the BMEs. They are commonly known as offers (instruction to increase power) and bids (instruction to decrease power).

In addition to the self-dispatched energy declarations, BMEs must present prices associated to the bids and offers instructions made by the market operator. The market operator must find the necessary instructions that match supply and demand while minimizing the incurring costs. Balance has been developed by PSR for Energy Balancing Market Operators in order to optimize the system's balancing cost.

Two methodologies have been implemented, based on different market designs:

- **Balancing Market Type I:** The Market Operator is responsible for assuring that the accepted bids and offers do not violate the operating constraints declared by the BMEs, such as the minimum stable generation, ramp constraints, minimum up time and minimum downtime. Start-up and shut-down decisions must also be made by the Market Operator, based on the accepted bids and offers and the self generation declared by the BME.
- **Balancing Market Type II:** The BMEs have different types of bids and offers to select from: hourly fractional or non-fractional, block bids and flexible bids. These different types of bids can be used by the BMEs to accommodate their operating (technical) constraints. In this formulation, the Market Operator does not need to take into explicit consideration the technical constraints of the units. Therefore it is required to decide whether to accept or reject the different types of bids and offers in order to match supply and demand at minimum cost.

## Methodology and modelling

The objective of Balance is to minimize the costs associated to the accepted instructions (offers and bids) that match supply and demand. Balance calculates the bids and offers that will be accepted, based on the corresponding prices declared by the BMEs and their relation between supply (given by the BMEs self-dispatch) and the forecasted demand.

In Balancing Market Type I, additional precautions must be taken as several technical constraints must be respected. For instance, it may be more economical to instruct a BME to start operation in a given hour based only on the offer price. However, once started, this BME may have to remain in operation for a long period of time due to technical reasons. Thus it may no longer be economical to accept this offer. Other technical constraints that must be considered are ramp rates and minimum and maximum level of stable power outputs.

Balance formulates and solves a mixed integer linear mathematical programming problem with Xpress - a commercial package developed by Dash Optimization.

The integer variables are associated with start up and shut down decisions given by the Market Operator to the BMEs in the Balancing Market Type I, whereas the decisions to accept/reject non-fractional bids and offers and block bids and offers introduce the integer variables in the Balancing Market Type II.

The solution approach is to use a branch and bound algorithm combined with the use of a cutting plane algorithm that strengthens the problem formulation and reduces the search space (number of branches that must be explored in the B&B tree). Balance invests heavily in the addition of valid inequalities to the linear relaxation (initial node), and mildly on the addition of valid inequalities for the remaining nodes of the search tree.

This strategy has performed well in applications of considerable size.

Balance allows the selection of an appropriate convergence tolerance. It will stop searching for better alternatives whenever the duality gap is smaller than the convergence tolerance. A null convergence tolerance means that only the true global optimum is accepted. In most practical applications, the definition of a small convergence tolerance (i.e. 0.5%) greatly reduces the solution computational time. The selection of the maximum processing time is also possible. Balance will return the best solution found whenever the elapsed time reaches the maximum allowed time.

## Model Input and Output

Balance is used to generate hourly MWh load/unload instructions for balancing the estimated hourly MWh load against hourly MWh production values.

The module receives as input the following data from an external database:

### For both market types

- The load forecasts to determine net generation that needs to be met by Balancing Entity Generators (MWh/h)
- The hourly generation of the Balancing Entities (MWh/h) submitted as self schedule (also known as final physical notification)

### For Market Type I only

- The Technical parameter values of the BMEs, include: the Power Availability of the BME, the Minimum Stable Generation, the Minimum Run & Shutdown Times, and Power-dependant Ramp Up and Ramp Down Constraints
- The Load / Unload bid and offer prices for each BME and for all the different periods ("day", "night" and peak "values")
- The total production limit (MWh for a specific hour) for a single or group of BMEs

### For Balancing Market Type II

- The bids and offers of the Balancing Entities (MWh/h and \$/MWh), with different types of bid/offer, such as “single hour bids”, “block bids”, “flexible bids” and “non-fractional acceptance bids”
  - **Hourly Bids/Offers:** Identification, Balancing Entity ID, Time block ID, Information type (bid or offer), Bid-Offer type (non-fractional, fractional), the energy amount (MWh/h) and price (\$/MWh)
  - **Flexible Bids/Offers:** Identification, Balancing Entity ID, Information type (bid or offer), Total Energy Limit for the day (MWh), Maximum Capacity in each hour (MWh/h), Energy price (\$/MWh)
  - **Block Bids/Offers:** Identification, Balancing Entity ID, Information type (bid or offer), Initial hour, Final hour (t2), energy amount (MWh/h) and price (\$/MWh)
- Generation constraints in the form of minimum and maximum generation volume for one or a group of Balancing Entities, for the 24 hours of the day ahead.

## Results

Balance produces constrained and non-constrained merit orders dispatch, i.e. minimum cost acceptance of bids and offers for each hour of the following day, identifying for each Balancing Entity (portfolio generation), the bid/offer accepted volume and its associated price. The output of BMEs is:

- Model status (optimum solution found, integer solution found, infeasible, etc.)
- The Hourly System Marginal Price
- The corresponding cost (objective function value)
- Final hourly generation schedule of each balancing entity (self schedule + accepted offers – accepted bids)
- For Market type I – the accepted bids and offers in each hour;
- For Market Type II – the accepted fractional & non-fractional hourly bids and offers, accepted block bids and offers, accepted flexible bids in each hour.

## Graphical User Interface

All data input/output in Balance is made through Excel spreadsheets. Balance has also been used as a stand-alone component integrated with an external system, without using its interface. The next figures illustrate some snapshots of data of Balance.

### Hourly Demand (MWh)

	00h	01h	02h	03h	04h	04h
<b>Forecast Demand</b>	15378	14489	13827	13544	13551	13696
<b>External Exports</b>	190	178	176	184	188	217
<b>Internal Imports</b>	53	50	48	47	48	48
<b>Gen. by Non-BMEs</b>	1257	1238	1235	1229	1258	1301

	00h	01h	02h	03h	04h	04h
<b>Total Demand to be Met by BMEs</b>	14258	13379	12720	12452	12433	12564

Table: Hourly Demand

### Final Physical Notification (MWh)

	00h	01h	02h	03h	04h	04h	06h	07h
<b>Unit #01</b>	1210.0	1210.0	1210.0	1210.0	1210.0	1210.0	1210.0	1210.0
<b>Unit #02</b>	1560.0	1560.0	1560.0	1560.0	1560.0	1560.0	1560.0	1558.0
<b>Unit #03</b>	784.0	784.0	784.0	784.0	784.0	784.0	784.0	783.0

Table: Final Physical Notification

### Availability (MWh)

	00h	01h	02h	03h	04h	04h	06h	07h
<b>Unit #01</b>	1210.0	1210.0	1210.0	1210.0	1210.0	1210.0	1210.0	1210.0
<b>Unit #02</b>	1560.0	1560.0	1560.0	1560.0	1560.0	1560.0	1560.0	1558.0
<b>Unit #03</b>	784.0	784.0	784.0	784.0	784.0	784.0	784.0	783.0

Table: Availability

### Offer and Bid Prices (\$/MWh)

	Day					
	From 6:00		To 17:00		From 17:00	
	Offer Price 1	Offer Price 2	Bid Price 1	Bid Price 2	Offer Price 1	Offer Price 2
<b>Unit #01</b>	38.18	38.18	1.27	13.88	38.18	38.1
<b>Unit #02</b>	70.19	70.19	0.37	25.52	70.19	70.1
<b>Unit #03</b>	69.54	69.54	0.37	25.29	69.54	69.5

Table: Bid and Offer Prices

## Integration with external models

The DADT Optimization Model has been integrated with an external application developed jointly by the Turkish Electricity Transmission Company (TEİAŞ) and Deloitte – Turkey. This Web-Based application is responsible for the management of the Market Operation, which has security control rules for the introduction of the self dispatch schedules and bids & offers information. The system uses the same application to introduce the demand forecast and eventually the energy transfer capacity limits.

When the market clearing hour is reached everyday, Balance is called from the Web-based application, which also sends all of the data files. It then formulates and solves the optimization problem that determines the accepted bids and offers, and calculates the system marginal price in each hour, returning these and other results to the application.

The integration mechanism in place in the Turkish system is shown next. The figure also shows the relationship between the Balance (known there as DADT - Day Ahead Dispatch Tool) and the Water Value Model (SDDP), also developed by PSR.

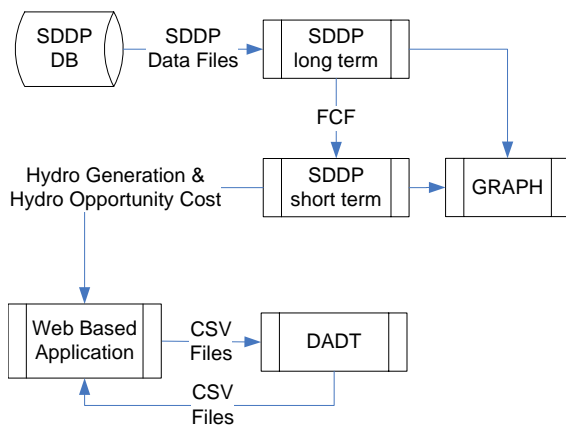


Fig: Process flow

## Applications of the model

During the transition period of TEİAŞ' Balancing and Settlement System Project, load and unload instructions for generators will be given by Balance.

## Example Case Study

Balance has been used by TEİAŞ (Turkey) as a internal tool, responsible for determining the Day Ahead Dispatch.

The model has been used for a period of twenty-four hours, and with approximately one hundred BMEs. The solution is achieved in a few minutes time.

The following graph and table were created with Balance using a case input data.

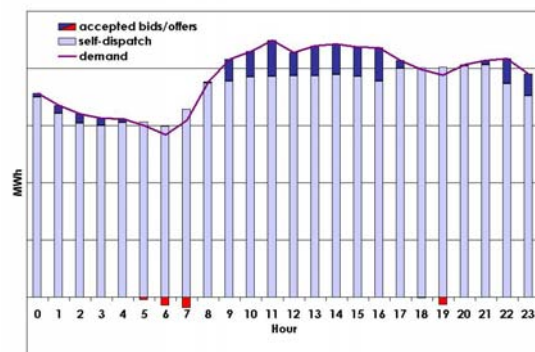


Fig: Process flow

Instructions (MWh)											
	00h	01h	02h	03h	04h	04h	06h	07h	08h	09h	10h
Unit #01	196	432	464	475	479	471	435	382	304	225	195
Unit #02	279	346	389	403	407	397	351	284	186	88	47
Unit #03	137	171	192	199	201	196	173	139	90	41	21
Unit #04	132	166	188	195	197	192	167	132	80	29	11
Unit #05	277	343	384	397	402	391	344	276	175	78	43
Unit #06											
Unit #07		1	5	7	7	6	1				
Unit #08	45										
Unit #09											
Unit #10	70	91	104	109	110	107	92	71	39	7	
Unit #11	-137								-225	133	121
Unit #12	-861	-807	-773	-762	-758	-767	-804	-858	-939	-1022	-1053
Unit #13	-309	-289	-277	-273	-272	-275	-288	-308	-337	-366	-377
Unit #14	-178	-167	-160	-158	-157	-159	-167	-178	-195	-212	-218
Unit #15	66		66				81	81	81	81	81

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