Robust Dispatch to Manage Uncertainty in Real Time Electricity Markets

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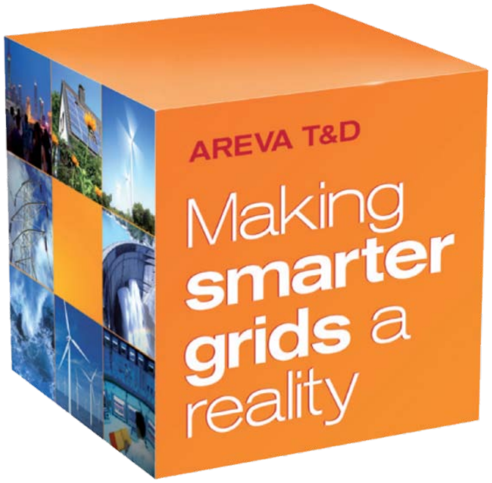
Outline

- Introduction
- Robust Dispatch to Manage Uncertainty
- Application Examples
- Conclusions



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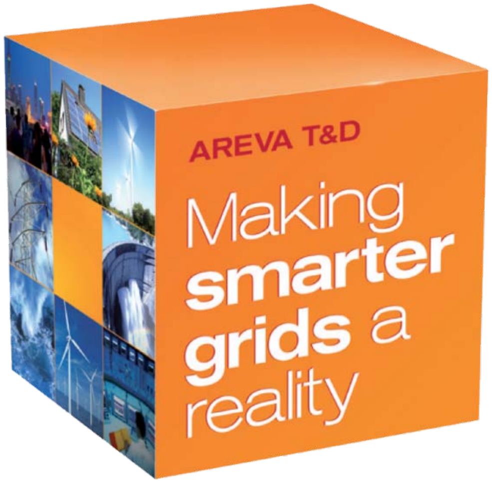
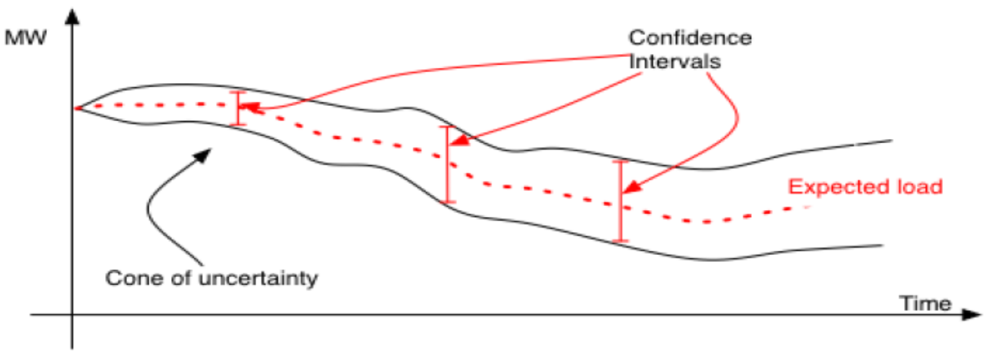


Introduction: Smart Grid Challenges

- A lot of emphasis of renewables, distributed energy resources (DER) and demand response (DR), PHEVs etc.
- Increase amount of uncertainties:
  - Generations and Demand Response
  - Demand forecast
  - Transmission constraints
  - Resource characteristics
- Modeling of uncertainties
  - Confidence Interval
  - Scenario-based



- Volumes and distributiveness of DERs and DRs
  - Aggregation model
- Smart Dispatch
  - Holistic forward-looking view of system conditions
  - More robust solution

Introduction: Problems with Current Resource Dispatch

Current operation

- **Alternative "independent" single interval dispatches: Medium, High (+ΔD) and Low (–ΔD) demand**
- **Operator must choose one**
- **No trend (profile) of generation instructions**

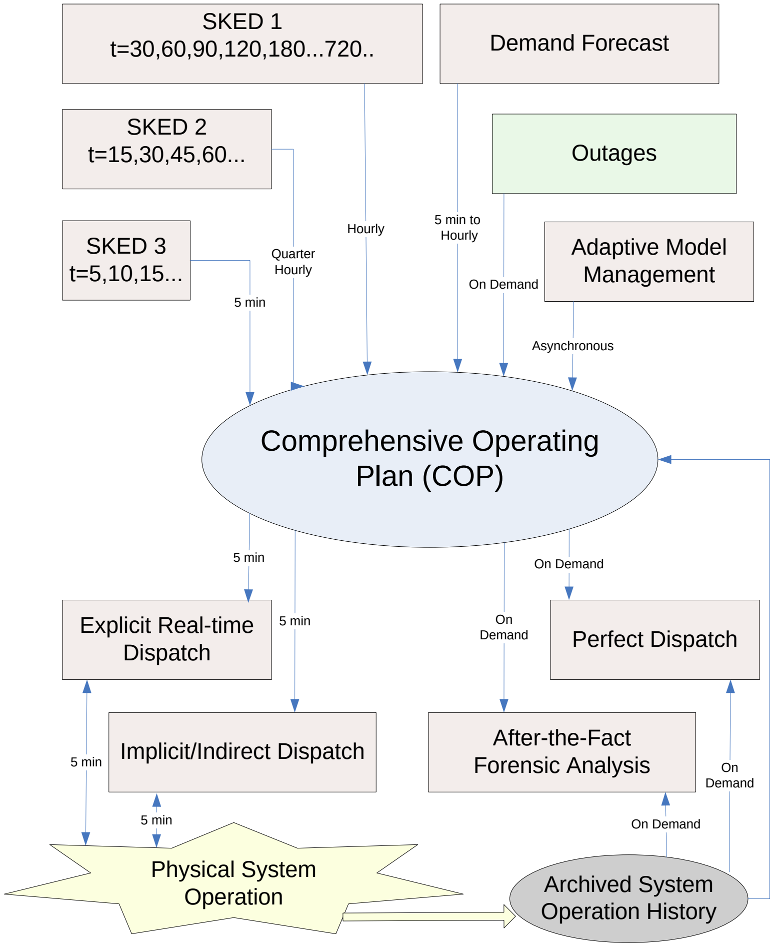
  → **non/late-responsive generators**

  → **turn-around for generators**

Problems

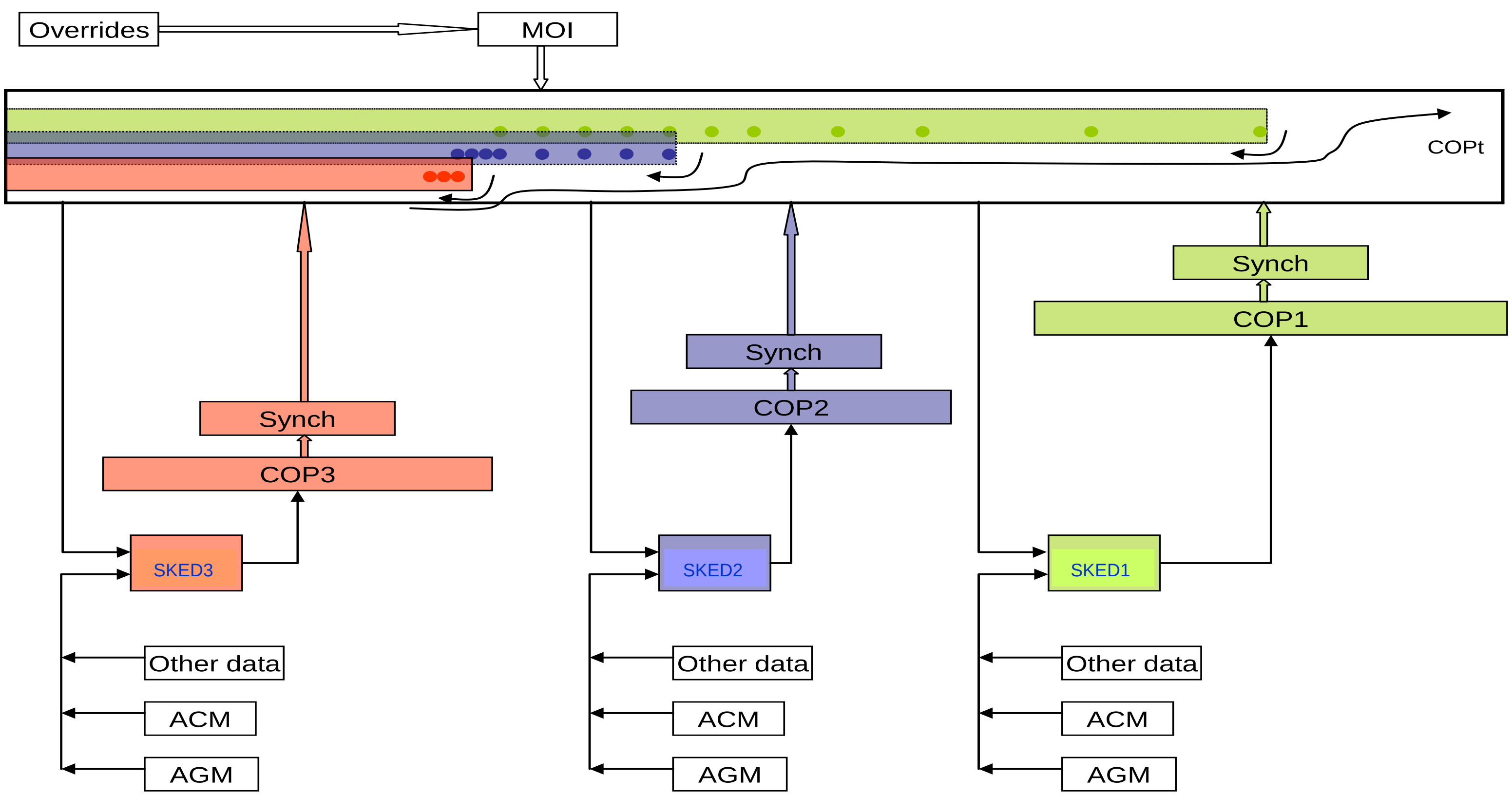
- **Excessive turn-around for generators**
- **Non-responsive generation**

- Look-Ahead Scheduling Functions (SKED1, 2 & 3): security constrained unit commitment and economic dispatch sequences with different look-ahead periods (e.g. 6 hours, 2 hours and 20 minutes) used to update the Comprehensive Operating Plan (COP), considering the "reality" (from State Estimator) as well as more updated forecasts of the future.
- For SKED1 and SKED2, the studies shall be time-coupled.
- Due to the concern of pricing, SKED3 shall have the flexibility of being configured as either time coupled or not coupled. When running in a decoupled mode, for each SKED3 interval, the latest available SE shall be the initial status, and each SKED3 interval shall consider the envelope provided by the Comprehensive Operating Plan (COP).

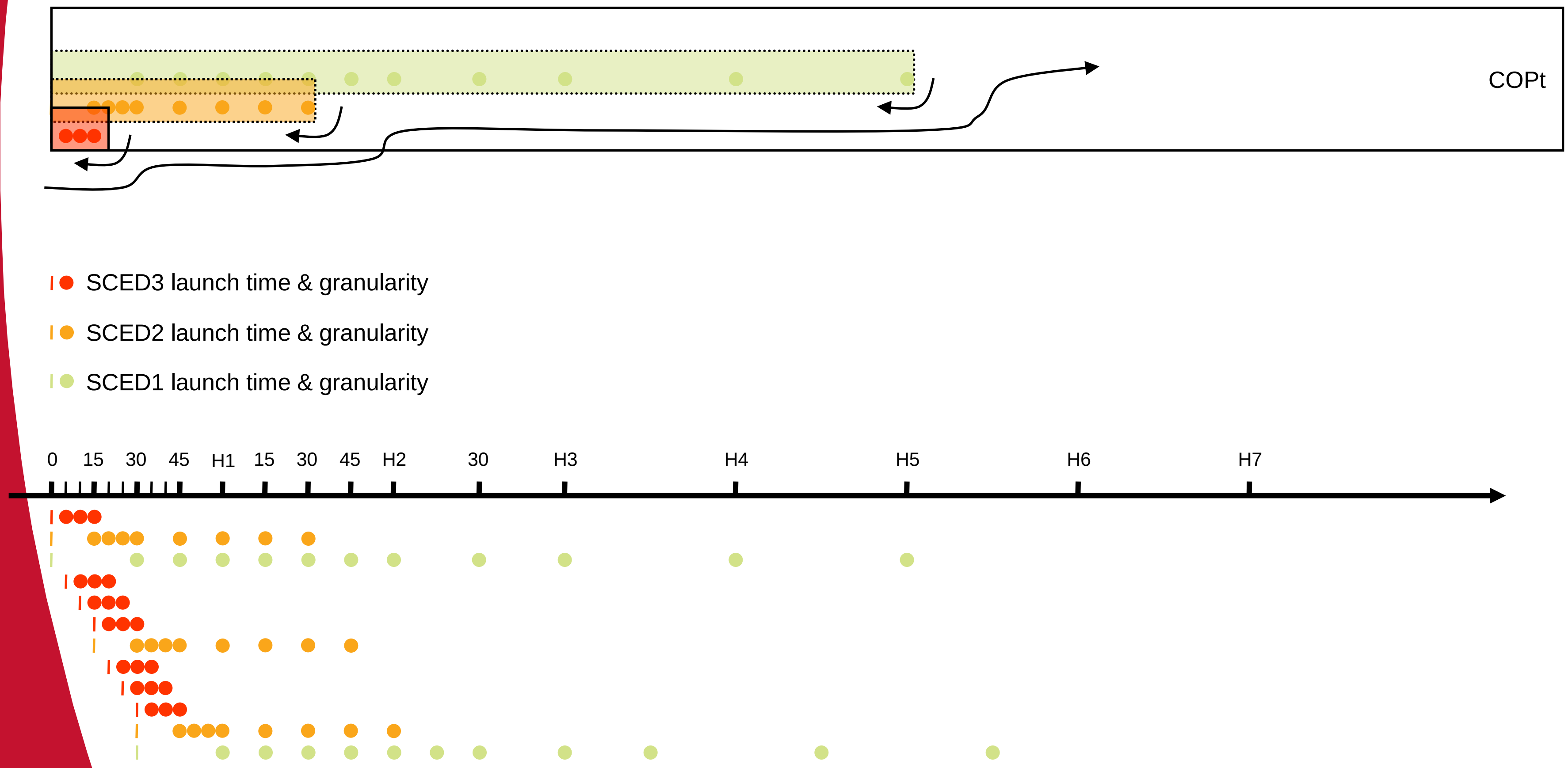


Comprehensive Operating Plan (COP)

- **COP is an application to coordinate scheduling data to and from a certain class of power system applications and present a comprehensive, synchronized and more harmonized view of scheduling data to applications, to system operators or other stakeholders for the purpose of power system operations.**



SKED 1, 2 & 3 Execution Sequences



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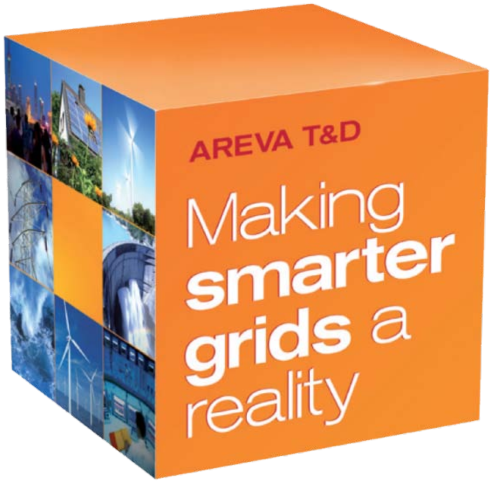
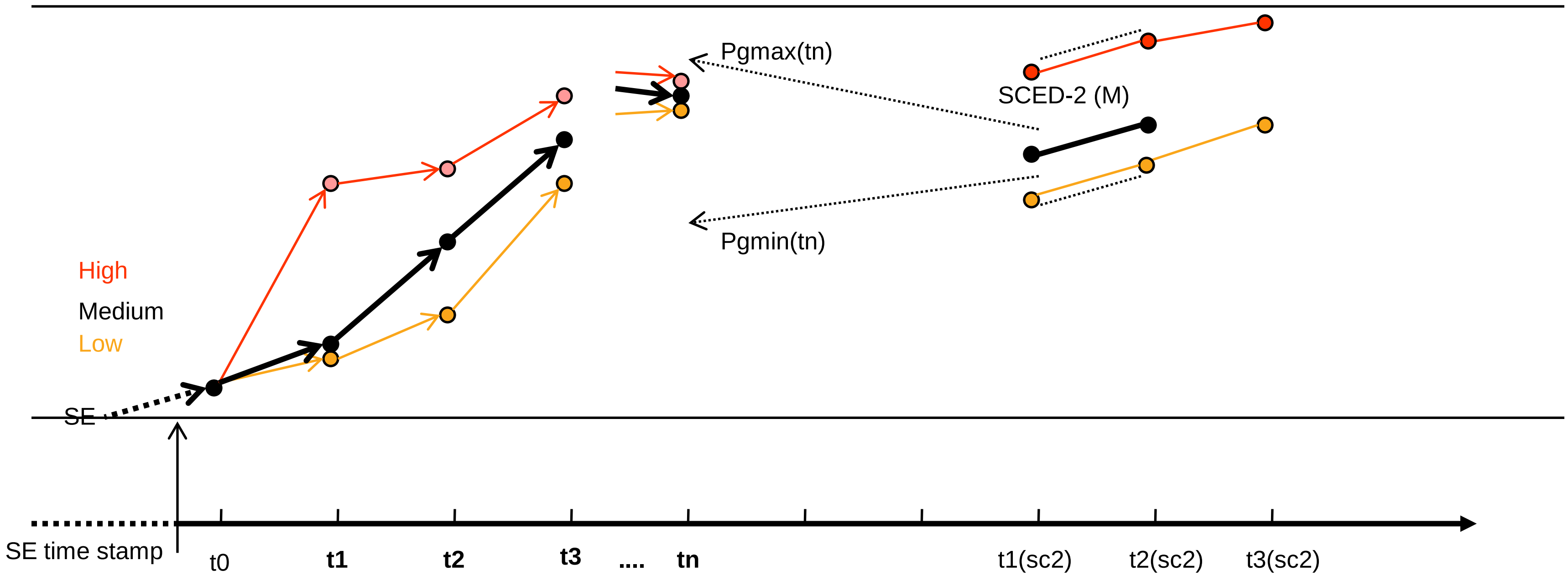


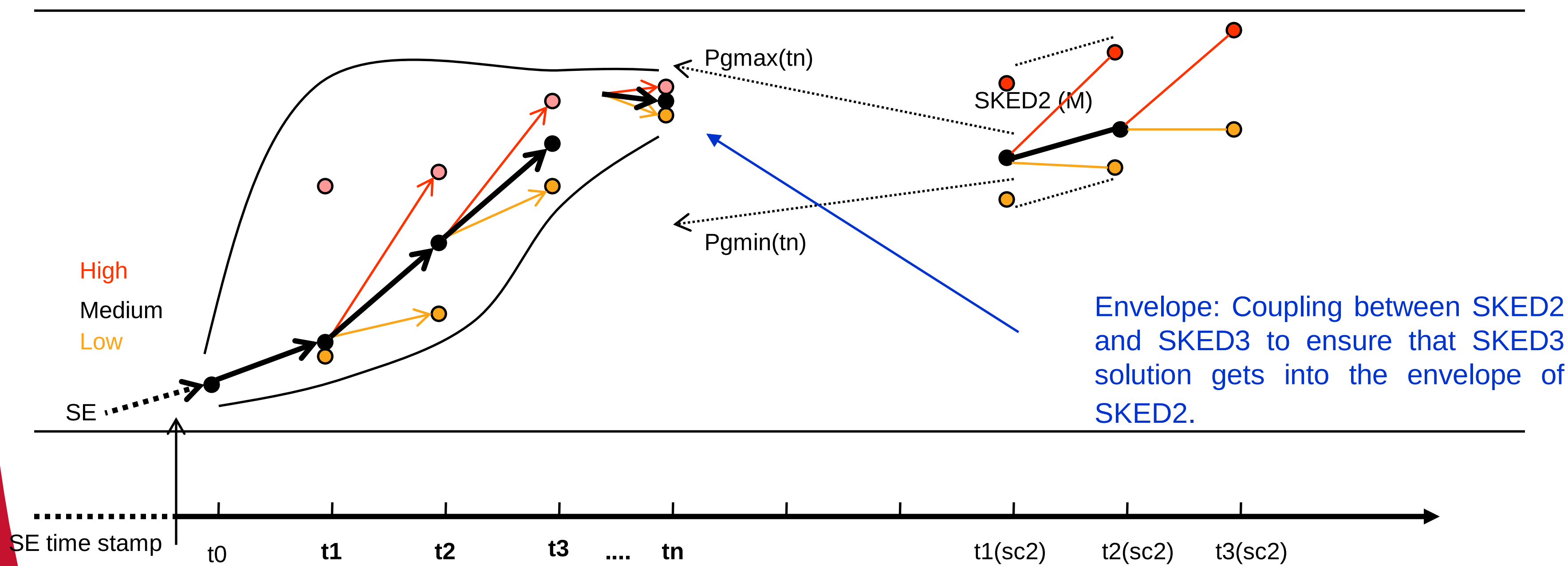
SKED3: Current Approach



Three "independent" solutions

- **Dispatcher can switch between H/M/L solutions; however reachability is not guaranteed**

SKED3 Future: Robust Dispatch



One robust solution

- **Three demand scenarios coordinated into one robust solution**
  - **"reach-ability" between medium and high and between medium and low demand scenarios**

Robust Dispatch

Deployment (avoid overcompensation)

steam deviation = ΣPg real – ΣPg instructed

If (steam deviation < – tol) and (ACE < – tol ace) **then**

K = – steam deviation / (Pdh – Pdm) **0 ≤ K ≤ 1**

Pg = Pgm + K*(Pgh – Pgm)

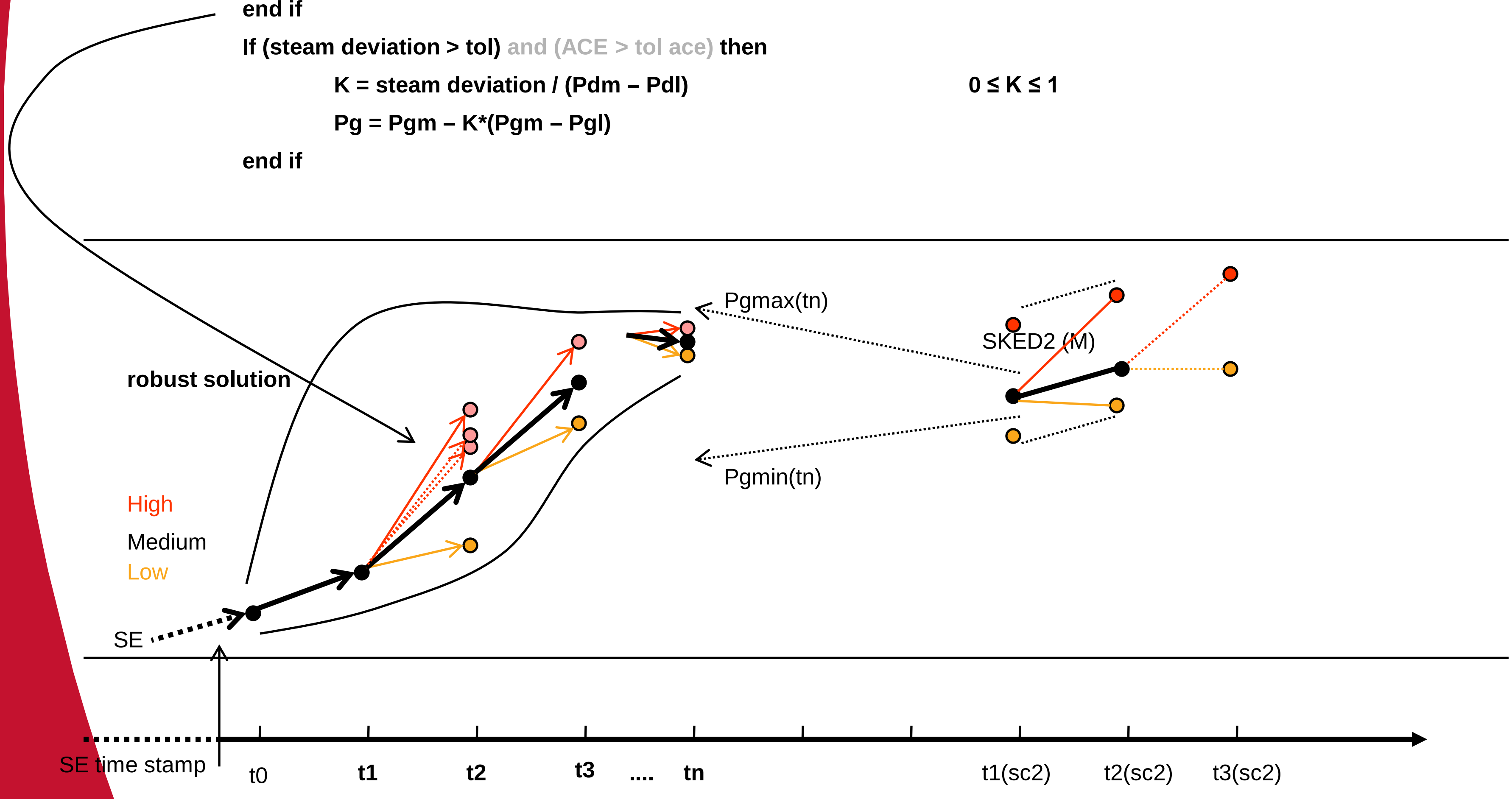
end if

If (steam deviation > tol) and (ACE > tol ace) **then**

K = steam deviation / (Pdm – Pdl) **0 ≤ K ≤ 1**

Pg = Pgm – K*(Pgm – Pgl)

end if



Robust Dispatch (Basic Formulation)

Minimize

$$\sum_t \left\{ \sum_i \left(c_{i,t} * Pgm_{i,t} \right) * (time_t - time_{t-1}) / 60 \right\}$$

$$+ \sum_t \left\{ \sum_i \left(c_{i,t} * Pgh_{i,t} \right) * (time_t - time_{t-1}) / 60 \right\}$$

$$+ \sum_t \left\{ \sum_i \left(c_{i,t} * Pgl_{i,t} \right) * (time_t - time_{t-1}) / 60 \right\}$$

subject to *for* $\forall t = \{t1, \ldots tn\}$

$$\sum_i Pgm_{i,t} = PdemandM_t$$

$$Pg_{i,t}^{\min} \le Pgm_{i,t} \le Pg_{i,t}^{\max}$$

$$-(time_t - time_{t-1}) * RRDn_{i,t} \le Pgm_{i,t} - Pgm_{i,t-1} \le (time_t - time_{t-1}) * RRUp_{i,t}$$

$$-F_{k,t}^{\max} \le \sum_i Dfax_{Fk,i,t} * Pgm_{i,t} \le F_{k,t}^{\max}$$

Reach-ability M→H

$$\sum_i Pgh_{i,t} = PdemandH_t$$

$$Pg_{i,t}^{\min} \le Pgh_{i,t} \le Pg_{i,t}^{\max}$$

$$-(time_t - time_{t-1}) * RRDn_{i,t} \le Pgh_{i,t} - Pgm_{i,t-1} \le (time_t - time_{t-1}) * RRUp_{i,t}$$

$$-F_{k,t}^{\max} \le \sum_i Dfax_{Fk,i,t} * Pgh_{i,t} \le F_{k,t}^{\max}$$

Reach-ability M→L

$$\sum_i Pgl_{i,t} = PdemandL_t$$

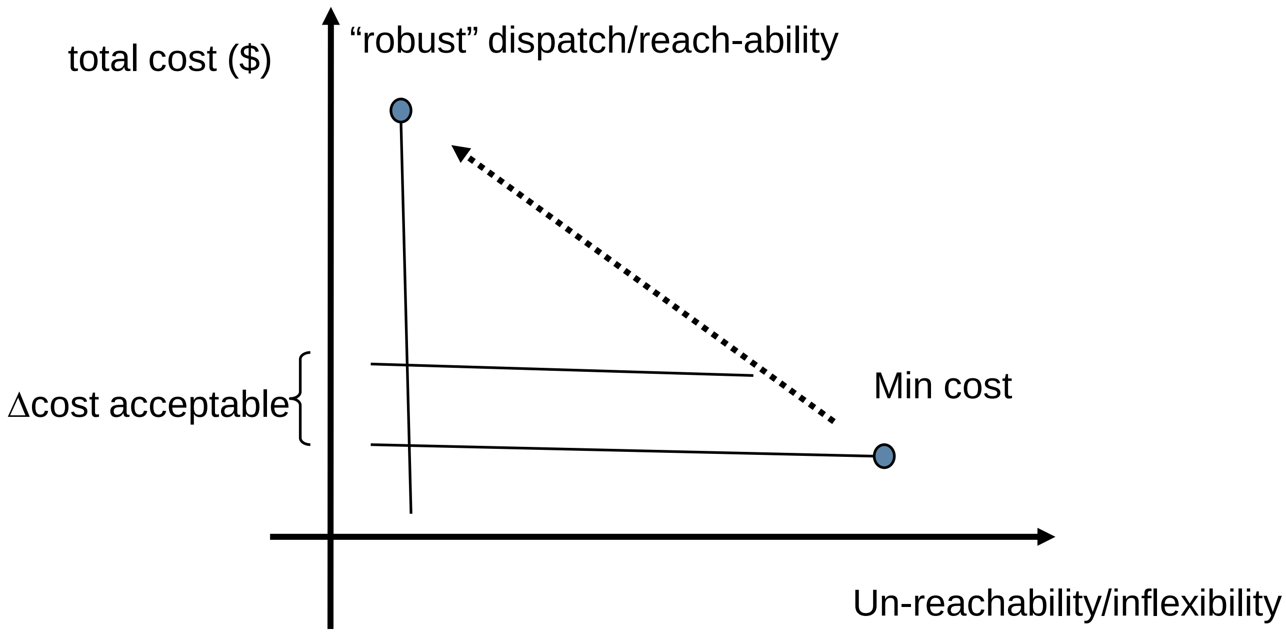
$$Pg_{i,t}^{\min} \le Pgl_{i,t} \le Pg_{i,t}^{\max}$$

$$-(time_t - time_{t-1}) * RRDn_{i,t} \le Pgl_{i,t} - Pgm_{i,t-1} \le (time_t - time_{t-1}) * RRUp_{i,t}$$

$$-F_{k,t}^{\max} \le \sum_i Dfax_{Fk,i,t} * Pgl_{i,t} \le F_{k,t}^{\max}$$

Limiting the Cost of Robustness

robustness vs. cost



$$\sum_t \left\{ \sum_i \left(c_{i,t} * Pgm_{i,t} \right) * (Time_t - Time_{t-1}) / 60 \right\} \leq (1 + DeltaCost) * CostBC$$

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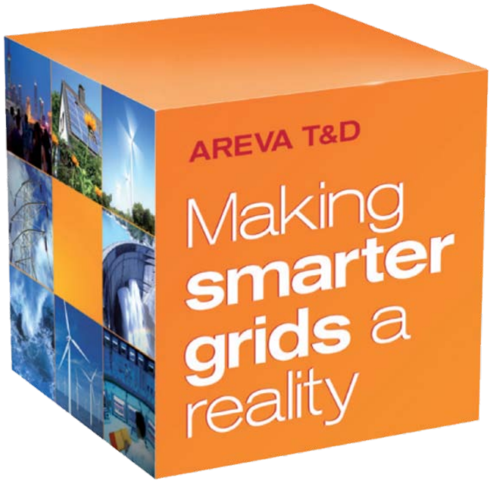
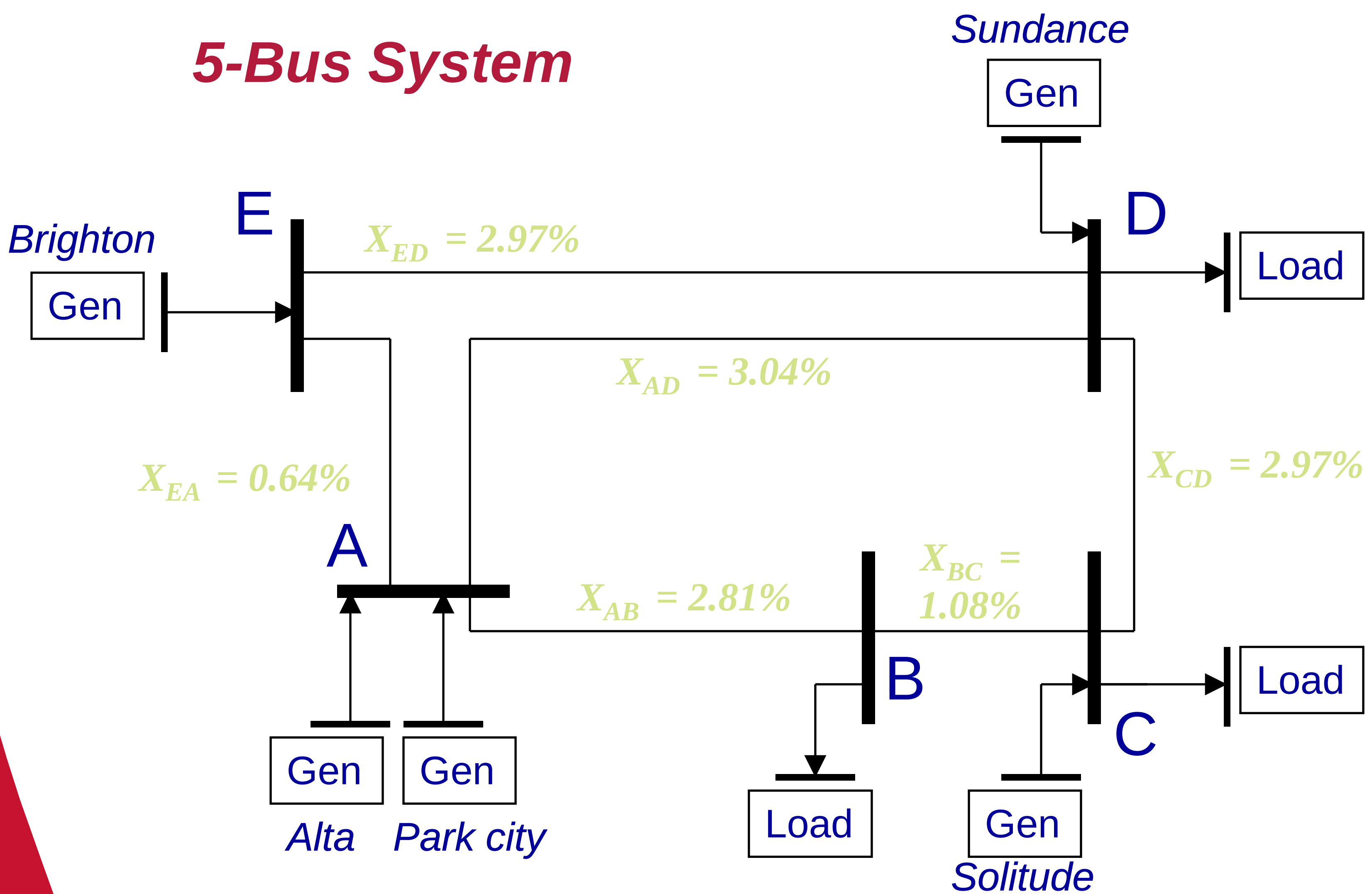


Examples


5-Bus System
Sundance
Gen
E
D
Brighton
Gen
X_ED = 2.97%
Load
X_AD = 3.04%
X_EA = 0.64%
X_CD = 2.97%
A
X_BC = 1.08%
X_AB = 2.81%
B
Load
C
Gen
Gen
Load
Gen
Alta
Park city
Solitude

GCA - Dynamic Dispatch (DSPD)

SKED3

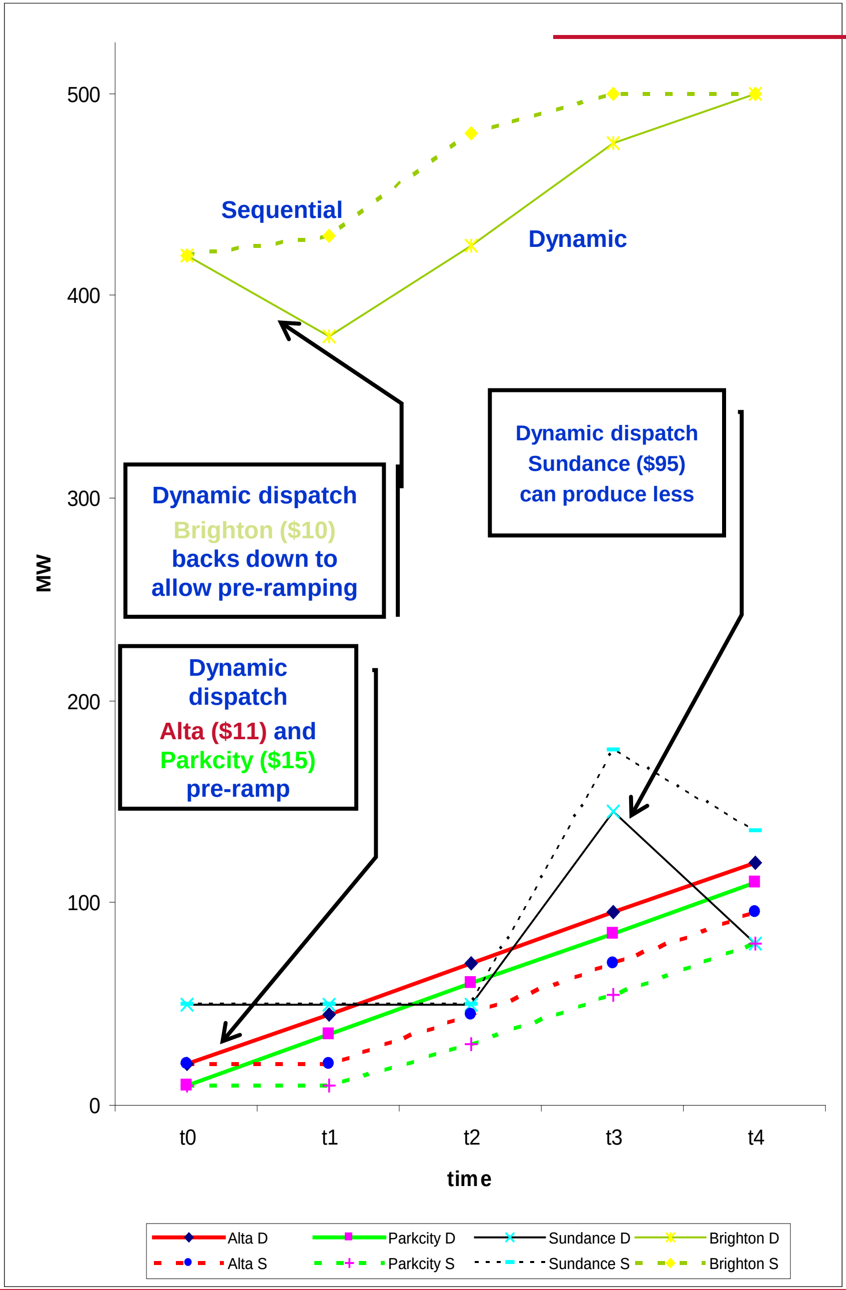
sequential vs. dynamic dispatch Value of pre-ramping

Cost	t1	t2	t3	t4	total
Dynamic dispatch	9570	10670	20845	15570	56655
Sequential dispatch	9420	10495	23220	20070	63205

	PriceE	MaxRampUp	MaxRampDn	PgSE
Alta	11	5	100	20
Parkcity	15	5	100	10
Solitude	30	10	100	0
Sundance	95	100	100	50
Brighton	10	10	100	420

Pgmin	t0	t1	t2	t3	t4
Alta		20	20	20	20
Parkcity		10	10	10	10
Solitude		0	0	0	0
Sundance		50	50	50	50
Brighton		350	350	350	350

Pgmax	t0	t1	t2	t3	t4
Alta		150	150	150	150
Parkcity		150	150	150	150
Solitude		0	0	0	0
Sundance		400	400	400	400
Brighton		500	500	500	500



GCA - Dynamic Dispatch (DSPD)

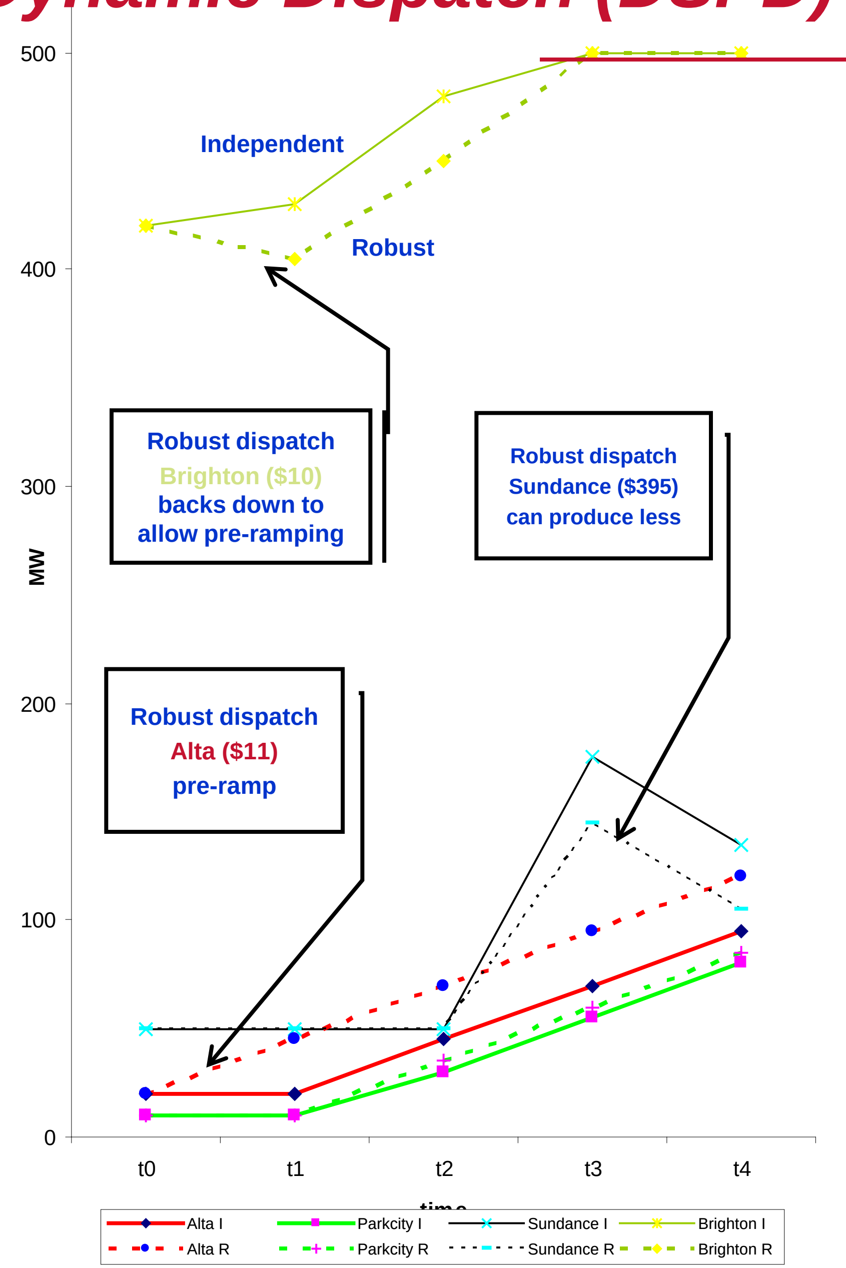
SKED3

independent vs. robust dispatch
Value of reach-ability

Cost	t1	t2	t3	t4	total
M independent t1 & t2 + H t3 & t4	*2035*	*2125*	*6310*	*5048*	*15517*
M robust (M→H) t1 & t2 + H t3 & t4	*2037*	*2129*	*5352*	*4089*	*13607*
perfect forecast M t1 & t2 + H t3 & t4	*2048*	*2139*	*5362*	*3298*	*12846*

	PriceE	MaxRampUp	MaxRampDn	PgSE	Gbus	Pgmin	Pgmax
Alta	11	5	100	20	A	20	150
Parkcity	15	5	100	10	A	10	150
Solitude	30	10	100	0	C	0	0
Sundance	395	100	100	50	D	50	400
Brighton	10	10	100	420	E	350	500

	t0	t1	t2	t3	t4
time	0	5	10	15	20
Pdm	500	510	605	610	620
Pdh	500	510	605	800	810
Pdl	500	505	600	605	615



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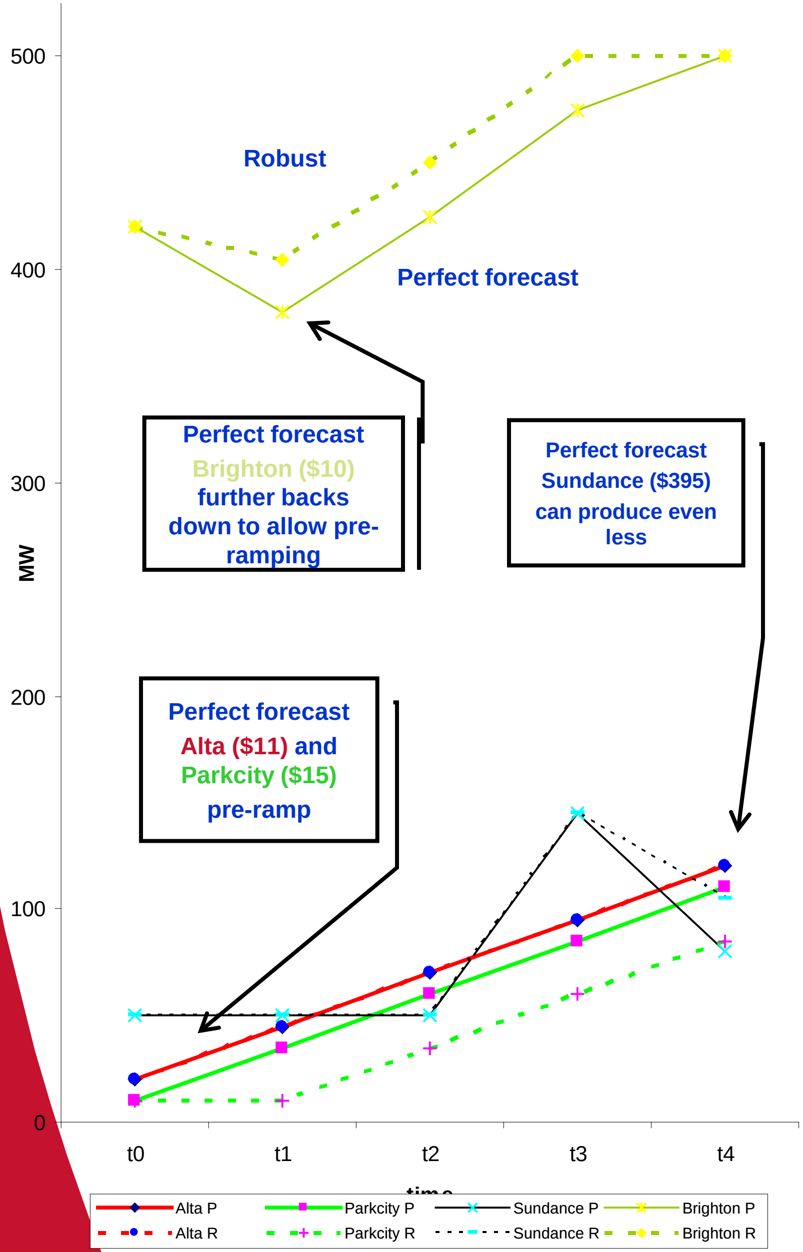

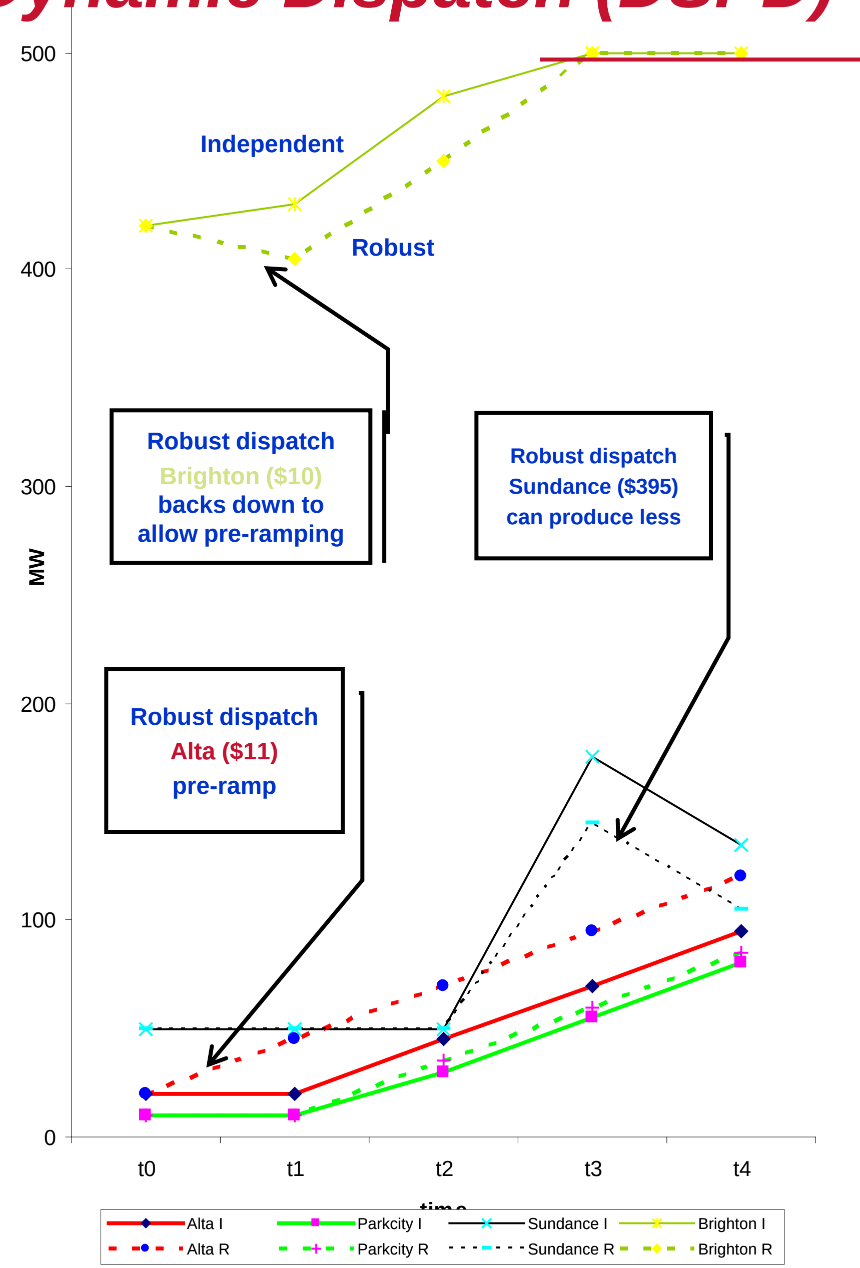

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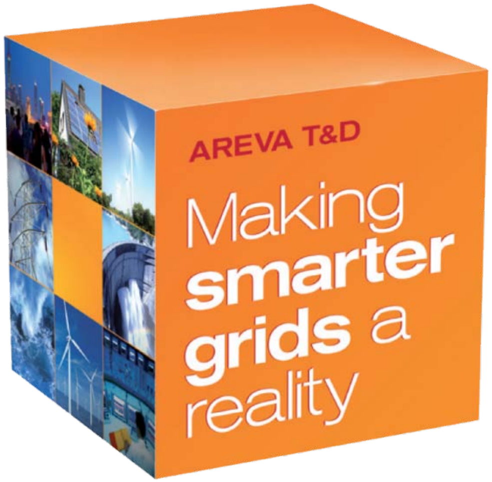

Conclusions

- Discussed the needs for robust dispatch.
- A simple approach to deal with uncertainties in the real-time security constrained economic dispatch is proposed.
- A mathematical formulation of the proposed robust dispatch solution is presented.
- A robust solution that coordinates multiple demand scenarios could guarantee “reachability”.
- An 5-bus example is given to illustrate the proposed concept of robust dispatch.

Q & A