

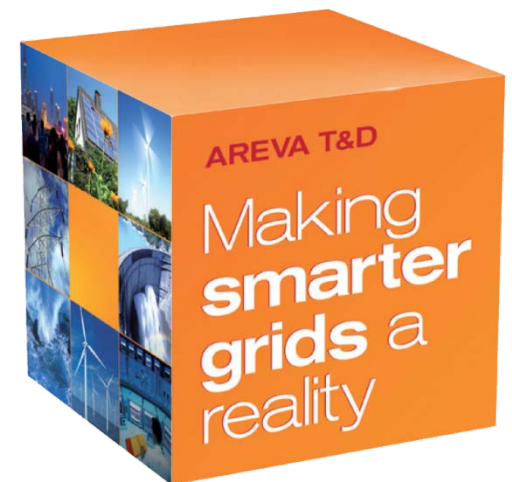
# ***Robust Dispatch to Manage Uncertainty in Real Time Electricity Markets***

**Ricardo Rios-Zalapa, Xing Wang, Jie Wan, Kwok W. Cheung**

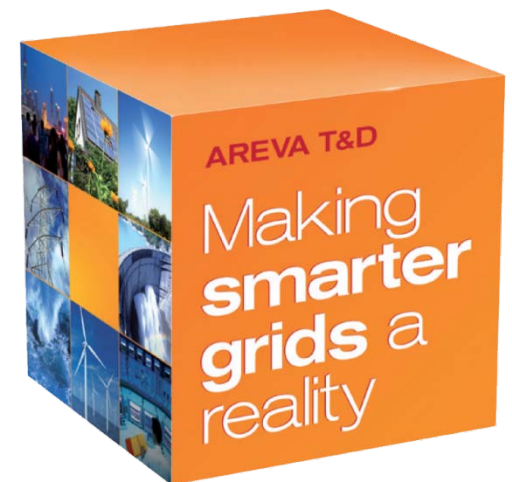
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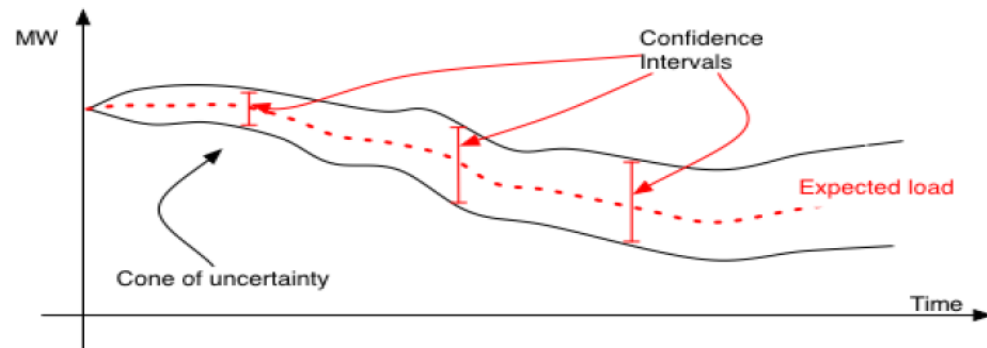
- ▶ **Introduction**
- ▶ **Robust Dispatch to Manage Uncertainty**
- ▶ **Application Examples**
- ▶ **Conclusions**



- ▶ **Introduction**
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- ▶ 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

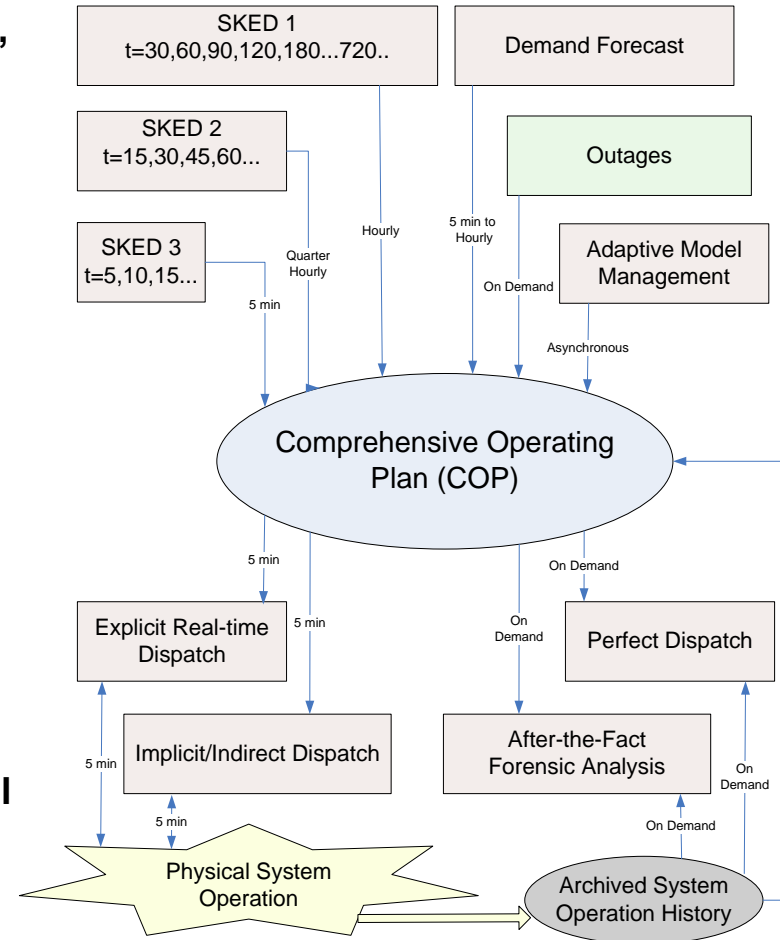
## Current operation

- ▶ Alternative “independent” single interval dispatches: Medium, High (+ $\Delta D$ ) and Low ( $-\Delta D$ ) demand
- ▶ Operator must choose one
- ▶ No trend (profile) of generation instructions
  - non/late-responsive generators
  - turn-around for generators

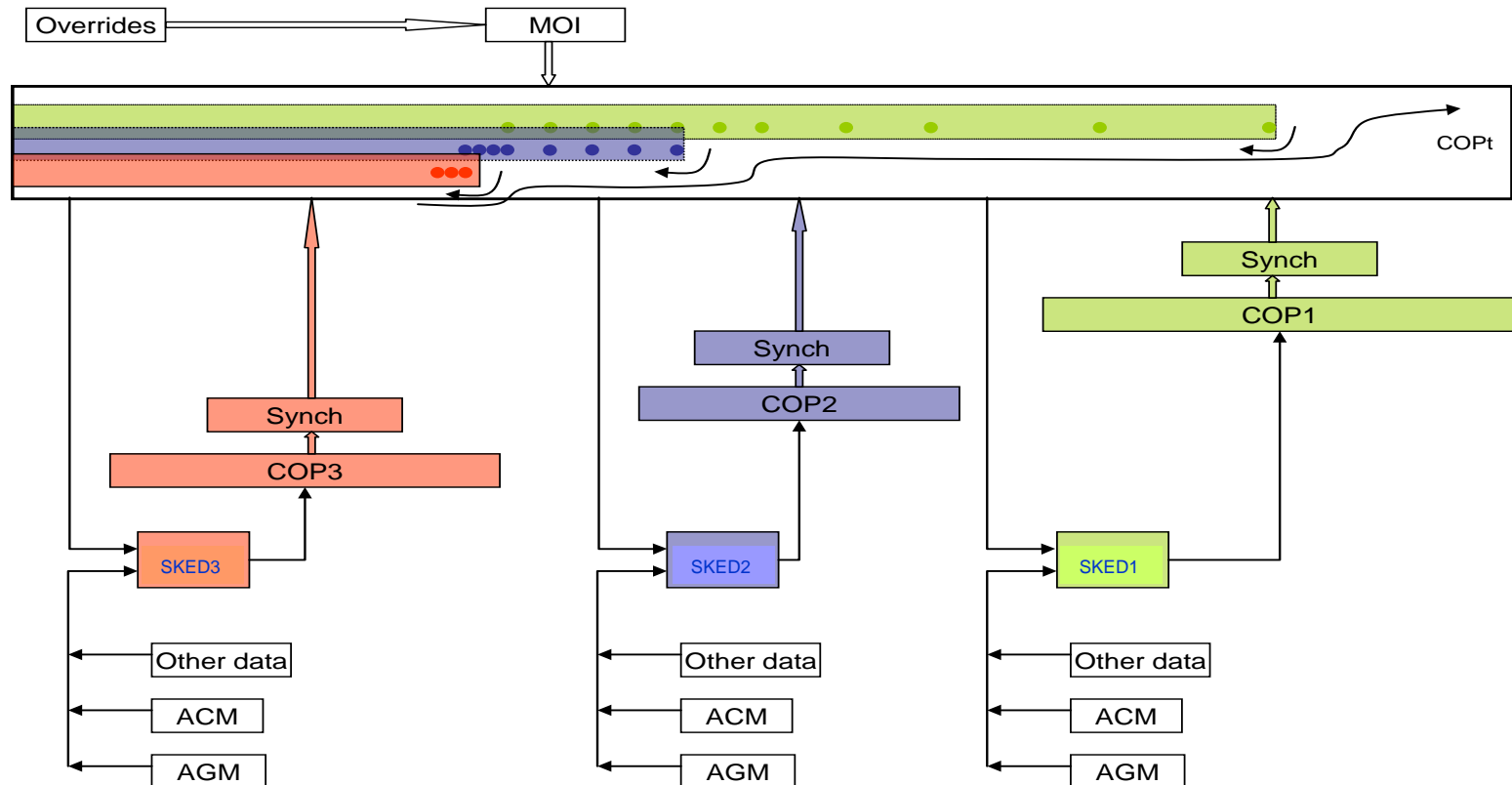
## Problems

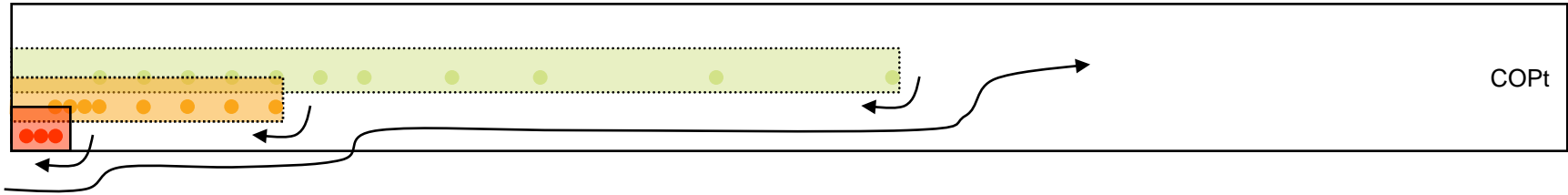
- ▶ Excessive turn-around for generators
- ▶ Non-responsive generation

- ▶ **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).

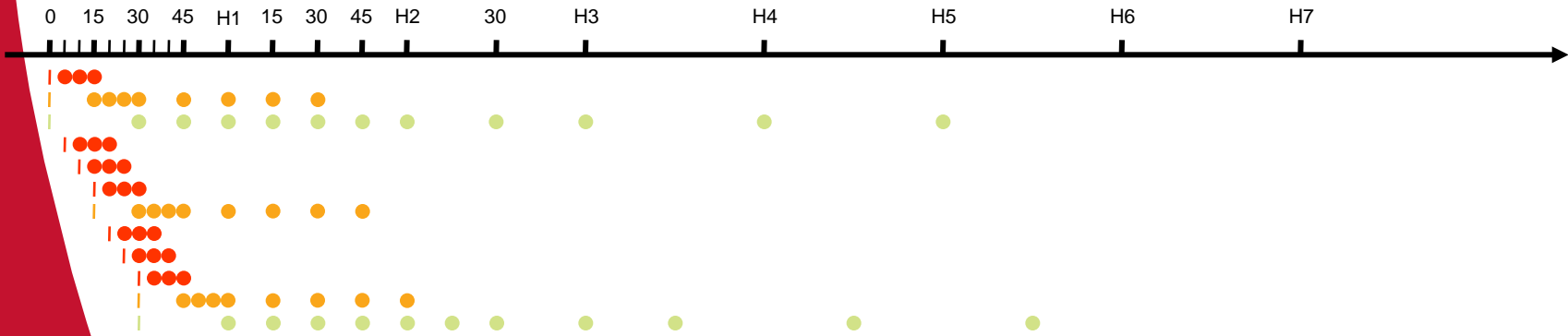


- ▶ COP is an application to coordinate scheduling data to and from a certain class of power system applications and present a comprehensive, synchronized and more harmonized view of scheduling data to applications, to system operators or other stakeholders for the purpose of power system operations.

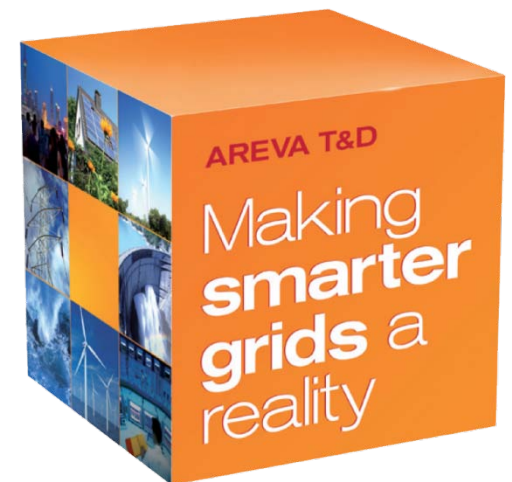


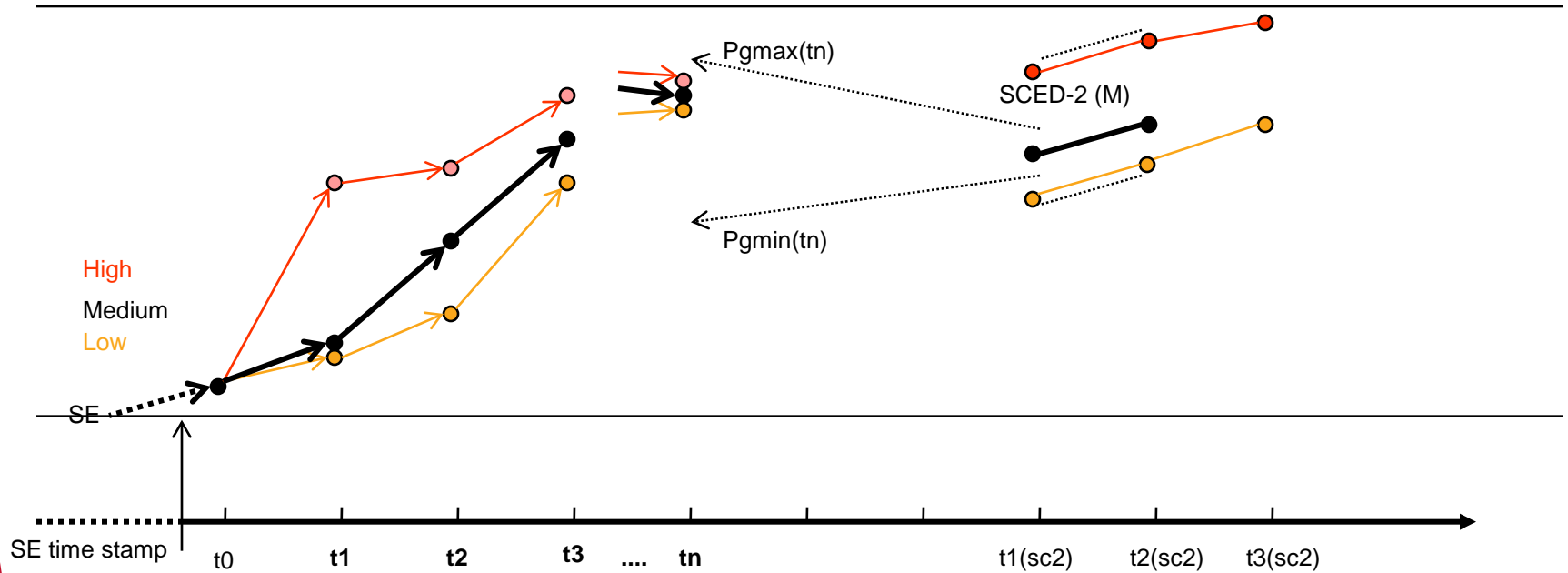


- SCED3 launch time & granularity
- SCED2 launch time & granularity
- SCED1 launch time & granularity



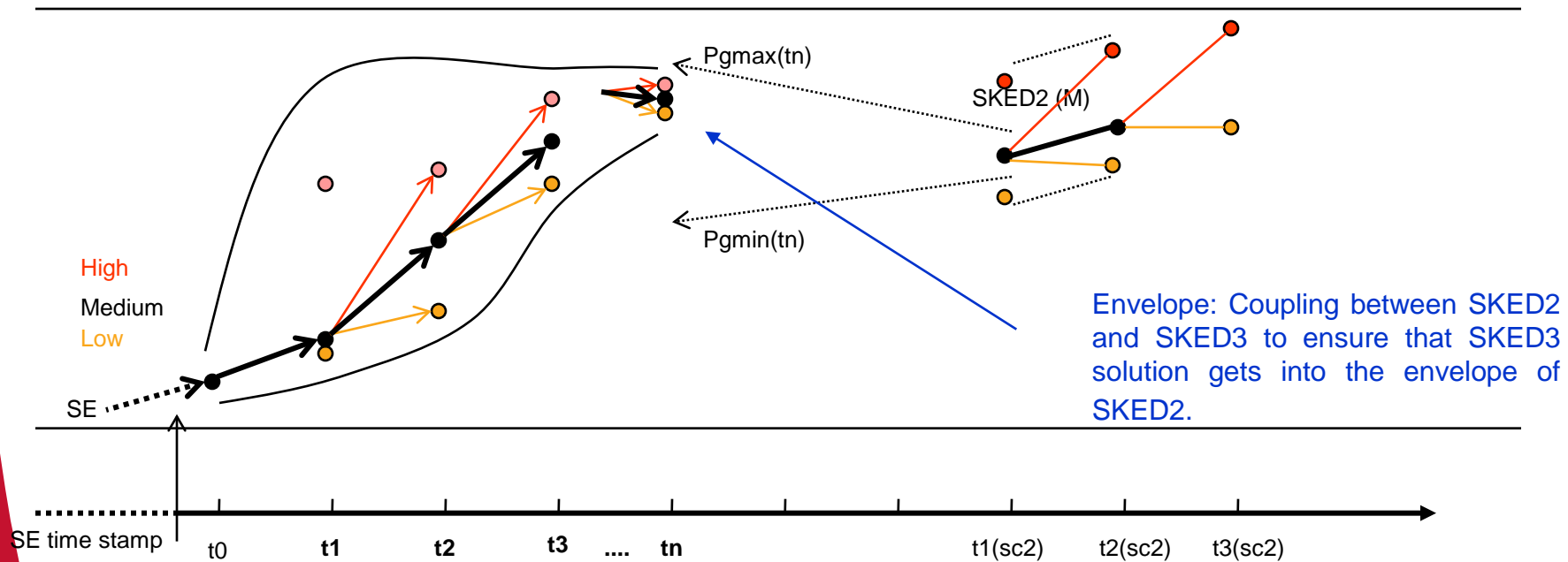
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## Three “independent” solutions

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



## One robust solution

- ▶ Three demand scenarios coordinated into one robust solution
  - ◆ “reach-ability” between medium and high and between medium and low demand scenarios

## Deployment (avoid overcompensation)

$$\text{steam deviation} = \Sigma P_g \text{ real} - \Sigma P_g \text{ instructed}$$

If (steam deviation < - tol) and (ACE < - tol ace) then

$$K = - \text{steam deviation} / (P_{dh} - P_{dm})$$

$$0 \leq K \leq 1$$

$$P_g = P_{gm} + K * (P_{gh} - P_{gm})$$

end if

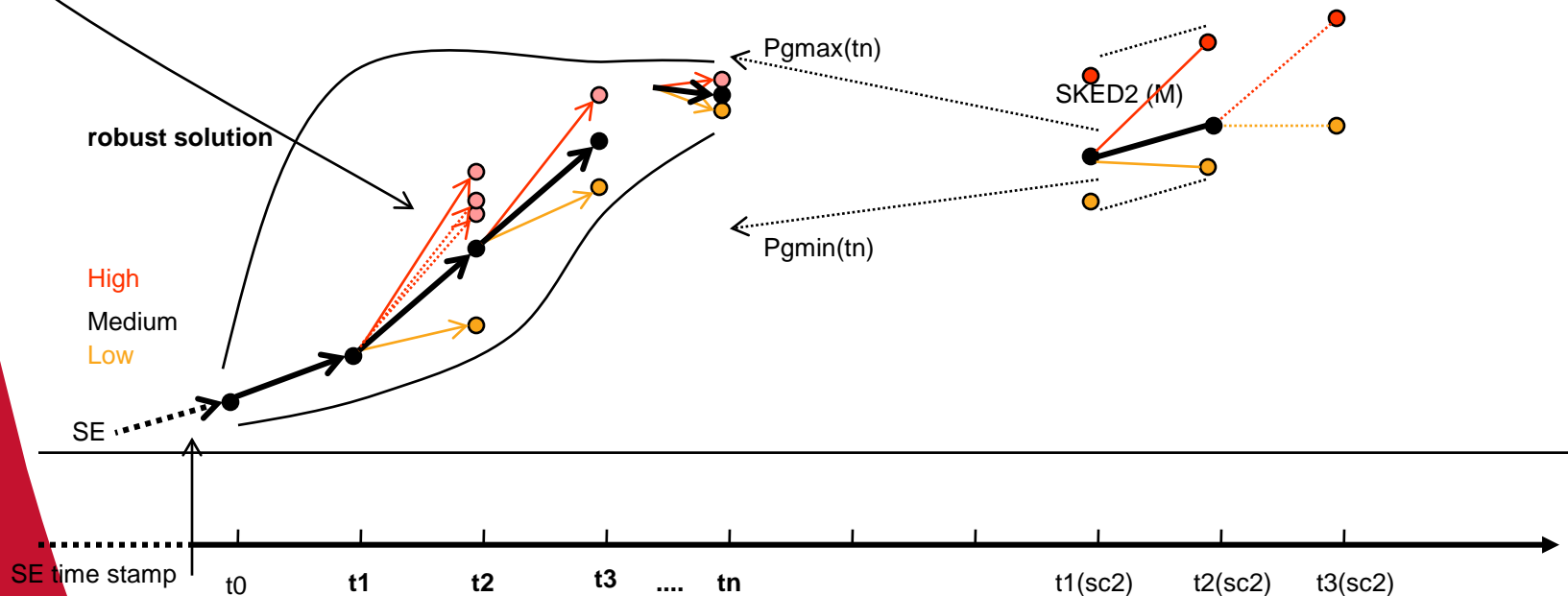
If (steam deviation > tol) and (ACE > tol ace) then

$$K = \text{steam deviation} / (P_{dm} - P_{dl})$$

$$0 \leq K \leq 1$$

$$P_g = P_{gm} - K * (P_{gm} - P_{gl})$$

end if



Minimize

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

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

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

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

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

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

Reach-ability M→H

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

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

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

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

Reach-ability M→L

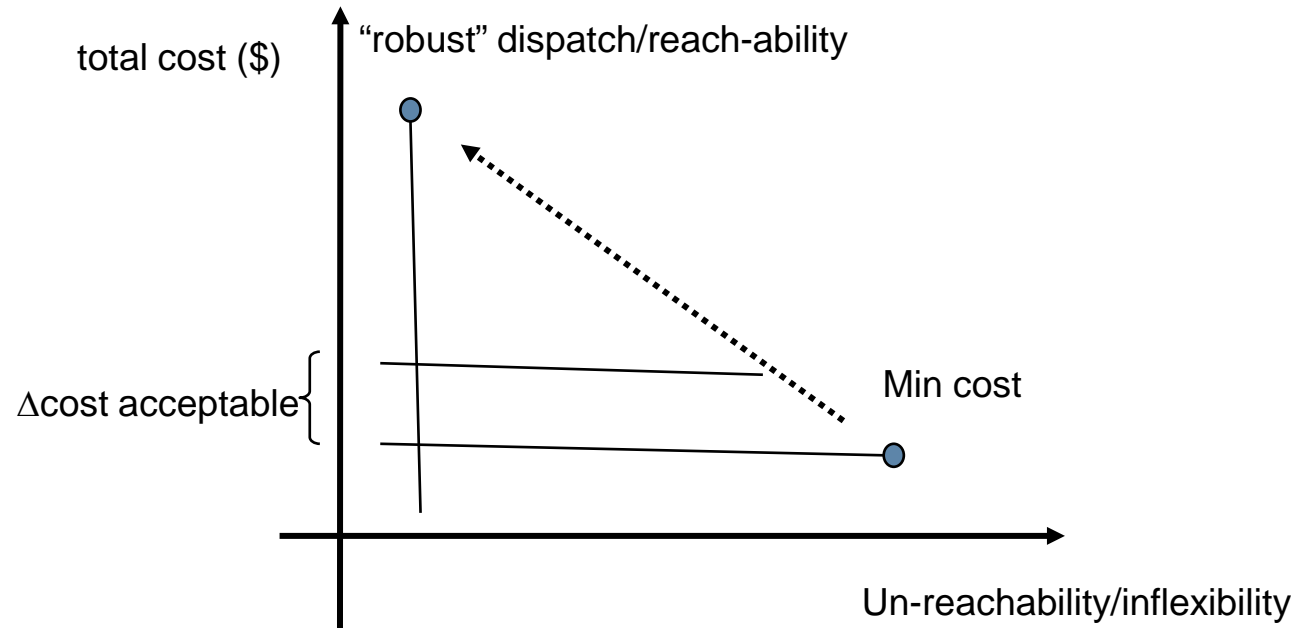
$$\sum_i Pgl_{i,t} = PdemandL_t$$

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

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

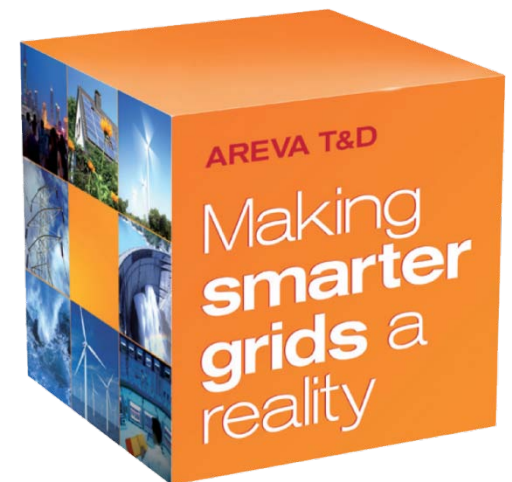
$$-F_{k,t}^{\max} \leq \sum_i Dfax_{Fk,i,t} * Pgl_{i,t} \leq F_{k,t}^{\max}$$

## robustness vs. cost



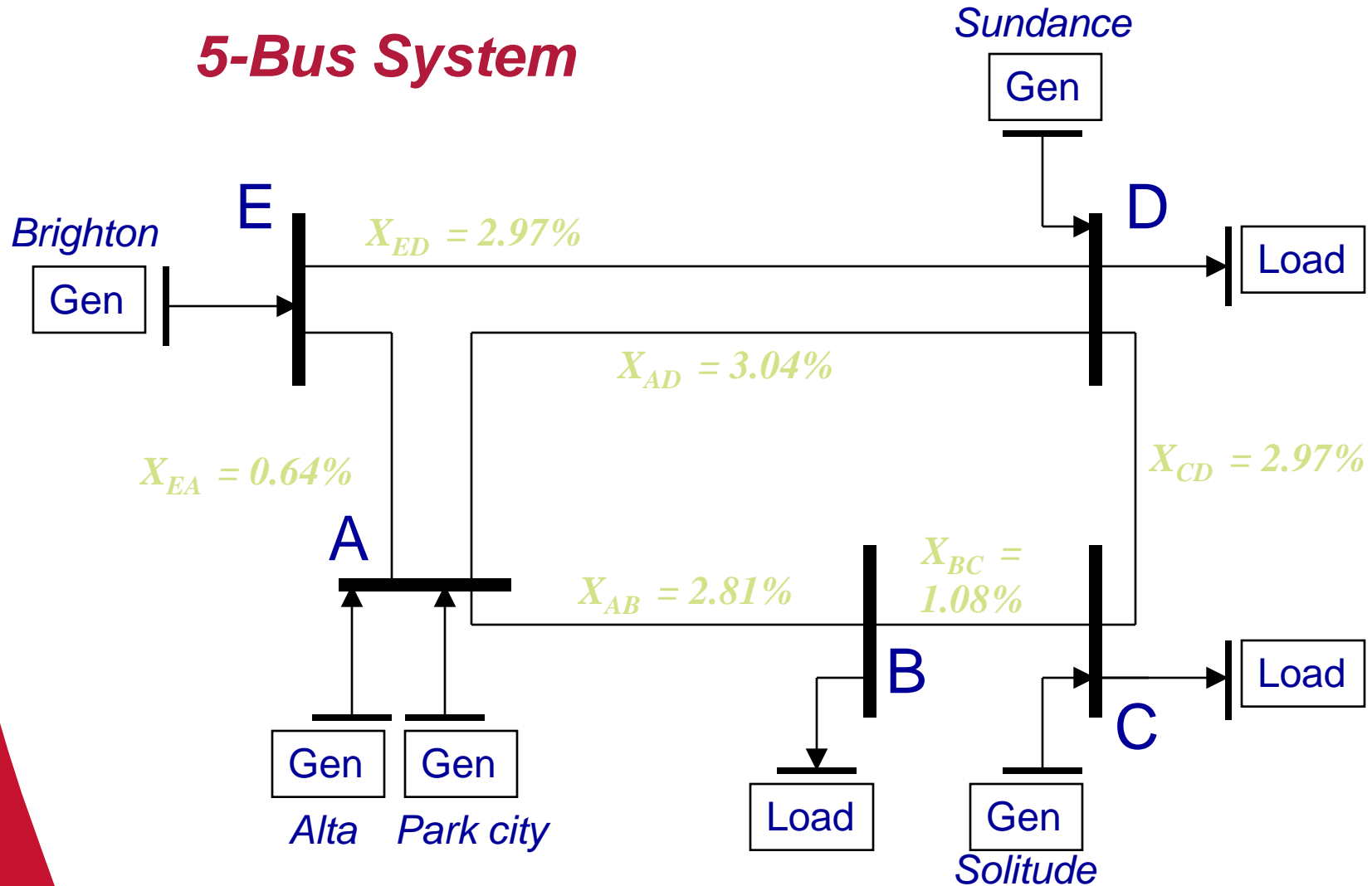
$$\sum_t \left\{ \sum_i (c_{i,t} * Pgm_{i,t}) * (Time_t - Time_{t-1}) / 60 \right\} \leq (1 + DeltaCost) * CostBC$$

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Examples

5-Bus System



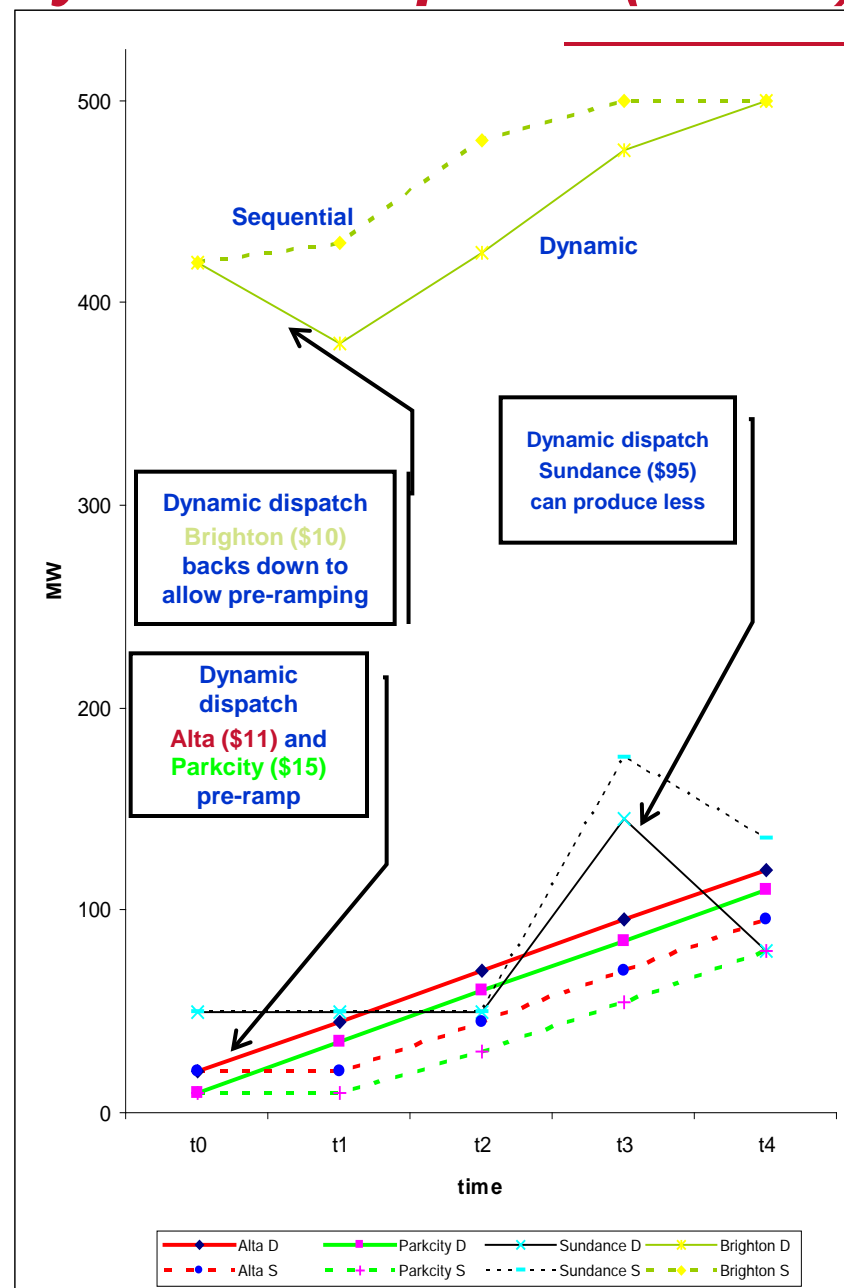
## SKED3 sequential vs. dynamic dispatch Value of pre-ramping

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



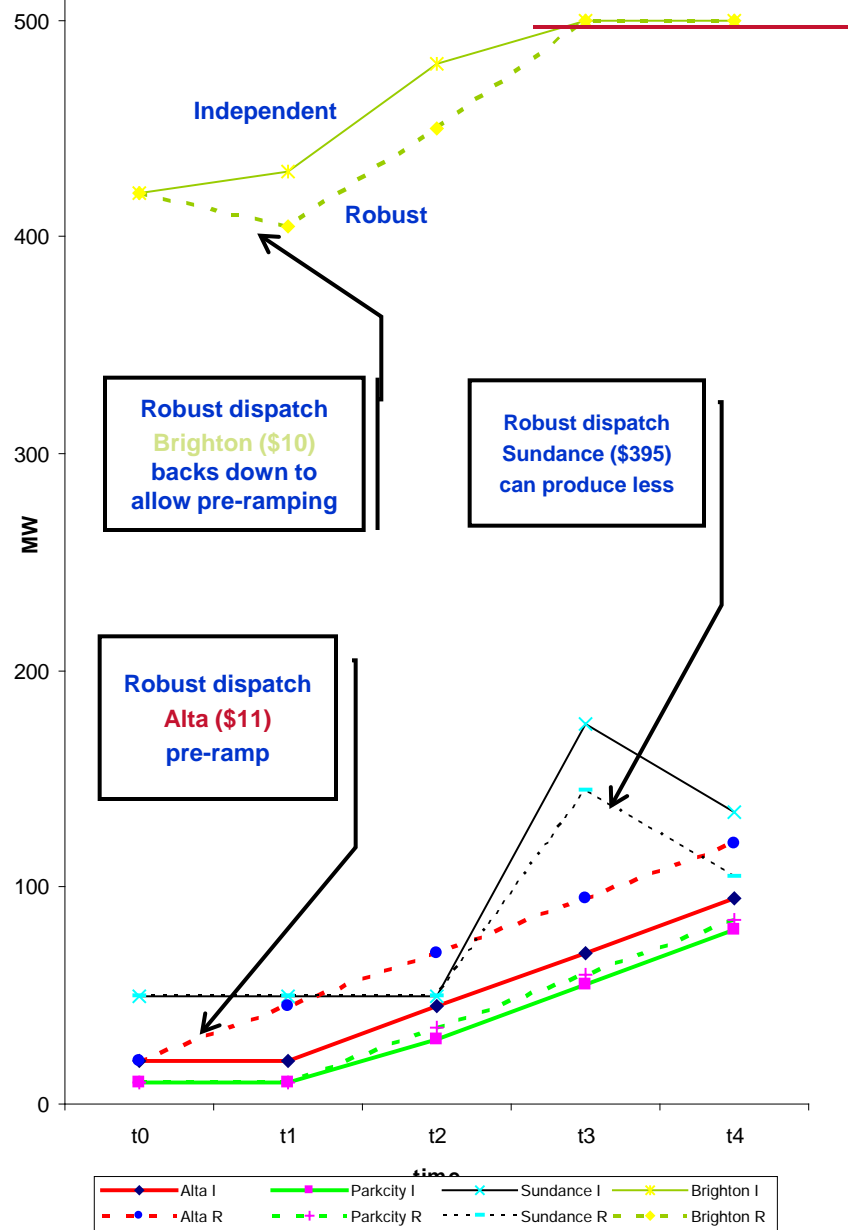
## SKED3

### independent vs. robust dispatch Value of reach-ability

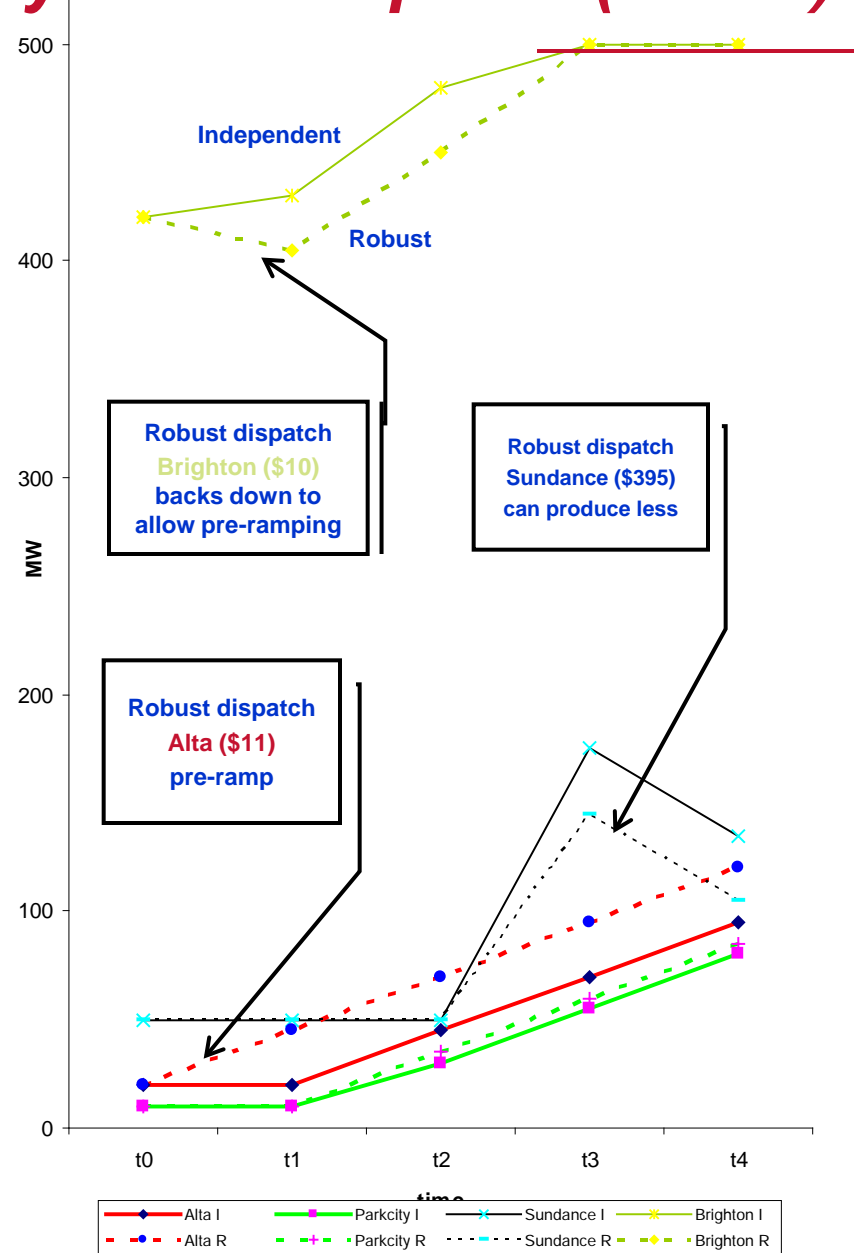
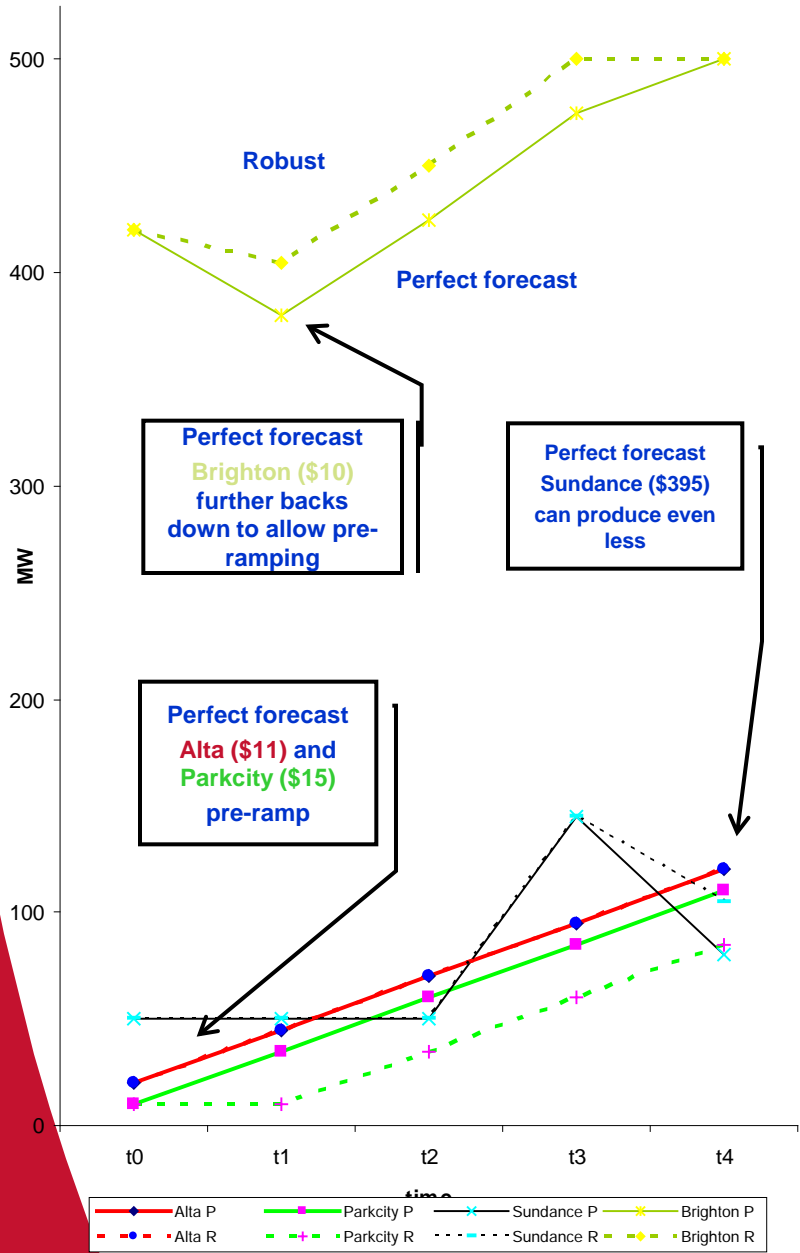
Cost	t1	t2	t3	t4	total
M independent t1 & t2 + H t3 & t4	2035	2125	6310	5048	15517
M robust (M→H) t1 & t2 + H t3 & t4	2037	2129	5352	4089	13607
perfect forecast M t1 & t2 + H t3 & t4	2048	2139	5362	3298	12846

	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

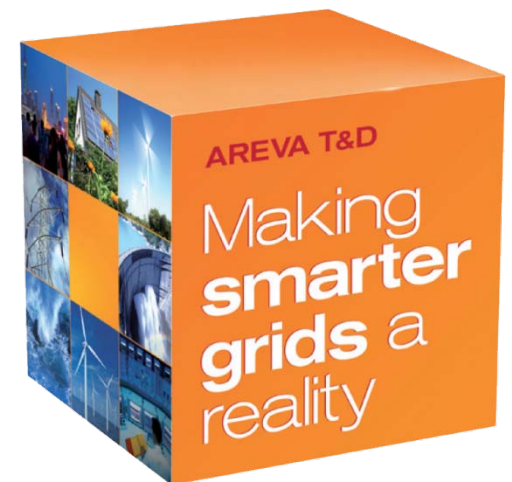
	t0	t1	t2	t3	t4
time	0	5	10	15	20
Pdm	500	510	605	610	620
Pdh	500	510	605	800	810
Pdl	500	505	600	605	615



# GCA - Dynamic Dispatch (DSPD)



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- ▶ 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

