AIP (PLEXOS) Market Simulation Model Validation Project

Workshop 2 – Initial Findings

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2 March 2007, Belfast Hilton, Belfast

Agenda for today's Workshop

1. Introduction to Workshop
2. Overview of project activities to date
3. Review of data validation activity and initial thoughts
4. Review of PLEXOS validation work and initial thoughts
5. Outline of next steps and process/timetable for completion

Introduction to Workshop

Mike Wilks, Principal Consultant

Introduction to Workshop

- 2nd in a sequence of 3 Project workshops open to all market participants
- Overall aim is to highlight project activities undertaken to date and to provide an overview of initial thoughts and conclusions for discussion/feedback
- The two main parts of today's Workshop will be detailed review and discussion of KEMA's data and model validation work undertaken to date
- Final element of the Workshop will be to outline proposed next steps and timetable for Project completion
- **But first**………some reminders

Reminder: project aims and timeframe

- This project has two fundamental aims
  - to establish a validated Plexos model of the SEM that is ready to accurately predict prices (i.e. SMP with unconstrained schedule quantities by unit)
  - to achieve the consensus agreement and confidence of market participants in the validated model
- The project is to be delivered by KEMA to the AIP by end March 2007 *(subject to extent of any identified model workarounds to be developed and implemented)*

Reminder: project activities #1

- There are 5 required component activities within this project

i. **Validation of model algorithms** against T&SC and other relevar associated documents for unconstrained (SMP) model run

ii. In conducting (i), **identification, development and implementation of any required model workarounds** internal (preferably) or external to PLEXOS to ensure a "compliant" simulation model of the SEM – *where a major issue arises implementation may be beyond March*

iii. **Validation of modelling assumptions** such as operating regime of Moyle and pumped storage; modelling of forced outages; treatment of TLAFs; definition of legitimate SRMC components et

(Continued over)

Reminder: project activities #2

(continued from previous slide)

iv. **Validation of model input data** – primarily validation of generato technical data but also reviewing reasonableness of other input data such as demand and wind data,

v. **Participant inclusion** – this is a key thread running throughout th project to ensure best outcome for the above. KEMA has and will continue to engage with all market participants including the TSOs The primary focus of engagement will be regarding model data ar assumptions but KEMA will also welcomes comments on model algorithms.

Reminder - activities not covered by this Project

- We are not cross-validating PLEXOS against the ABB model
- We are not reviewing or seeking to change the draft T&SC (using v1.
  as the baseline for model validation)
- We are not validating transmission data and assumptions – our revie
  only relates to the unconstrained PLEXOS model of the SEM (we are
  using the PLEXOS 4.896 R3 release version as baseline)
- We are not validating Uplift Option D rules/results
- We are not addressing capacity payments and their calculation
- **This Project does not represent a validation of any SEM market price forecast**

Outline of Project Activities to date

Mike Wilks, Principal Consultant

Outline of Project activities to date #1

- Initial Process Workshop
  - Some feedback (4 parties); adopted slight changes in process
- Data Questionnaires
  - A few late (1 received yesterday!); 1 non-compliant and to be resubmitted
  - Varying degrees of revision by market participant (from none to wholesale)
  - Some data errors apparent and being addressed bilaterally
  - Some "interesting features" being, and to be, examined/explored further
- Bilateral meetings
  - 8 parties visited including EirGrid and SONI
  - very productive and highlighted some key data items to examine further and overarching data issues to resolve; some feedback on PLEXOS too

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Outline of Project activities to date #2

- Conducting own parallel review of generator technical data
  - Referring to KEMA international database of plant technical performance
  - We are aware there is a certain degree of freedom in mapping reality to model
  - Exploring various interesting aspects of generator data including significant revisions
  - Also seeking to "bottom out" overarching data issues (e.g. SRMC components)
- Conducting ongoing sequence of PLEXOS functionality tests
  - Includes review of shadow pricing and PLEXOS Uplift modelling functionality
  - Are including some operating mode comparisons (RR v MIPS) as requested by participants – bearing in mind "horses for courses"
  - Have identified potential data structure efficiencies/enhancements
  - Seeking to utilise as relevant/appropriate ABB test scripts
- Held PLEXOS Workshop with Elan and continue to engage on queries/issues arising during model validation
- **More detail of the above and initial thoughts to follow in the next Sections**

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Review of Data Validation activity and initial thoughts

Dave Lenton, Senior Consultant

Data Validation - outline of discussion

1. Process to date
2. Issues raised on generators technical data
   - Consistency of data
   - Contractual vs technical issues
   - What is unconstrained?
   - What is in SRMC?
3. Update on other data parameters
4. Next steps in validation process

Process to date

- 2 Feb Data Questionnaire to all Suppliers and Generators
  - Re-submission of generator data
  - Issues on other data items
- 16 Feb Discussions with market participants in Dublin
- 19 Feb Deadline for Re-submission of data (partly met)
- 22-23 Feb Discussions with market participants in Belfast
- 19 Feb – 1 March – Anomalies resolved with generators
- 5 March – Revised Draft Generator Technical Data to be issued

Generator data received

- New Generator Data received from
  - Energia - 16 Feb
  - ESB – 21 Feb
  - Synergen – 22 Feb
  - Tynagh Energy – 16 Feb
  - Edenderry Power – 22 Feb
  - Aughinish Aluminia -19 Feb
  - ESBi – 1 March
- Premier Power (19 Feb) - no change to previous submission
- Discussion have been held with AES - need to resubmit

Overview of major data changes #1

Parameter	Changes
Min Stable Capacity	Increases, Huntstown 1 - 21.2 MW, Huntstown 2 - 39 MW, Tynagh 18 MW, Moneypoint – All units 21 MW Aghada CT Units 5 MW increase to 15 MW
Max Export Capacity	Increase in Dublin Bay Power 19 MW Reduction in Huntstown 1 – 8 MW, Huntstown 2 – 11 MW
No Load and Heat Requirement	Huntstown 1 increase by 77%, Huntstown 2 increase by 34% Poolbeg Unit 3 decrease by 10%
Capacity Point	Driven by changes in Min Stable Capacity and Max Capacity

Overview of major data changes #2

Parameter	Changes
Incremental Heat Rate Slope	Aghada CTs >4% increase in heat rate for incremental 1 and 2.
Forced Outage Rate	Great Island increased from 9% all units to 19 -21% Poolbeg Unit 3 increased from 12% to 22% Tarbert increases from 6-12% to 15-19%
Mean Time to Repair	Huntstown Units increased to 55 hours from low levels of 24 & 36 hours
Ramp Rate up and Down	Tynagh decreased 19 to 10 MW up and 19 to 8 MW down Huntstown 2 decrease from 10 MW to 5 MW Up

Overview of major data changes #3

Parameter	Changes
Min Up Time	Lough Rea/ West Offley decrease from 12 to 5 hours Tarbert 1 and 2 decrease from 20 hours to 4 hours
Min Down Time	3 hour increase for Huntstown 2 Aughinish 2 now set at 4 hours not previously given
Reserve	Northwall 5 has decreased on Tertiary 3 from 72 to 20MW Poolbeg 1 and 2 had 20 MW increase
Start Up Energy	Huntstown 1 increased from 650 GJ to 20,000 GJ from cold Huntstown 2 increased from 3,000 GJ to 20,000 GJ from cold

Overview of major data changes #4

Parameter	Changes
Synchronisation Times	Poolbeg Unit 3 increased from 12 hours to 30 hours from cold Huntstown 2 increased from 0.5 hours to 12 hours from cold.
Boundary Times	Significant increases from warm to cold for Dublin Bay Power 8 – 72 hours and Huntstown 2 from 12 – 72 hours

- In addition a number of anomalies have been discussed and resolved with participants
- Process of technical review of new and existing data on-going

Review of consistency of submissions

- We need confirmation that participants have interpreted the parameters in the same way. Key areas of concern
  - Start Up Energy
    - Energy required to bring the Unit to 0 MW
  - No Load
    - Energy per hour the unit would require to maintain 0 MW
  - Calculation of Heat Rate
    - Rate at which fuel is consumed to generate electrical power
    - Higher Heating Value/Lower Heating Value
- Expectation that all figures are now net of station load
- KEMA will be contacting participants to confirm interpretation

Example I – Start Up Energy - CCGTs

Unit Name	Max capacity	Start up Energy (GJ) Cold	Start up Energy (GJ) Warm	Start up Energy (GJ) Hot
Dublin Bay Power	415	7700	2600	
Huntstown	335	20000	10000	5000
Huntstown Phase II	391	20000	10000	5000
Marina CC *	112.29	50	50	50
Northwall Unit 4	163	80	80	80
Poolbeg Combined Cycle	480	2000	2000	2000
Tynagh	404	2811	1633	1144
Ballylumford CCGT 31	240	50	50	50
Ballylumford Unit 32	240	50	50	50
Coolkeeragh CCGT	404	50	50	50

Example II – Start Up Coal Stations

Unit ID	Unit Name	Max capacity	Start up Energy (GJ) Cold	Start up Energy (GJ) Warm	Start up Energy (GJ) Hot
MP1	Moneypoint Unit 1 FGD SCR	282.5	14620	6920	4360
MP2	Moneypoint Unit 2 FGD SCR	282.5	14620	6920	4360
MP3	Moneypoint Unit 3 FGD SCR	282.5	14620	6920	4360
K1	Kilroot Unit 1	201	2247	1645	973
K2	Kilroot Unit 2	201	2247	1645	973

Example III – No Load & Heat Rates

Unit Name	No Load Heat Requirement (GJ/hr)	Incremental Heat Rate Slope [GJ/MWhr]			
		1 to 2	2 to 3	3 to 4	4 to 5
Aghada Unit 1	187.53	7.877	8.122	8.654	8.74
Aghada CT Unit 4	279.86	7.683	9.533	0	0
Poolbeg Unit 1	80.18	9.508	10.228	0	0
Poolbeg Unit 2	80.18	9.508	10.228	0	0
Poolbeg Unit 3	245.86	8.447	0	0	0
Ballylumford Unit 4	179.27	10.51	-		
Ballylumford Unit 6	179.27	10.51	-		

Higher Heating Value (HHV) versus Lower Heating Value (LHV)

- Need consistency in how heat rate slope calculated
- Gas power stations
  - Gas as a fuel is normally priced in HHV Terms which includes the moisture content of gas
  - Heat rate will need to be higher to account for lower quality gas
  - Suggested that all generators confirm data in HHV terms
  - Note - Manufacturers figures tend to calculate in LHV terms
- Coal power station
  - Coal quoted prices in LHV
  - Suggestion that all generators confirm data in LHV terms

Issue for CCGT heat rates

- In reality, CCGT stations do not have a monotonically increasing heat rate curve
- Most operators have chosen to reflect this by adopting a single incremental
- Certain degree of freedom in setting this single incremental (in combination with no load) to most appropriately define HR curve
- There was suggestions that more guidance is needed on how the heat rate should be calculated
- Participants will need to take a view on typical loading and thus most reflective model representation of HR curve

Primacy of true technical parameters or commercially specified technical parameters

- Believe some parameters may be based on contractual issues not technical true performance/limits
- RAs have indicated that data should be true technical performance i.e. market has primacy over contracts
- Key parameters where KEMA has observed potential use to reflect commercially specified technical performance include:
  - Min Down time
  - Min Up Time
  - Start up and No Load
  - (Forced Outage Rates)
- Such data parameters will need to be revised to reflect true technical performance
- Impact on SEM associated contracts will be for market participants and if required RAs to resolve

Example - Min Up and Down Times

Unit Name	Min UpTime (mins)	Min Up Time (hrs)	Min Down Time (mins)	Min Down Time (hrs)
Aghada Unit 1	240	4	210	3.5
Aghada CT Unit 4	0	0	45	0.75
Poolbeg Unit 1	180.00	3.00	120.00	2.00
Poolbeg Unit 2	180.00	3.00	120.00	2.00
Poolbeg Unit 3	255.00	4.25	210.00	3.50
Ballylumford Unit 4	240.00	4.00	420.00	7.00
Ballylumford Unit 6	240.00	4.00	420.00	7.00
Ballylumford Unit 10	600.00	10.00	480.00	8.00

Short Run Marginal Cost #1

- Has been a key discussion point with Participants
- **RAs have specified SRMC Bidding Principles rather than detailed SRMC rules and have advised:**
  - Expect consistency of approach across each company portfolio and over time
  - Consistency not necessarily required across participants
- This provides some degree of freedom for participants
- Participants to decide what items to include, how to cost and include within data
  - In doing so will need to consider whether this will be acceptable to the market monitor
- Two previous excluded items that should be included are:
  - Transmission Loss Factors to increase price (Day/night issue)
  - Variable Operation and Maintenance Cost (€/MWh)

Potential Short Run Marginal Cost #2

- In discussions participants have highlighted a number of potential extra components of SRMC:
  - Loss of capacity payments from a constrained plant
  - Cost of credit lines and broker fees
  - Gas Transport Charges
  - Higher SRMC for testing days of back up fuel
  - Costs of switching from main to back up fuel to increase max capacity
- A number of Probabilistic Premiums have been suggested
  - Fuel prices cost for changes from indicative schedule
  - Cost and probability that a plant may have to switch fuels
  - If a plant had to run in a state with a higher heat rate (OCGT vs CCGT)
  - Likely extra maintenance when running beyond normal operational limits

What is meant by unconstrained?

- Some discussion on whether some 'constraints' should be included in unconstrained schedule
- Interconnector – Technical constraints
  - Limited to 400 MW transferred to Ireland from Scotland
  - Transmission Entry Capacity (TEC) limited to 80 MW in Scotland
  - Should be reflected in modelling
- Pumped Storage – (System constraint)
  - Limit on the upper reservoir to retain "fast reserve"
  - Should not be reflected in modelling
- Emissions Constraints
  - KEMA need to understand which plants, if any, are impacted by binding emissions constraints in 2008
  - Should be reflected in modelling

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Fuel and GB power prices

- Two options for difference on fuel prices

  (i) Fuel Prices series produced by Ilex

  - Gas prices have changed considerably
  - Low range forecasts now seem appropriate
  - Includes consistent set of BETTA prices
  - Prices may move more between now and LOOP3

  (ii) Latest fuel prices from recognised indexes

  - Morgan Stanley, Argus, Point Carbon
  - Need to decide how to adjust modelled BETTA prices to use for Moyle
  - Could seek to establish mathematical relationship…

Setting of market demand

- Forecast independently by System Operators
- KEMA checking consistency of approach
- Includes the following components
  - Allowance for Losses
  - Small Scale Generation
  - Impact of DSM Programmes

Transport prices

- Gas Transport prices based on published forecast tariffs for each location
- Will include commodity element in SRMC (but not capacity)*
- Note change in NI Transport Tariff (75% Capacity, 25% Commodity from previous 50/50)
- Coal prices will vary per location
  - Moneypoint has Port access so API 2 index price sufficient
  - Kilroot add an additional €7per tonne

* Need to confirm treatment with RAs (SMP or capacity)

Wind

- Intention is to move from one wind series for the whole of Ireland to 3 or 4 regional series covering Ireland
- Based on historic figures of regional availability/output and scaled to reflect new capacity
- Wind capacity sourced from published information from Eirgrid and SONI

Next steps

- Updated version of Generator Technical Data circulated on Monday 5th March with supplementary clarifications
- Resubmission can be made until 9am Monday 12 March
- KEMA continuing to undertake our own technical investigation
- Bilateral dialogue and discussions with participants
  - Meetings on request by participant
  - Meeting on request by KEMA to resolve any data queries (if requireD)
- Will seek to baseline all data by 19 March
- We will highlight any remaining data concerns to RAs in our final report and outline views on appropriate alternative values
  - We will seek to not have to do this if possible but will not avoid it if necessary

Review of Plexos Model Validation activity and initial thoughts

Adrian Palmer, Senior Consultant

Model Validation – outline of discussion

1. PLEXOS overview
2. Commercial offers
3. Technical offers
4. Special cases
5. Shadow prices
6. Uplift
7. PLEXOS configuration

PLEXOS Overview

- **PLEXOS Objective Function**
  - Meet demand at lowest cost subject to constraints
  - All costs specified in PLEXOS are included in the objective function (incremental, no-loa start, VOM, etc)
- **PLEXOS Shadow Prices**
  - Automatically determined as part of the solution to the optimisation problem
  - Represents the price of the demand constraint:

    Δ (Objective Function) / Δ (Demand)
  - Typically, but not always, determined by the SRMC of a marginal generator
  - Shadow price in a given period can be "set" by multiple generators over multiple periods
- **Releases**
  - PLEXOS 4.896 R3, PLEXOS 4.894 R2

PLEXOS Unit commitment options

- **Linear Relaxation**
  - Integer restriction on unit commitment is relaxed
  - Unit start up variables included in the formulation but can take non-integer values
  - Fastest to solve but can distort the pricing and dispatch outcomes as semi-fixed costs (start cost and unit no-load cost) can be marginal and involved in price setting
- **Rounded Relaxation**
  - RR integerises the unit commitment decisions in a two-pass optimisation
  - Very fast compared to a full integer optimal solution
  - Recommended option for most situations
- **Integer Optimal**
  - Unit commitment problem is solved as a mixed-integer program (MIP)
  - Unit on/off decisions are optimised given tolerances (relative gap and max solution time

Shadow Prices & SRMC (1)

- Consider two generation plants A and B

	A	B	
Marginal Costs	10	20	€/MWh
CO_2 Emissions	2	1	kg/MWh

- **Problem:**

MIN cost 10 A	+	20 B				
subject to	A	+	B	=	12	(DEMAND)
		A	<=	10	(CAPACITY)	
		B	<=	7	(CAPACITY)	

- **Solution:** A = 10

  B = 2

- **Price:** If ↑ Demand by 1, need to ↑ B by 1

  Price = Δ Cost = 1 * 20 = **20**

Shadow Prices & SRMC (2)

- Now consider adding a CO_2 emission constraint

- **Revised problem:**

MIN cost 10 A	+	20 B				
subject to	A	+	B	=	12	(DEMAND)
		A	<=	10	(CAPACITY)	
		B	<=	7	(CAPACITY)	
2 A	+	B	<=	19	(CO_2)	

- **Solution:** A = 7

  B = 5

- **Price:** If ↑ Demand by 1, need to ↓ A by 1 and ↑ B by 2

  Price = Δ Cost = 2 * 20 - 1 * 10 = **30**

Commercial Offers

- **Heat rates**
  - Generators have submitted no load costs and incremental heat rates
  - Input heat rate step functions utilised directly by PLEXOS in determining SRMC
  - Validated by checking PLEXOS reported SRMC at multiple load points
- **Start-up costs**
  - Only warm start costs utilised to date
  - Option to model fixed (€) start cost as well as start fuel (GJ)
  - Need to test materiality of adding cold and hot start costs
- **TLAFs**
  - Need to test modelling of marginal loss factors in PLEXOS, assuming generato
    will internalise these if not in EPUS

Technical Offers

- **Technical constraints**
  - Minimum stable level (MSL), ramp rates, minimum on/off times, rough running range, time-profiled minimum and maximum availability
  - Validated that constraints not violated
- **Observations**
  - Ramp rates not binding for most units in starting data set with hourly TPD
  - Run-up to MSL not modelled to date: units block load at MSL (actually free to load at MSL + max ramp)
  - Intend to test materiality of modelling unit run-up

Special Cases (1)

- **Wind**
  - Modelled with hourly all-island capacity factor series
- **CHP**
  - Modelled as must-run with zero offer price at maximum availability
  - Exclude from Uplift by removing heat rates, no-load and start up
- **Hydro**
  - Optimised subject to monthly energy targets (daily constraint decomposition from MT Schedule)
  - Testing materiality of MSL and ramp constraints on hydro units

Special Cases (2)

- **Pumped storage**
  - Optimised subject to pump efficiency, head and tail reservoir limits
  - Testing materiality of MSL, min pump load and rough running range constraints
- **Moyle**
  - Model ability to buy and sell at BETTA input prices
  - Superposition: If the same price applies to both purchases and sales, an optim
    solution with gross purchases and sales is equivalent to an optimal solution wit
    net trades (can be avoided by adding a small Bid-Ask spread)
  - Adjust interconnector offers and bids for expected Uplift / Capacity payments?
  - Incorporate interconnector losses

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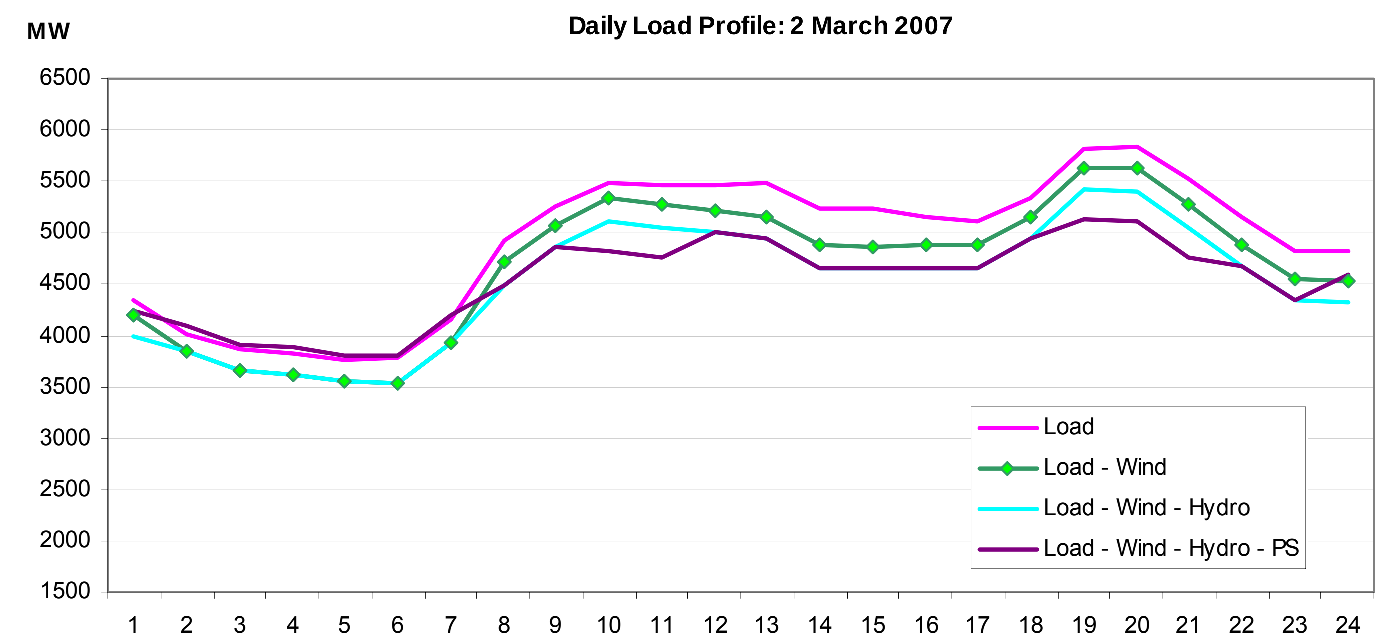
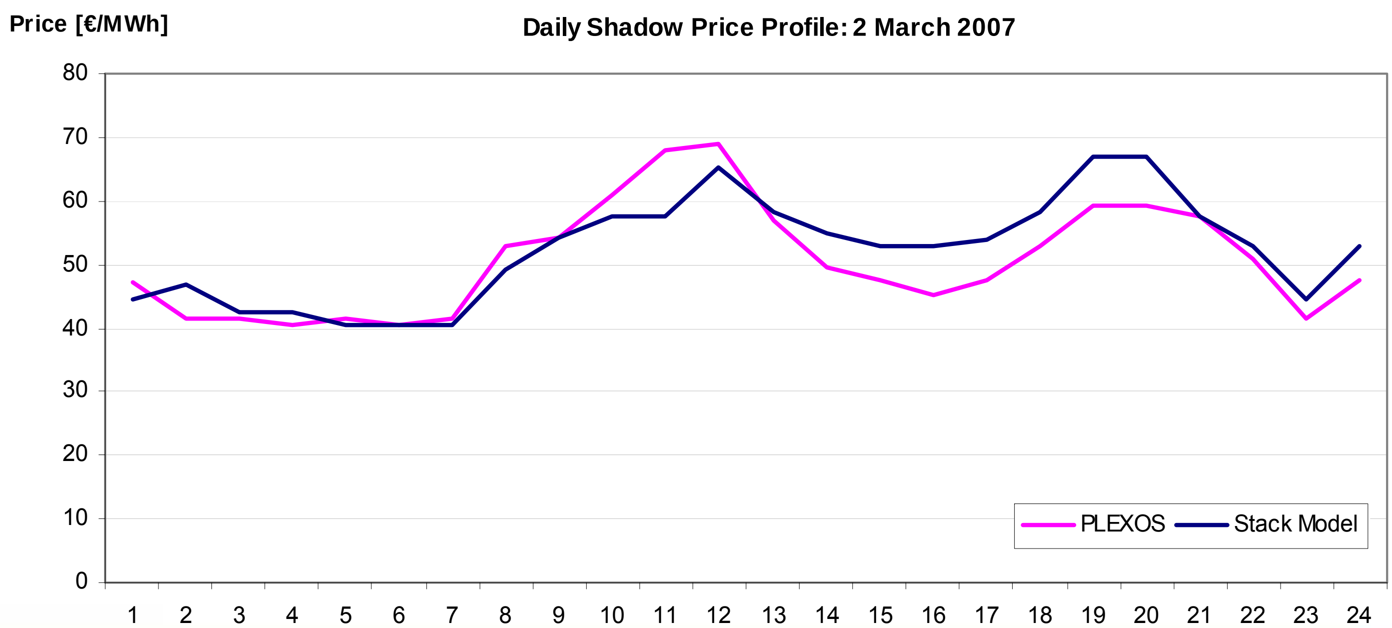
Shadow Prices: Sense Check

- **Stack Model**
  - Developed to sense check PLEXOS shadow prices
  - Supply stack based on full load SRMC
  - Hydro optimised against monthly load profile
  - Pumped storage optimised against daily load profile
  - Hourly arbitrage with BETTA prices
  - Priced at intercept of seasonal supply stack with hourly load net o
    wind, hydro and pumped storage

Shadow Prices: Sense Check



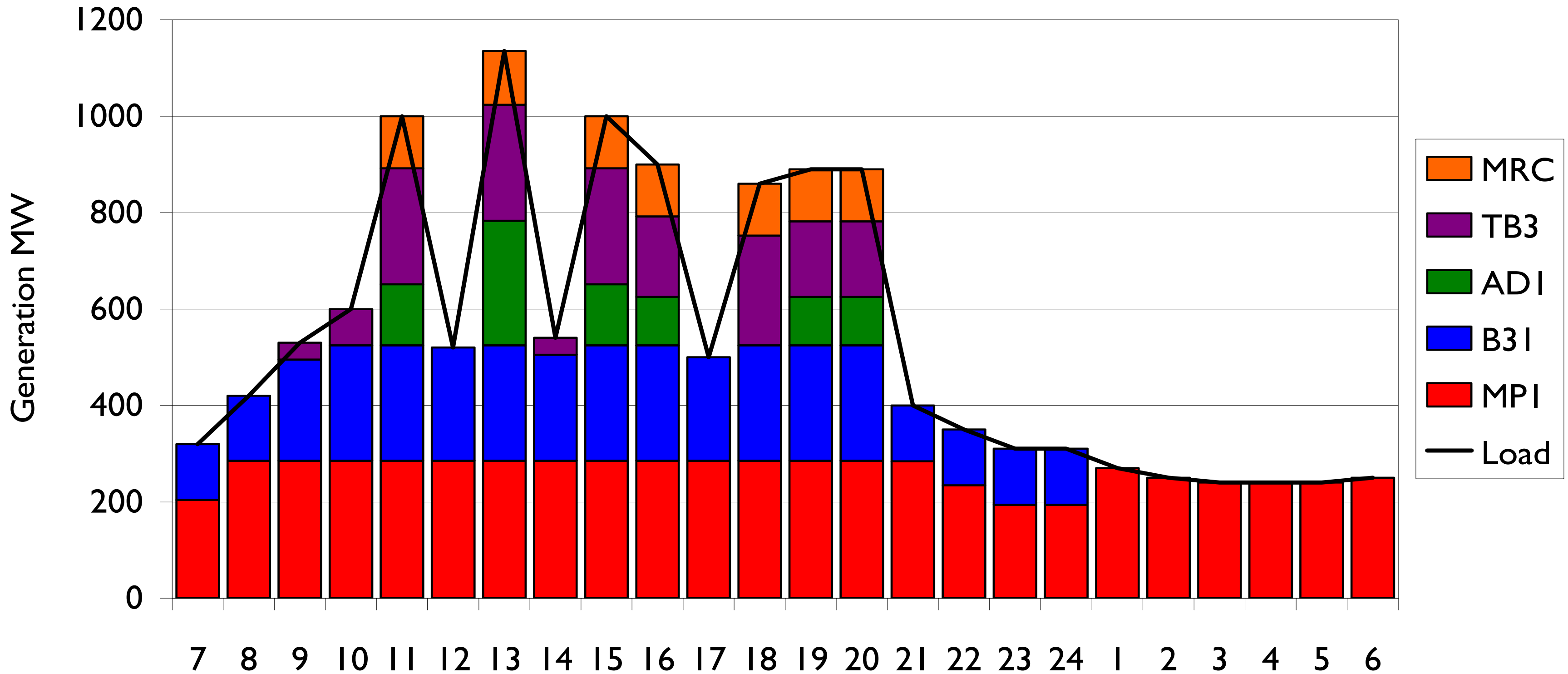


Shadow Prices: Generic Checks

- Examine instances of units running with SRMC above shadow price (e.g. at MSL, ramp constraint)
- Examine linkage between shadow prices, SRMCs and BETTA prices
- Validate PLEXOS SRMC values
- Check for constraint violations
- Assess impact of dynamic constraints

Shadow Prices & Constraints (1)

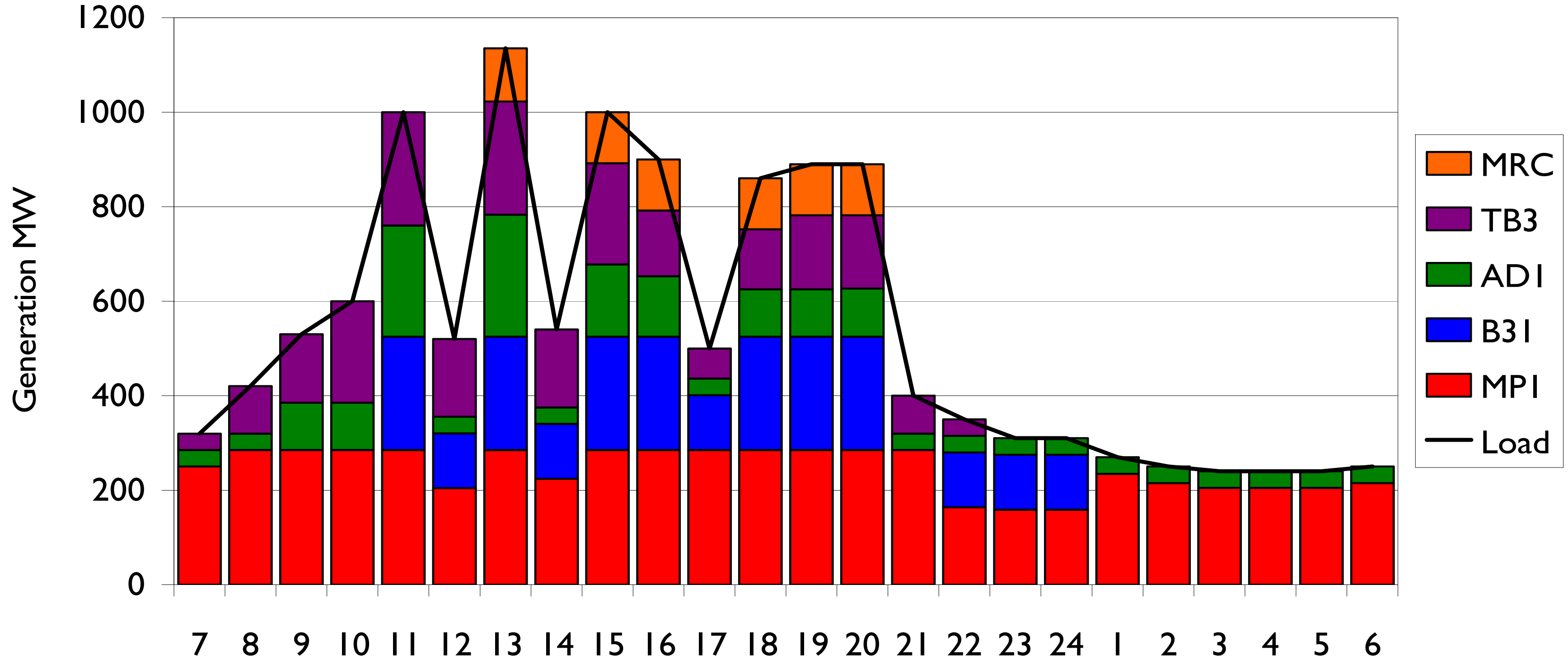
- Run simple (five plant) model without dynamic constraints and start costs



- Shadow price in peak period 13 of 91.93 €/MWh
- Represents SRMC of most expensive unit (MRC) at full load

Shadow Prices & Constraints (2)

- Re-run model with ramp rate constraints and start costs



- Shadow price in peak period 13 of 158.16 €/MWh
- TB3 has spare capacity but is constrained by ramp rates - shadow price reflects cost of re-dispatch in adjoining hours to meet period 13 incremental load

Uplift

- Uplift testing currently underway
  - “Rev Min” constraint not currently modelled within PLEXOS: will assess likely materiality at proposed δ
  - Start cost carry forward
  - Exclusion of “price takers” from revenue minimisation objective and cost recovery constraint

PLEXOS Configuration: Horizons

- **MT Schedule**
  - Annual optimisation
  - Daily duration curve of 4 blocks
- **ST Schedule**
  - Daily optimisation
  - Hourly trading period
  - 06:00 – 06:00 with 6 hour look-ahead to 12:00
  - Intend to test alternative configurations

PLEXOS Configuration: Commitment

- **RR**
  - Tested various rounding thresholds (0 – 10)
  - Can observe increasing unserved energy above 5

- **MIP**
  - Tested various Relative Gaps (1%, 0.5%, 0.3%)

Next steps and process for Project completion

Mike Wilks, Principal Consultant

Next steps after this Workshop

- Seeking written feedback on the issues and findings highlighted at this workshop – deadline 9am, 12 March.
- Will issue interim updated Generator technical data for peer review on Monday plus accompanying standard supplementary and clarification questions– seeking feedback by deadline of 9am, 12 March.
- Will engage bilaterally as required with participants on “interesting features” of data KEMA feels require further explanation/discussion. May require face-to-face meetings w/c 12 March.
- Participants can seek bilateral meetings with KEMA even if not directly approached – to take place w/c 12 March.
- Aim to complete above by 19 March.

Process for project completion

- Over next two weeks conduct 2nd iteration on data validation exercise as just indicated – subsequently seek to finalise validated input data and modelling assumptions
- Seek to complete Plexos validation work by mid/late March – will identify any required workarounds; will pros/cons of different Plexos operating modes
- Will provide reports on both of the above to the RAs end March – expect public versions to be released
- Will conduct Final Conclusions workshop in Dublin w/c 26 Mar
- Delivery of reports and Workshop represent project completion
- KEMA conclusions on input data and modelling assumptions will feed/advise Loop 3 and other RA modelling

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