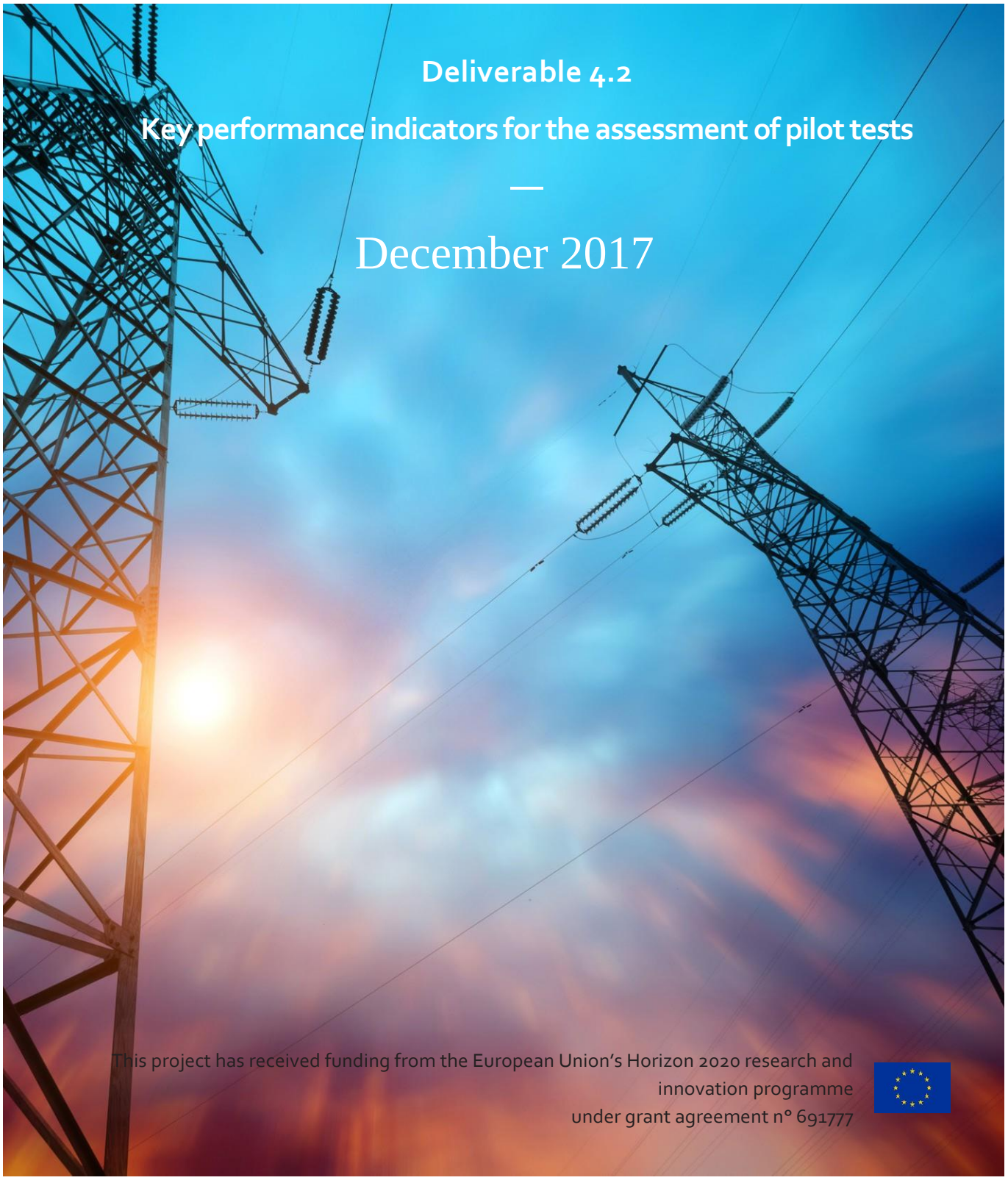
FutureFlow



Deliverable 4.2

Key performance indicators for the assessment of pilot tests

December 2017

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No	Chapter	Subchapter	Responsible
1	**Introduction**		EKC
2	**Approach**		EKC
3	**Balancing KPIs**	IT KPIs	EIMV
		Technical KPIs	EKC, ELES, GEN-I, CG
		Market & economic KPIs	EKC, EIMV
4	**Redispatching KPIs**	Redispatching, technical & economic KPIs	EKC
5	**Annex**	Pricing principles example	EKC

Glossary

Refer to ENTSO-E glossary, https://www.entsoe.eu/data/data-portal/glossary/Pages/home.aspx.

Abbreviations

Acronym	Term	Acronym	Term
ACE	Area Control Error (≡ FRCE)	IN	Imbalance Netting
aFRR	Automatic frequency restoration reserve	IP	Imbalance Price
AGC	Automated Generation Control	IS	Imbalance Settlement
AMF	Available Maximum Flow	ISP	Imbalance Settlement Period
ANF	Already Nominated Flow	IT	Information Technologies
ATC	Available Transfer Capacity	JAO	Joint Allocation Office
BRP	Balance Responsible Party	KPI	Key performance indicator
BSP	Balancing Service Provider	LFC	Load-frequency control
C&I	Commercial and industrial	LFCR	Load-frequency Control & Reserve
CACM	Capacity Allocation and Congestion Management	MC	Market Coupling
CAF	Common Activation Function	MCP	Market Clearing price
CB	Critical Branch	mFRR	Manual Frequency Restoration Reserve
CEE	Central-East Europe	MOL	Merit Order List
CGM	Common grid model	MP	Marginal Price
CMO	Common Merit Order	MRC	Multi-Regional Coupling
CMOL	Common Merit Order List	MW	Megawatt
CO	Critical Outage	MWh	Megawatt-hour
CWE	Central-West Europe	NC	Network Code
CZC	Cross Zonal Capacity	NPP	Nuclear Power Plant
D-1	Day-ahead	NRA	National Regulatory Authority
D-2	Two-days ahead	NTC	Net Transfer Capacity
DG	Distributed generation	OH	Operational Handbook
DR	Demand response	OL	Open Loop
DSM	Demand side management	OPF	Optimal Power Flow
EA	Explicit Auction	PFC	Power Flow Colouring
EB	Electricity Balancing	PFD	Power Flow Decomposition
EC	European Commission	PI	Proportional-Integral
ENTSO-E	European Network of TSOs for Electricity	PTDF	Power Transfer Distribution Factors
EU	European Union	RAM	Remaining Available Margin
FAT	Full Activation Time	RES	Renewable energy sources
FB	Flow-based	RR	Replacement Reserves
FCFS	First come - first served	RD	Redispatching
FCR	Frequency Containment Reserves	RSC	Regional Security Coordinator
FF	FutureFlow	SEE	South-East Europe
FRCE	Frequency Restoration Control Error (≡ ACE)	SHB	Slovenia-Croatia-BiH (Control block)
FRM	Flow Reliability Margin	SO, SysOp	System Operation
FRR	Frequency Restoration Reserves	SO GL	Guideline on Electricity System Operation
GCC	Grid Control Cooperation	Fmax	Maximum Flow
GCT	Gate Closure Time	TPP	Thermal Power Plant
GL	Guideline	TSC	TSO Security Cooperation
GSK	Generation Shift Key	TSO	Transmission system operator
HPP	Hydro Power Plant	WP	Work Package
ID	Intra-day	XB	Cross-Border

1 Introduction

Work package 4 (WP4) deals with the definition of use cases and Key Performance indicators (KPIs), and assessment of pilot tests. Its objectives are therefore:

- To define use cases to test the prototype DR&DG flexibility aggregation platforms and the prototype Regional Balancing and Redispatching Platform.
- To propose performance indicators and the experimental measurements to be made in order to validate the scaling up and replication of the innovative solutions if deemed successful.
- To assess the tests of the prototype DR&DG flexibility aggregation platforms and the prototype Regional Balancing and Redispatching Platform according to these KPIs.

Table 1: Task 4.2

WP4	**DEFINITION OF USE CASES AND KPIS, AND ASSESSMENT OF PILOT TESTS**	WP leader: **ELES**	**Deliverables**
Task 4.1	**DEFINITION AND IMPLEMENTATION PROCESS OF THE FOUR USE CASES**		
Task 4.2	**DEFINITION OF KEY PERFORMANCE INDICATORS**	Task leader: **EKC** Participating: ELES, MAVIR, TRANSELECTRICA, EIMV, GEN-I, SAP, CYBERGRID, GEMALTO	**D4.2:** Key performance indicators for the assessment of pilot tests (December 2017)
Task 4.3	**ASSESSMENT OF PILOT TESTS**		

This document (Deliverable 4.2) deals with the second among the listed WP4 tasks, i.e. describes how key performance indicators (KPIs) are defined consistently with the KPIs provided for the simulations performed in task 1.5. These KPIs are adapted to measure the performance of the pilot tests associated to each of the four use cases defined in task 4.1.

1.1 Document organisation

The document is organised through the following key chapters:

- Introduction – provides the introductory descriptions, document organisation and relations with other Tasks and Work Packages.
- Approach – provides the information on the tasks and the approach applied within the KPI definition process.
- Balancing KPIs – explains the KPIs used to measure the effects of analysed aFRR energy exchange processes within the simulations and pilot tests.
- Redispatching KPIs – explains the KPIs used to measure the effects of analysed solutions applied through the Redispatching simulations.

1.2 Relation to other tasks and work packages

This deliverable is related to the work performed/to be performed, within the:

Previous work being done within the Work Package 1:

- In Task 1.2 where the KPIs are firstly exercised on the theoretical level while defining Balancing and Redispatching Target models
- In Tasks 1.5 where early KPIs are used for the selection of the Balancing target model among the simulated ones, and where usage of KPIs is initially done within the Balancing and Redispatching simulations

Ongoing work within the Work Package 4 / Task 4.1.

- Where KPIs are defined consistently and simultaneously with the description of the four Use Cases

Forthcoming work within the

- Work Package 4 / Task 4.3, where KPIs will be used for the assessment of the pilot tests
- Work Package 5, recording KPIs during the Pilot Tests 1-4
- Work Package 6, during Impact analysis

2 Approach

During the assessment of both simulations performed under Task 1.5 and field pilot test performed in WP5, different key performance indicators are to be used in the FutureFlow project. Generally, they can be grouped into three levels, Project specific KPIs, General KPIs and Overarching KPIs. Each group is organized with a dedicated purpose to pursue specific goals of different tasks performed during the FutureFlow project implementation.

- Overarching KPIs: important for EU-wide integration of balancing markets and redispatch sevices, such as increase of balancing market liquidity, balancing quality, network transmission capacity
- General KPIs: related in general to integration projects, such as social welfare, market liquidity, costs
- Project specific KPIs: related to FutureFlow project-specific needs for indicators and comparisons

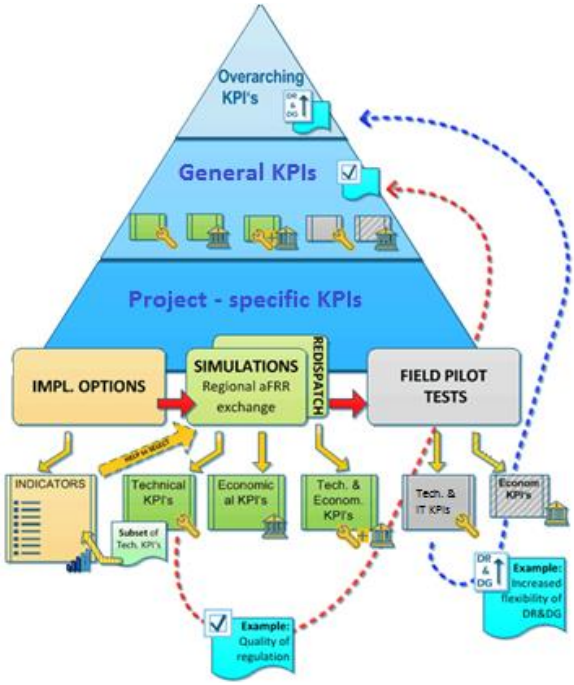

Figure 1: Levels of KPI used in the FutureFlow project

Regarding the respective points where KPIs are being used within the FutureFlow project, there are two main moments:

Early usage, during the simulations within the Task 1.5:

- Technical KPIs are being used for the comparison and selection of the most appropriate target model for balancing (aFRR energy exchange). This level appeared as necessary throughout the Year 1 on FutureFlow project, since several potential target models of aFRR energy exchange appeared as possible. One of them is being selected as the Balancing Target Model, primarily by using Balancing / Technical KPIs.
- Technical and economic KPIs are used for the assessment of redispatching simulations, which are being done within the Task 1.5, with the two main aspects: Redispatching optimization and Costs allocation;

Late usage, to measure the effects of pilot tests

- IT, Technical and Economic KPIs will be used for the assessment of results of Balancing Pilot tests, associated to the 4 use cases, as defined within the Task 4.1.
    - Use case 1: system tests to monitor the IT system performance; the assessment of the scalability and replicability properties of the developed prototype solutions; evaluation of robustness of the proposed solutions assessed from the cyber security perspective.
    - Use case 2: test cases to assess the technical performance, and economic indicators with involvement of DR&DG under the aggregators in the balancing process, independently for each TSO control area (exercised with zero Cross Zonal Capacity).
    - Use case 3: test cases to assess the technical performance, and economic

indicators with involvement of DG&DR under the aggregators in the balancing process, and across the TSO control areas (exercised with non-zero Cross Zonal Capacity).

- Use case 4: Aims at studying the introduction of the competition between the aggregators by allowing the switching of DR&DG between competing aggregators, within a control zone.

In general, regardless of assessing simulations or pilot tests, regardless of whether analysing balancing or redispatching, the following two parameters are varied to check the performance of the analysed solutions, wherever applicable:

- With/without involvement of DR&DG (at balancing or redispatching)
- With/without cross-border cooperation (at balancing or redispatching)

It is inevitable that the performance of the very pilot test would reveal some new and very illustrative KPIs which cannot be recognised now, while some of the proposed KPIs herein could appear as less illustrative. Therefore, the definition of KPIs should be understood as alive process, depending on the experience gathered throughout each respective project's phase. Consequently, the list of KPIs should be constantly updated.

3 Balancing KPIs

3.1 Balancing, IT KPIs

IT KPIs are closely related to the analysis of system performance in relation to the Use Case 1. IT KPIs are monitoring the performance of communication subsystems; these subsystems are supporting infrastructure that ensures transport of measurements, commands (setpoints) and bids between all system building blocks: FutureFlow Cloud platform, DEMO Site platform, aFRR aggregation platform (installed at BSP), DR&DG. A set of KPIs is used on interfaces between these building blocks.

- **Delay**

  Delay (latency) is one-way delay that is experienced by data packet on point-to-point communication path. It is measured in milli seconds [ms].

- **Packet loss**

  Packet loss is the absolute (number of lost data packets in unit of time) or relative (%) measure of lost data packets on communication path within a time unit (e.g. 1 h, 1 day). Packet (various packet lengths from 64 to 1500 bytes are taken into account) loss is the measure equivalent of lost bytes on the communications paths (physical layer) due to any technical reason (e.g. congestion, broken line, equipment failure). This parameter is crucial indicator of communications medium quality and congestion, since packet loss can also be the result of inadequate communication bandwidth.

- **Transferred amount**

  Transferred amount of data is the absolute amount of data that was transferred within a time unit (e.g. 1 h, 1 day). It is measured in bytes. This parameter measures the absolute requirement for communication bandwidth of our aFRR services.

3.2 Balancing, technical KPIs

Technical KPIs for balancing try to reflect and describe the technical performance of the integrated balancing processes, with a special attention given to the integration of DR&DG into the most challenging aFRR process. The defined KPIs are used for the selection of the Balancing Target model and for analysing the performance of Balancing Pilot Tests within The Use Cases 2, 3 and 4.

- **ACE (FRCE) quality**

  The quality of aFRR regulation with the goal to lower Area Control Error (ACE) is the main technical indicator of aFRR. These indicators will be monitored in a 15-minute and 1-minute basis (in line with SoGL), but as well as on hourly basis and within LFC controller time-cycle resolution. Also, national and pan-regional ACE quality indicators can be monitored (in 4 countries separately and jointly). The respective measured indicators are:

    - Standard deviation of ACE (comparing with hourly reference values taken from ENTSO-E Regular Quarterly Report of the Performance of the Primary and Secondary Load-Frequency Control, 15-minute reference value); small value of the standard deviation indicates a limited number of high imbalance values within observed period

- Mean value of ACE; small mean value indicates low impact on the frequency error and time error
- ACE should not exceed the given threshold (parameter Level 1) in more than 30 % of the time (15-min resolution)
- ACE should not exceed the given threshold (parameter Level 2) in more than 5 % of the time (15-min resolution)
- Number of events for which the ACE exceeds 60% of the FRR capacity and was not returned to 15 % within Time To Restore Failure (1-minute resolution)

  Parameter Level 1 and Level 2 would be imposed once available on the ENTSO-E level.
- Trumpet curve correspondence in case of sudden large deviations

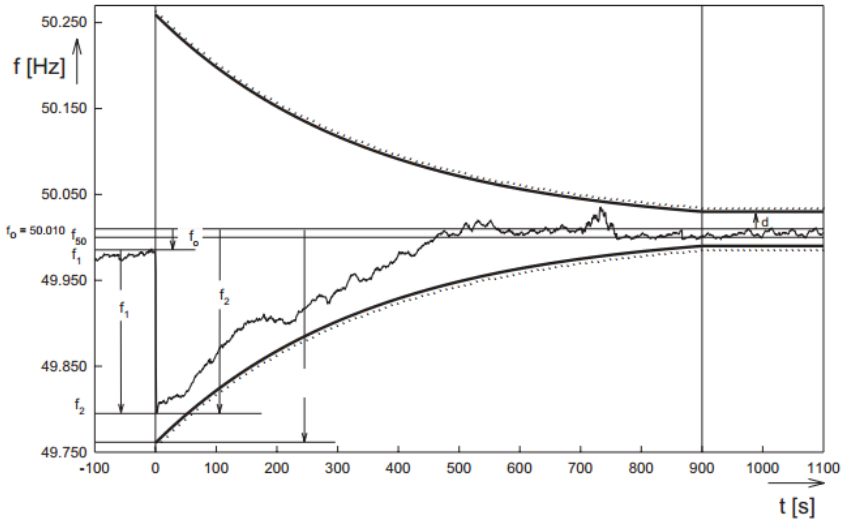

Figure 2: Trumpet curve

- **Full Activation Time of aFRR providers**

  Time of full activation of unit, i.e. the time between the activation request by TSO and the corresponding full activation. The aFRR provider shall respond within the defined Full Activation Time at least with a linear ramp rate.
- **Size of overshoot**

  Relative size of overshoot (MW overshoot/MW disturbance) of activated power in case of sudden disturbances.
- **LF controller settings**
  - Continuous Vs Stepwise bid activation
  - PI controller output (load variations of varying magnitude must be corrected within approximately 15 minutes, avoidance of overshoot (MW overshoot/MW disturbance) of activated power in case of sudden disturbances).
- **Size of Imbalance Netting effect**

The amount of avoided counter activations under Imbalance Netting (embedded within aFRR optimisation, or pre-netting, depending on Integration Option observed/selected).

- **ATC-based and Flow-based (FB) transmission capacity limits**

  The amount of cross border activations using different cross-border limits (i.e. ATC or FB).

  Occurrence of congestions under ATC or Flow-Based limits: periods when some borders (at ATC-based approach), i.e. CB/COs (at FB approach) are congested due to the aFRR cross-border exchange.

- **Quality of DR&DG response**

  Depending on the type of the DR&DG units, their reliability to deliver the service could differ. Therefore, it is important to monitor the quality of service provided by them.

  - Do they follow a set point send by TSOs to the aggregator?
  - How many additional DR&DG had to be activated to deliver the requested response compared to initial assessment
  - How do BSPs consisting of DR/DG units perform in comparison to the regular BSPs

- **Volatility of activations of BSP**

  The robustness of the optimization algorithm run in the CAF as well as of the entire implementation option will be assessed as one of the KPIs, assessing the volatility of activations of BSPs under different pilot test configurations; situations with less volatile i.e. more robust activations of a BSP in an observed period would be preferred.

- **Suspicious situations**

  This represents an indicator if there were any mistakes made during the design of the solutions, which could not be avoided/foreseen during the design phase applying normal/standard analytical approaches (like malfunction of optimisation algorithm, non-realistic outcomes, wrong calculation of resulting indicators, etc). This KPI represents manual ex-post analysis of the obtained results during the simulation.

3.3 Balancing, economic KPIs

Economic KPIs for balancing try to measure the economic indicators of simulated and pilot-tested solutions, as well as its reflection to the balancing market behaviour. The defined KPIs are primarily for analysing the performance of Balancing Pilot Tests within The Use Cases 2, 3 and 4, and only informatively during the selection of the Balancing Target model.

- **Balancing market liquidity**

  The size of eligible upward and downward offers for aFRR under different observed options and tests, compared with required country's aFRR reserve. Liquidity will be traced locally (within each control zone) and globally (sum of all control zones).

  Specific liquidity KPI for participation of DR&DG will be made, and compared to other sources.

- **Balancing market concentration and competitiveness**

Influence of different options and inclusion of DR&DG to the dispersity of balancing bidders.

Number of eligible providers/units (compliant to Standard Product, i.e. FAT).

- **aFRR energy costs and prices**

  Costs indicators of analysed options and solutions, can be measured using different primary settlement elements, without imposing final settlement solutions. They can be monitored per each ISP (15 min), on hourly basis (one bid validity period, corresponding to 4 ISPs), or cumulatively for the observed period (day, week, month).

  - Based on Global Marginal Pricing
  - Based on Local Marginal Pricing
  - Based on Pay-as-bid calculation principles (not expected as target settlement model, but provides good basic cost indicators)

  Annex 1 provides the illustrative example of the three groups of pricing principles for a single hour.

- **Shadow prices of congested borders/elements**

  Dual value of transmission network constraint within optimization, at potentially congested border (ATC) or Critical branch (Flow-based approach), calculated as a change in objective function value for incremental relaxation of the constraint.

4 Redispatching KPIs

Technical and economical KPIs for redispatching are used within the Redispatching simulations in Task 1.4 to reflect the technical performance of either internal or cross-border Redispatching, with/without inclusion of DR&DG, and related costs allocation based on Power Flow Colouring (PFC) method developed within FutureFlow project[1].

- **Technical efficiency of redispatching action**

  The amount of MW activated for the redispatching action, in relation to the size of overload.

  Number of overloaded branches before and after RD action.

  Delta activated power up / down / difference.

- **Activated Bids**

  Number of activated bids up / down.

  Inclusion of DR&DG units in Redispatching actions; effects on liquidity and competitivity.

  MW size of DR&DG involved in Redispatching action.

- **Redispatching costs**

  Total monetary cost of Redispatching actions after applying different Redispatching approach (national/cross-border) and bidding lists (conventional only/with DR&DG).

[1] Description of Redispatching algorithm and PFC costs allocation method are given in FutureFlow Deliverable 1.2 and exercised on the simulations within the Deliverable 1.4.

- **Shadow prices at congested elements**

  Dual value of transmission network constraint within optimization (i.e. Critical branch), calculated as a change in objective function value for incremental relaxation of the constraint.

- **Power Flow Colouring indicators**

  Size of Flows:

  - Loop Flows at CB/CO per area and in total
  - Export/Import Flows at CB/CO per are and in total
  - Total Flows at CB/CO

  Amount of costs allocated per TSO / region, based on:

  - Total Flows per area
  - Loop Flows per area

Annex 1: Pricing principles example as balancing market & economic KPIs

GLOBAL MARGINAL PRICING

	1-15min	16-30min	31-45min	46-60min	
mpUp (EUR/MWh)	480.0	480.0	439.0	354.8	
mpDown (EUR/MWh)	-204.0	-204.0	-204.0	-204.0	
	1-15min	16-30min	31-45min	46-60min	
MWhUp (MWh)	16.6	7.8	6.8	5.7	
MWhDown (MWh)	-4.0	-20.1	-19.2	-51.1	
	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	7955.4	3756.0	2971.6	2030.7	16713.6
costsDown (EUR)	811.5	4098.5	3922.1	10428.6	19260.8
total costs (EUR)					35974.4

LOCAL MARGINAL PRICING

LOCAL MARGINAL PRICING ELES

	1-15min	16-30min	31-45min	46-60min	
mpUp (EUR/MWh)	78.0	78.0	78.0	73.0	
mpDown (EUR/MWh)	-204.0	-204.0	-204.0	-204.0	
	1-15min	16-30min	31-45min	46-60min	
MWhUp (MWh)	1.2	0.4	0.3	0.0	
MWhDown (MWh)	-1.9	-8.2	-5.6	-12.1	
	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	94.4	28.7	26.4	0.0	149.4
costsDown (EUR)	390.3	1678.2	1148.5	2461.8	5678.7
total costs (EUR)					5828.2

LOCAL MARGINAL PRICING APG

	1-15min	16-30min	31-45min	46-60min	
mpUp (EUR/MWh)	480.0	480.0	439.0	354.8	
mpDown (EUR/MWh)	14.2	-2.6	-37.0	-2.6	
	1-15min	16-30min	31-45min	46-60min	
MWhUp (MWh)	10.5	5.8	6.0	3.6	
MWhDown (MWh)	-0.0	-0.1	-0.5	-0.2	
	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	5017.1	2779.8	2637.3	1273.7	11707.8
costsDown (EUR)	-0.4	0.3	18.0	0.6	18.4
total costs (EUR)					11726.2

LOCAL MARGINAL PRICING MAVIR

	1-15min	16-30min	31-45min	46-60min	
mpUp (EUR/MWh)	81.1	77.7	0.0	81.1	
mpDown (EUR/MWh)	-29.4	-29.4	-29.4	-29.4	
	1-15min	16-30min	31-45min	46-60min	
MWhUp (MWh)	2.3	0.6	0.0	2.1	
MWhDown (MWh)	-0.5	-1.9	-6.5	-0.6	
	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	184.6	46.5	0.0	173.0	404.2
costsDown (EUR)	15.9	55.4	190.3	18.1	279.7
total costs (EUR)					683.9

LOCAL MARGINAL PRICING TEL

	1-15min	16-30min	31-45min	46-60min	
mpUp (EUR/MWh)	55.0	55.0	55.0	0.0	
mpDown (EUR/MWh)	0.2	0.0	0.0	0.0	
	1-15min	16-30min	31-45min	46-60min	
MWhUp (MWh)	2.6	1.1	0.4	0.0	
MWhDown (MWh)	-1.5	-9.9	-6.6	-38.2	
	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	144.8	58.7	23.3	0.0	226.8
costsDown (EUR)	-0.3	-0.2	-0.1	-0.8	-1.5
total costs (EUR)					225.3

LOCAL MARGINAL PRICING ALL TSOs TOGETHER

	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	5440.9	2913.6	2686.9	1446.7	12488.2

PAY-AS-BID

PAY-AS-BID ELES

	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	98.4	20.2	28.1	0.2	146.8
costsDown (EUR)	28.0	433.5	298.4	888.9	1648.9
total costs (EUR)					1795.7

PAY-AS-BID APG

	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	1588.9	712.9	597.7	286.4	3186.0
costsDown (EUR)	-0.7	-2.5	-4.2	-2.0	-9.4
total costs (EUR)					3176.6

PAY-AS-BID MAVIR

	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	133.6	24.1	0.0	122.5	280.2
costsDown (EUR)	0.4	28.1	128.2	4.7	161.4
total costs (EUR)					441.7

PAY-AS-BID TEL

	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	188.9	74.4	61.1	0.0	324.4
costsDown (EUR)	-18.6	-35.9	-35.4	-54.4	-144.3
total costs (EUR)					180.1

PAY-AS-BID ALL TSOs TOGETHER

	1-15min	16-30min	31-45min	46-60min	1-60min
costsUp (EUR)	2009.8	831.5	686.9	409.2	3937.5
costsDown (EUR)	9.1	423.3	387.0	837.2	1656.6
total costs (EUR)					5594.1