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Generation Dispatch in a Smart Grid Environment

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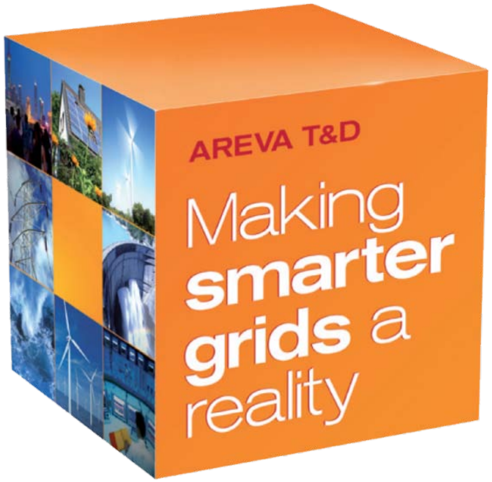
Outline

- Introduction
- Smart Grid Challenges
- Smart Dispatch Framework
- Generation Control Applications (GCA)
- Practical Applications of COP: An example
- Conclusions



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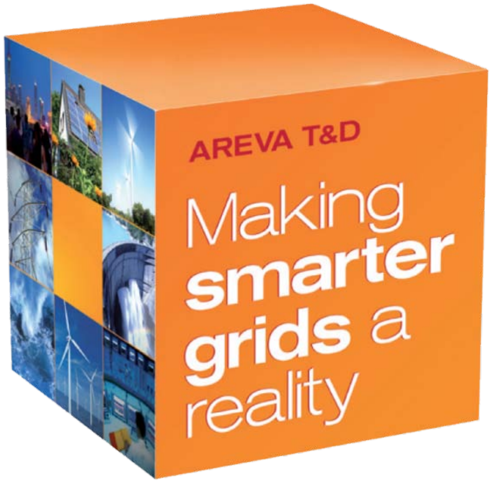
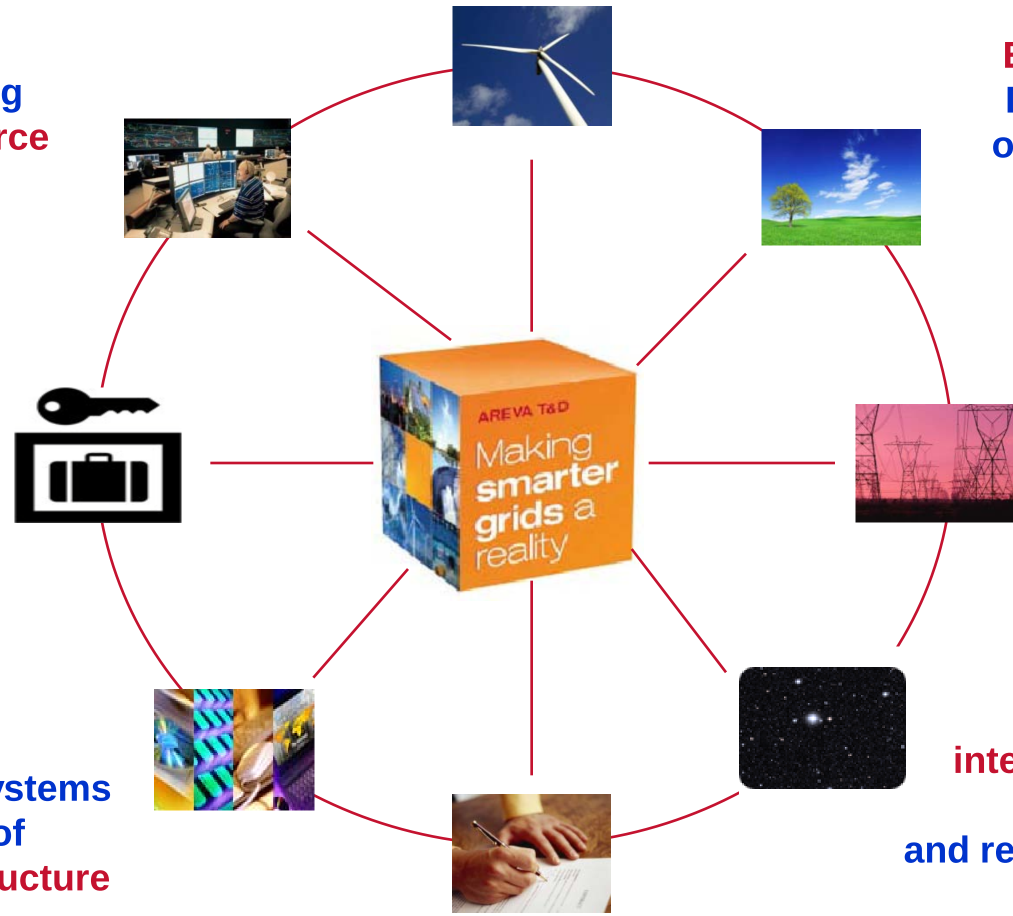


Global Drivers for Smarter Grid

Energy efficiency
under severe Supply Constraints

Retiring
Work force

Environment
Deployment
of Renewable
& CO2 free
energy



Threat of
cyber-security
attacks

New electrical
network
equipment
(PMU, FACTS,
HVDC, …)

Energy Systems
part of
IT infrastructure

Large
interconnected
Grids
and reliability issues

Evolving Regulatory framework
New business model
Less control on power generation

Smart Grid from Vision to Product

Smart Grid

Smart Dispatch

- Generation Portfolio Management including renewable
- Full Integration of pricing and demand/supply principles to manage the grid
- Dynamic balancing with centralized and distributed resource

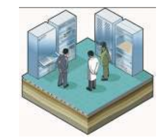
Smart Transmission Grids

- On-Line Stability Analysis & Defense Plans
- On-line Asset Management
- Smart Power Electronic Controls (HVDC, FACTS, SVC…)

Smart Distribution Grids

- Automatic Meter Management System
- Integrated Distributed Management Systems
- Renewable and load management integration

Smart Substation



- Substation Protection & Control Architectures
- Self-adaptive Defense Plans
- Secondary Distribution Smart Grid Box

Visualization, Situation Awareness and Decision Support Tools

System Architecture including Common Information Model

Secure, deterministic and reliable data communication

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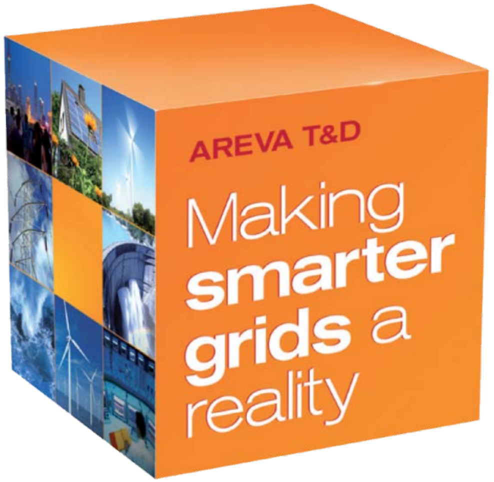


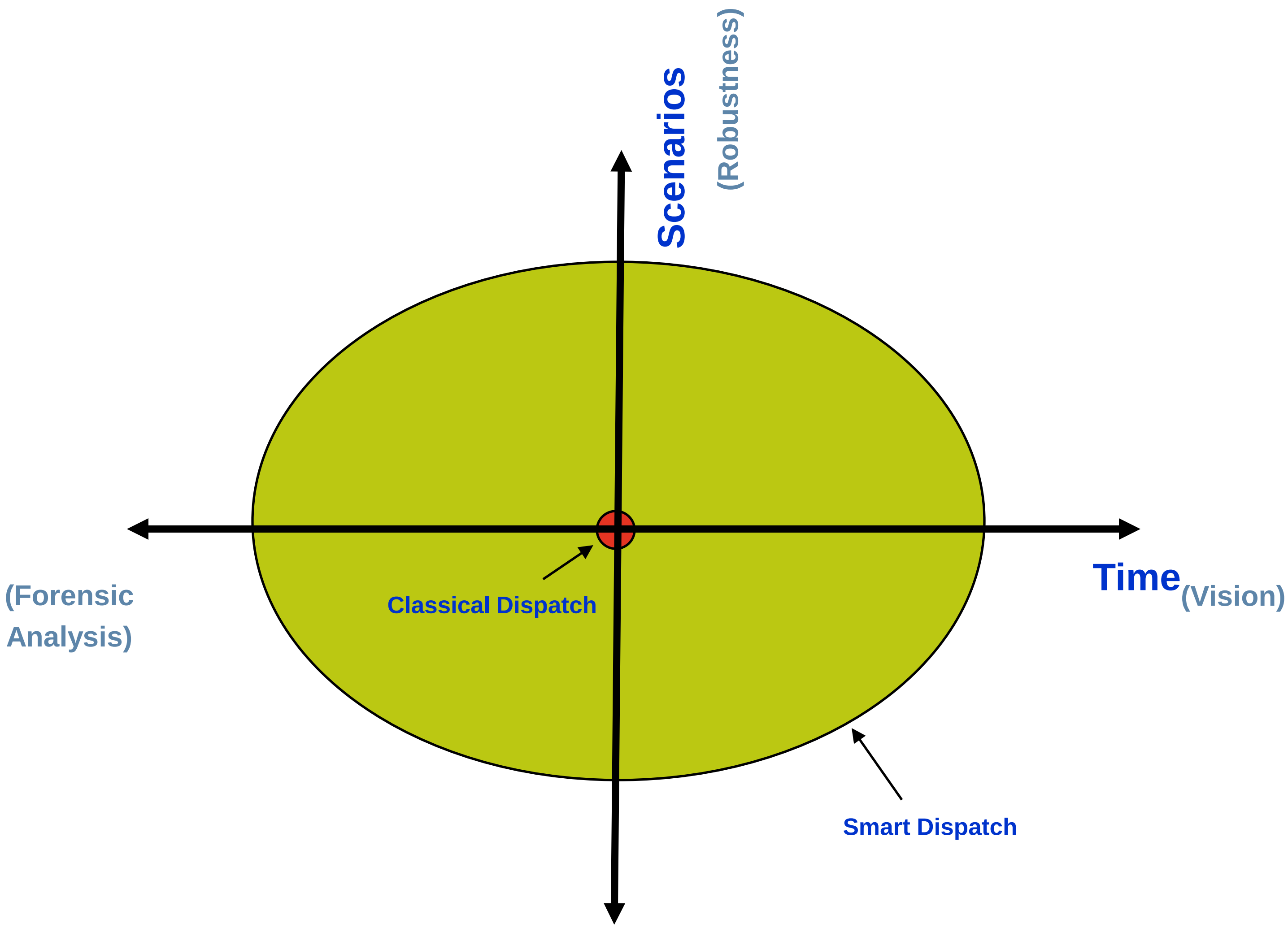
Functional Highlights of Smart Dispatch

- **Classical Dispatch**
  - **Unit Commitment Scheduling, Economic Dispatch, AGC**
  - **Grid security, scheduling, dispatch are Independent tasks**
- **Market-Based Dispatch**
  - **UC/ED with explicit transmission security constraints**
  - **Formal Day-Ahead and Real-time tasks**
  - **Pricing - Dual of the MW signal**
  - **Transparency & consistency**
  - **Large-scale system dispatch**
- **Smart Dispatch**
  - **Dispatch with explicit forward vision**
  - **Dispatch with intelligence (e.g. parameter adaptation)**
  - **Improve system resiliency against uncertainties (e.g. DER, RE, DR)**
  - **Mitigate root-causes for dispatch deficiencies**
  - **Process re-engineering for business/economic analysis**

Smart Grid Challenges

- A lot of emphasis of renewables, distributed energy resources (DER) and demand response (DR).
- From centralized to distributed infrastructure
- Increase amount of uncertainties
  - Generations and Demand Response
  - Demand forecast
  - Transmission constraints
  - Resource characteristics
- Modeling of uncertainties
  - Confidence Interval
  - Scenario-based
  - Monte-Carlo simulation
  - Real-time market: Delta MW
- Smart Dispatch
  - Forward-looking view of system condition
  - More robust solution

Expanded Dimensions in Smart Dispatch



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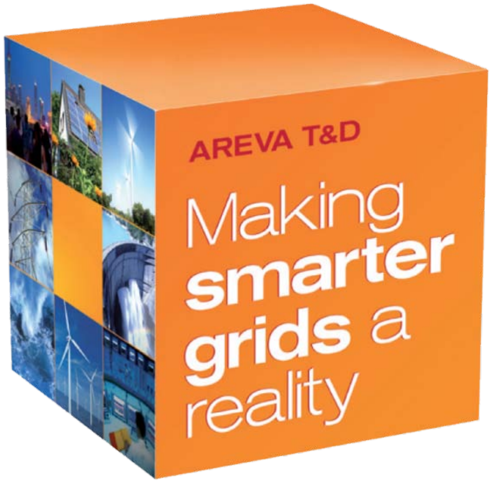
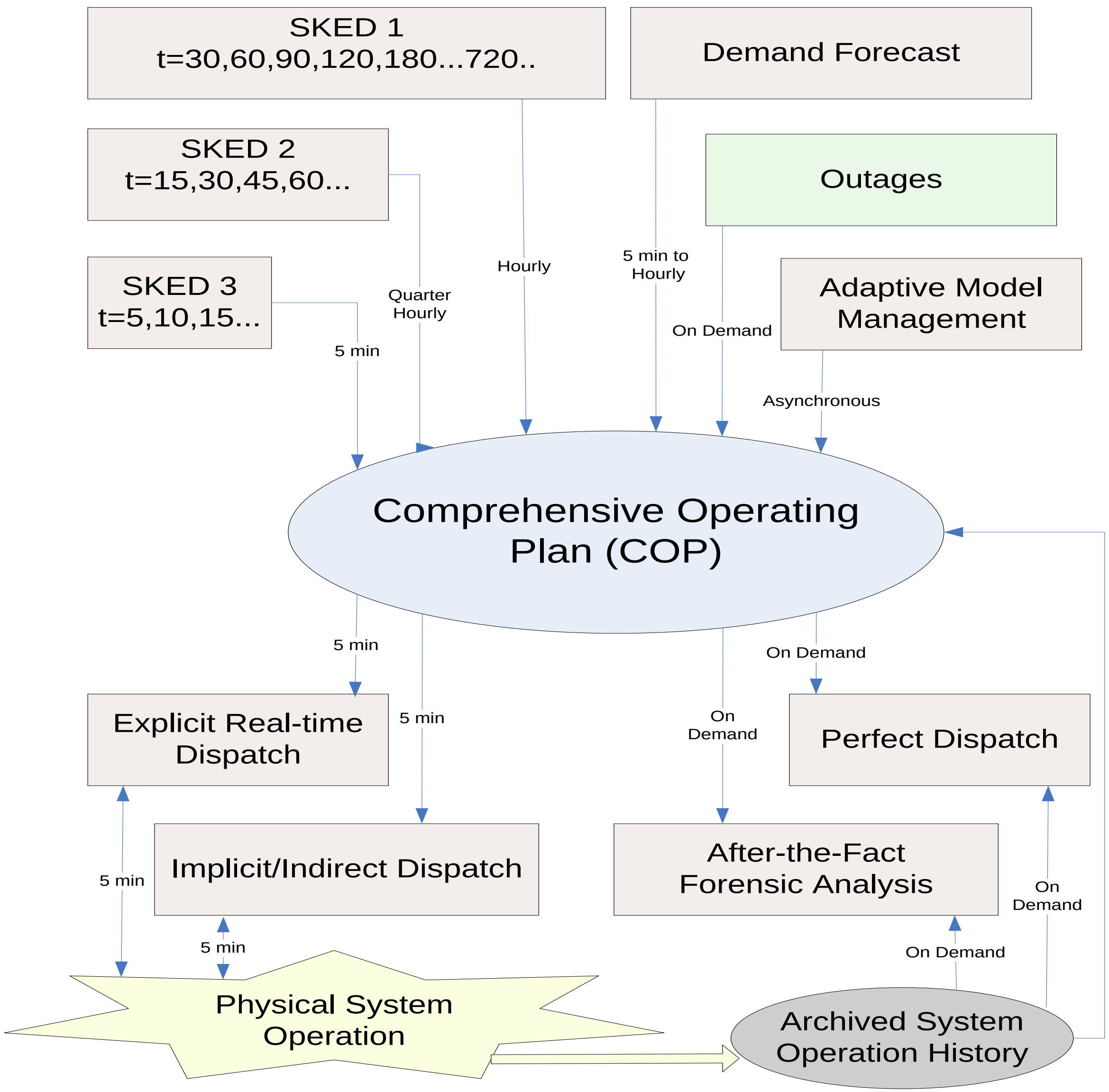
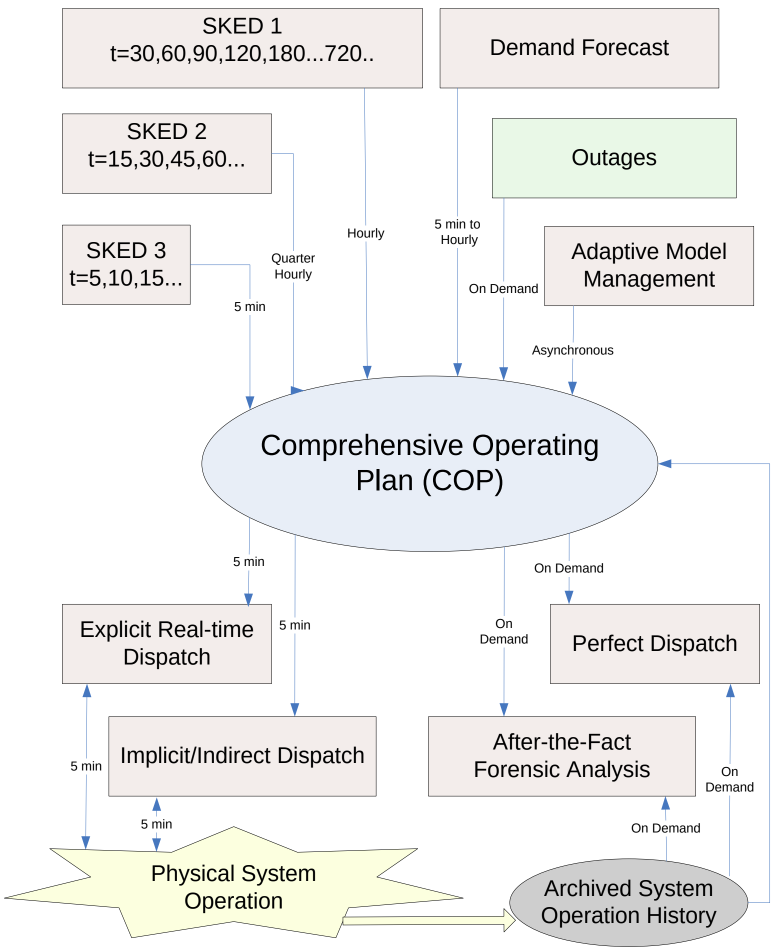


Vision of a Smart Dispatch System



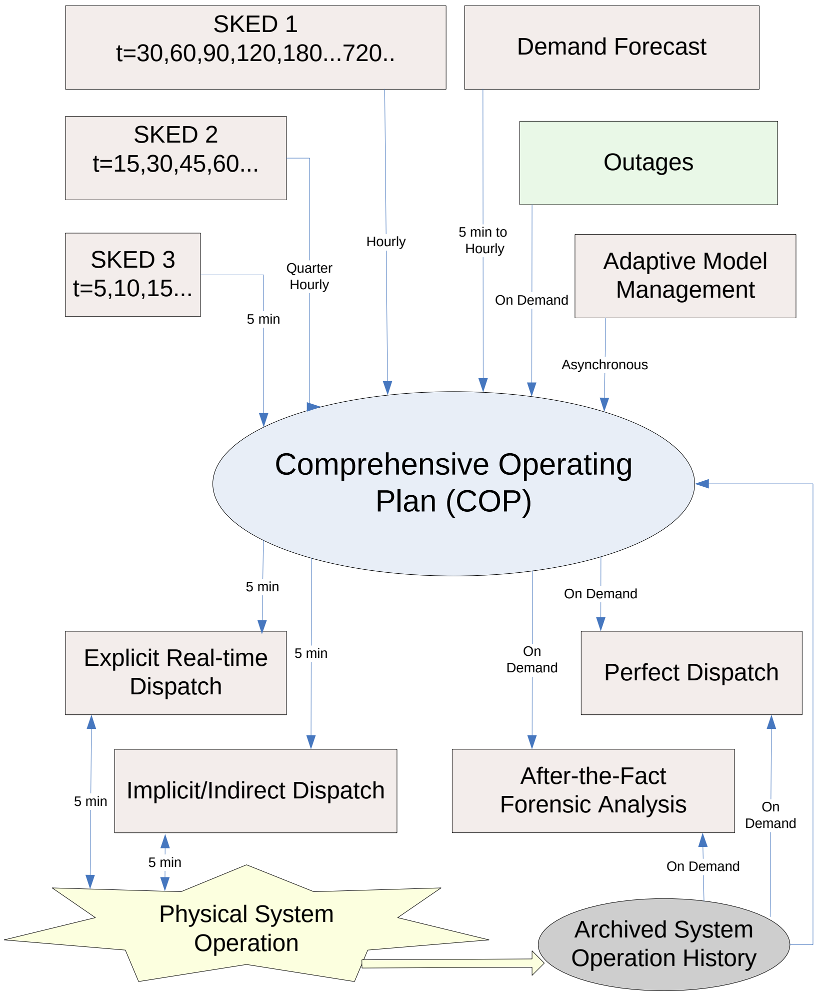
 Kwok Cheung

- Multi-stage resource 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)
- The results of each stage form progressively refined regions that guide the dispatching decision space of the subsequent stages.
- Various SKED cycles are coordinated through the Comprehensive Operating Plan (COP).



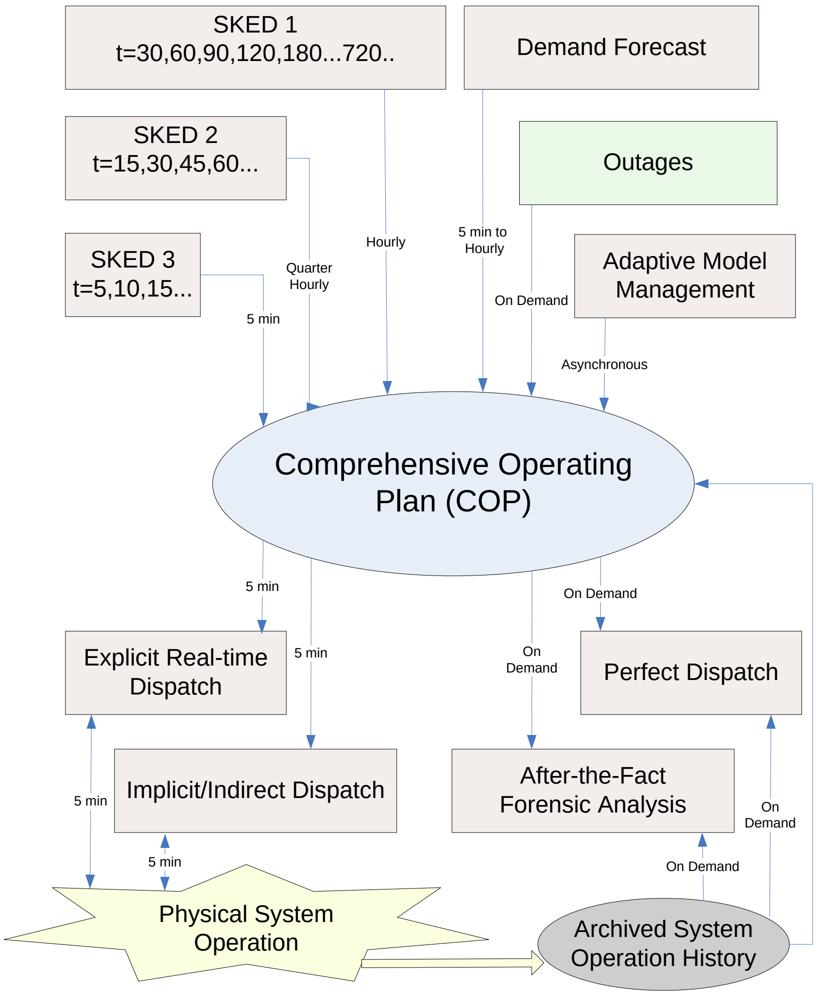
After-the-Fact Analysis

- **After-the-Fact Analysis (AFA)**
  - Systematic analysis of past events and practices
  - Quantitative assessments of how do specific events and practices affect system performance
  - Use-case comparative approach
- **Perfect Dispatch**
  - A class of use cases of AFA that focus on "Day-After" analysis of the performance of actual system dispatch results, including the impacts of specific events.



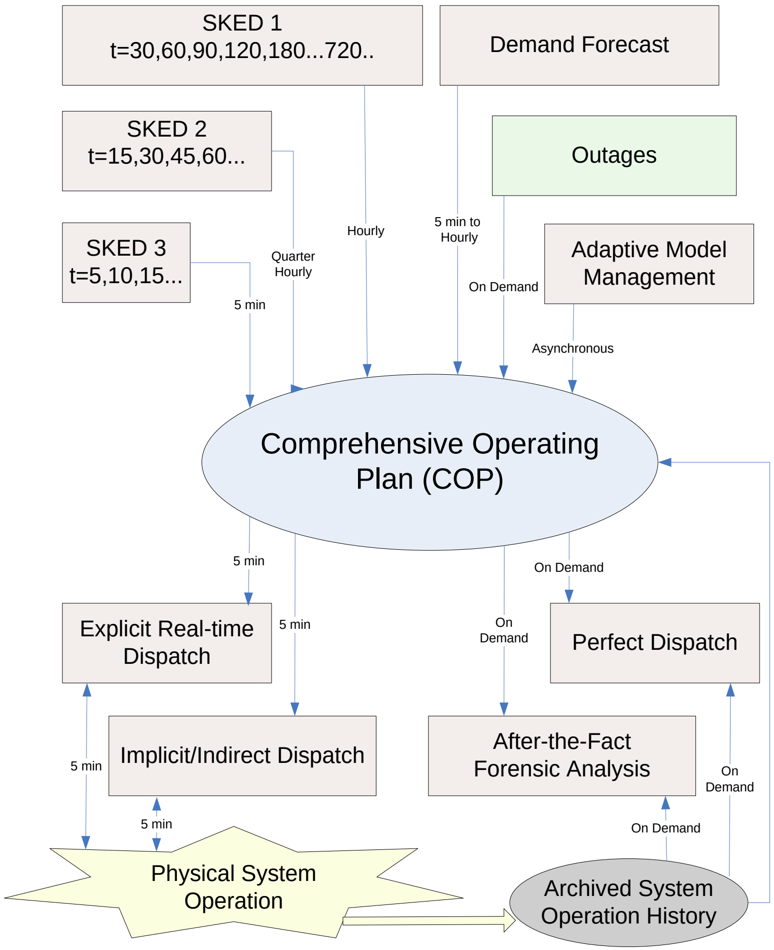
Demand Forecast

- Demand forecast takes DR, DER, and Wind generation into account.
- Need to integrate various forecast engines to achieve performance.
- Easy manipulation of forecast profile (similar day, transformation etc.)



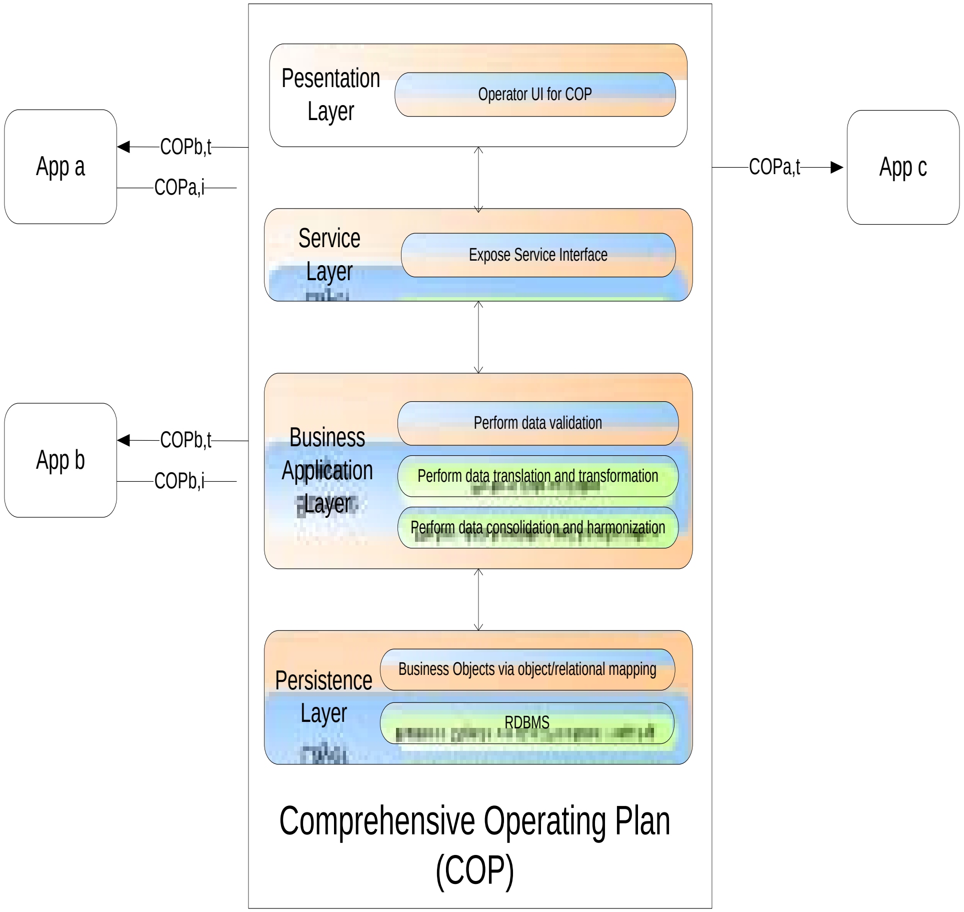
Adaptive Model Management

- **Adaptive Constraint Modeling (ACM)**
  - **ACM uses intelligent methods to preprocess transmission constraints based on historical and current network conditions, load forecasts, and other key parameters. It shall have ability to achieve smoother transmission constraint binding.**
- **Adaptive Generator Modeling (AGM)**
  - **AGM will provide other GCA components information related to specific generator operational characteristics and performances. The resource "profiles" may contain parameters such as ramp rate, operating bands, predicted response per MW of requested change, Max & Min limits, etc.**



Comprehensive Operating Plan (COP)

- COP has a presentation layer or a set of Operator UI of its own to support system operator decision making. However, it does not intend to replace but supplement UIs of individual scheduling applications.
- COP has a service layer to provide a set of APIs to interact with external power system applications or data sources.
- COP has a business application layer that performs validation, translation, transformation, consolidation and harmonization of various asynchronized scheduling data.
- COP has a persistence data layer (most likely relational) for some key scheduling data.



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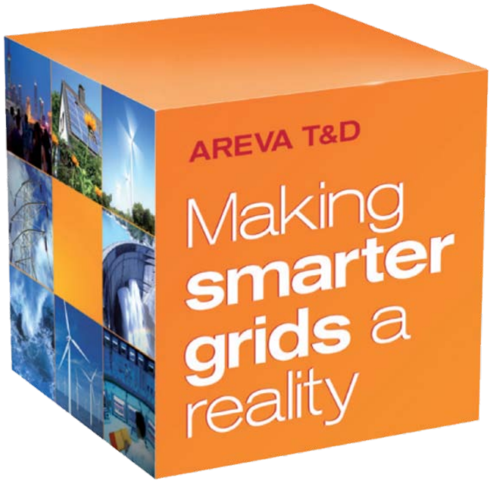


Generation Control Applications (GCA)

- Optimization engine for security-constrained multi-period, time coupled commitment and dispatch.
  - Mixed Integer Programming (MIP) / Linear Programming (LP) based
- Support both price- and cost-based modeling and analysis, for energy, ancillary services, demand response, energy conservation, and emission reduction.
- Coordinate multiple scheduling time horizons (Intra-day, near real-time, real-time) with Comprehensive Operating Plan (COP).
- COP-based adaptive scheduling and dispatch
- Typical Configuration:
  - SKED-DA: day-ahead resource commitment (hourly interval for a look-ahead window of a day or two)
  - SKED 1: intra-day incremental resource commitment (15 min to hourly intervals for a look-ahead window of 6-8 hours)
  - SKED 2: Fast-start resource commitment (15 min intervals for a look-ahead of 2-4 hours)
  - SKED 3: Real-time dispatch of generating resources every 5 min

GCA - Dynamic Dispatch

SKED3

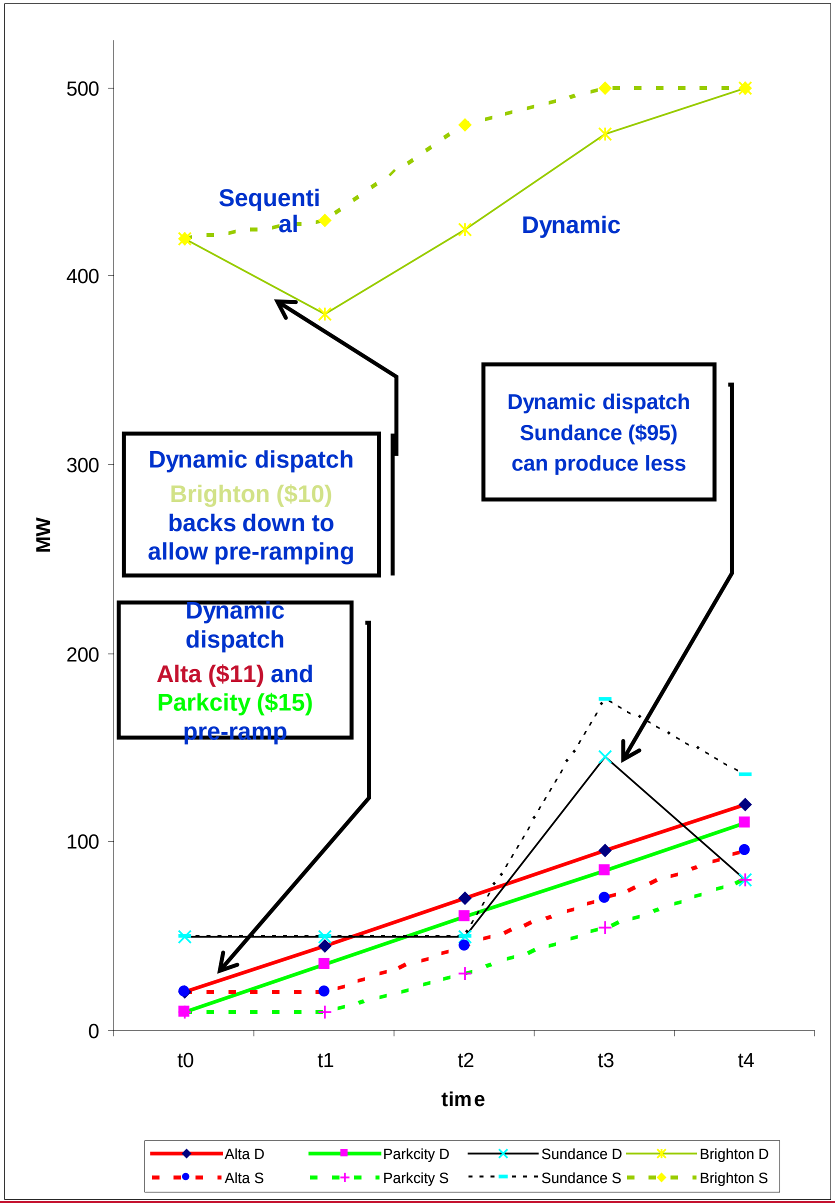
sequential vs. dynamic dispatch
Value of pre-ramping

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

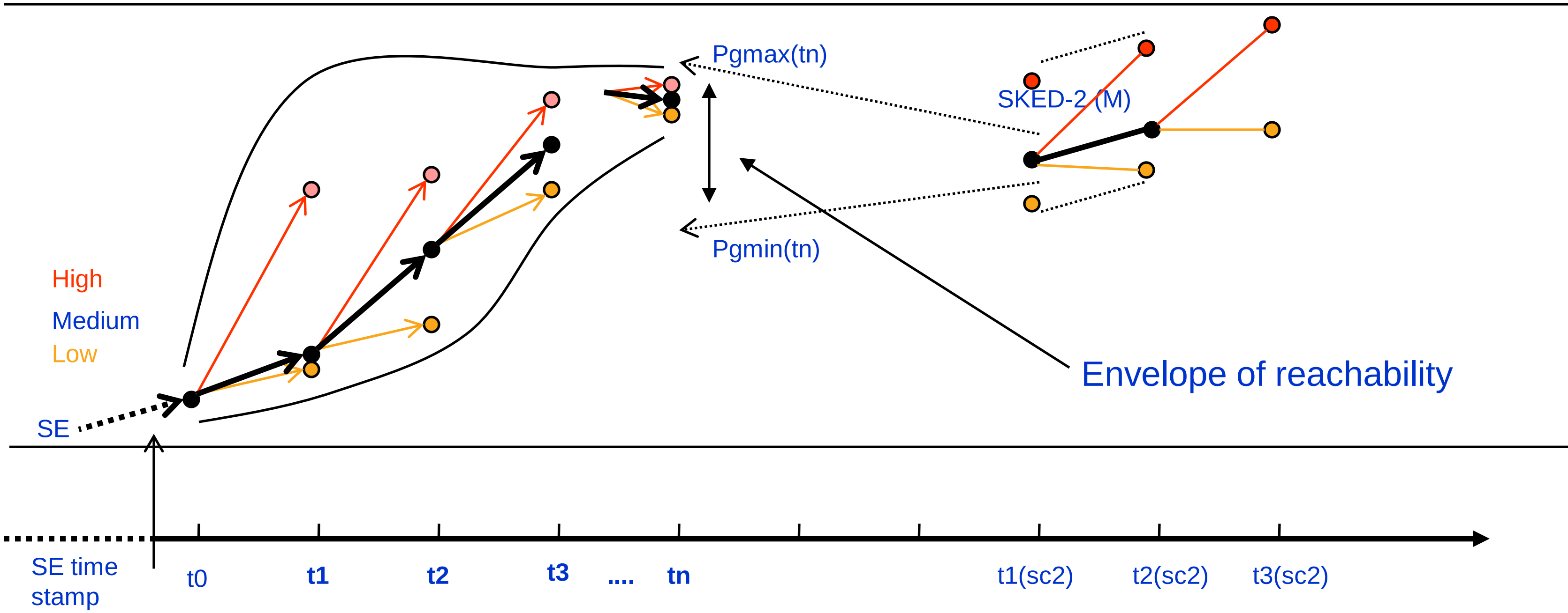
	PriceE	MaxRampUp	MaxRampDn	PgSE
Alta	11	5	100	20
Parkcity	15	5	100	10
Solitude	30	10	100	0
Sundance	95	100	100	50
Brighton	10	10	100	420

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



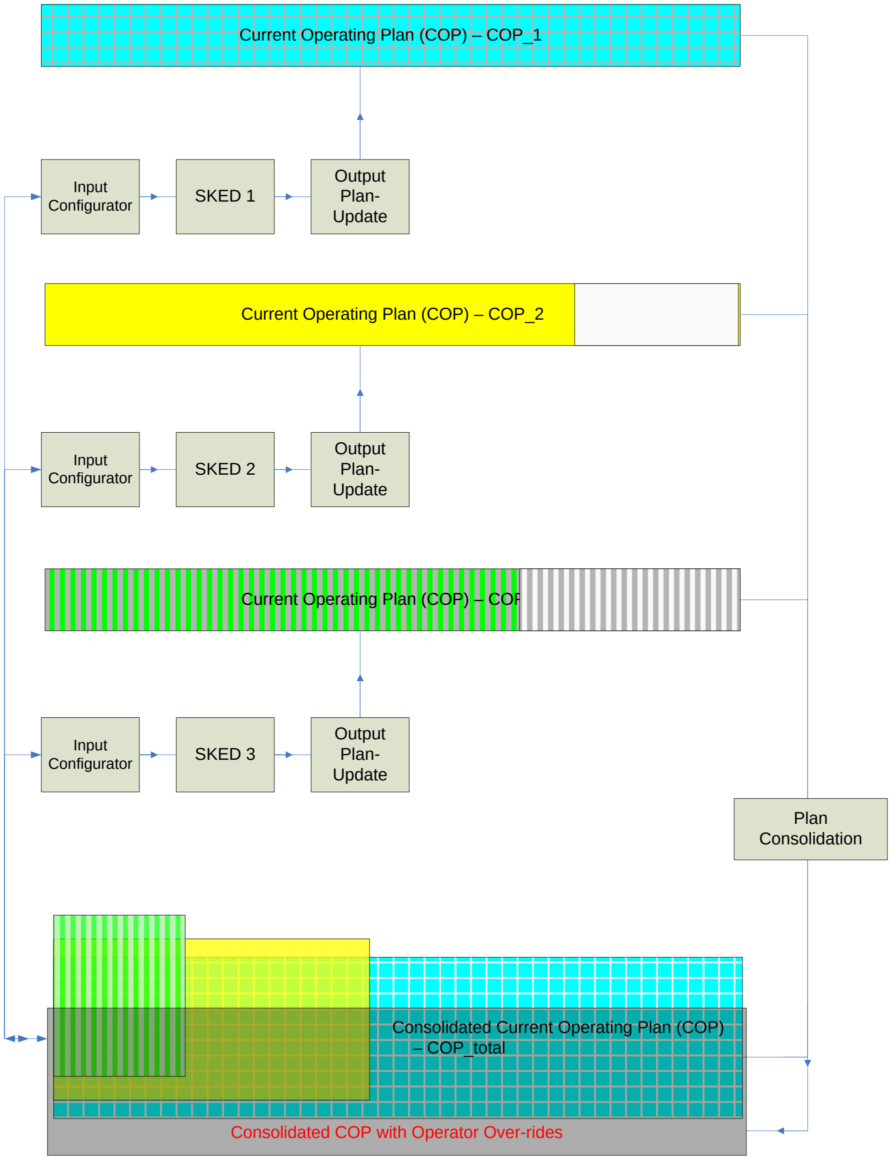
COP Coordination - Reachability



- **Coupling between SKED2 and SKED3 to ensure that SKED3 solution gets into the envelope of SKED2.**

COP Design Principles

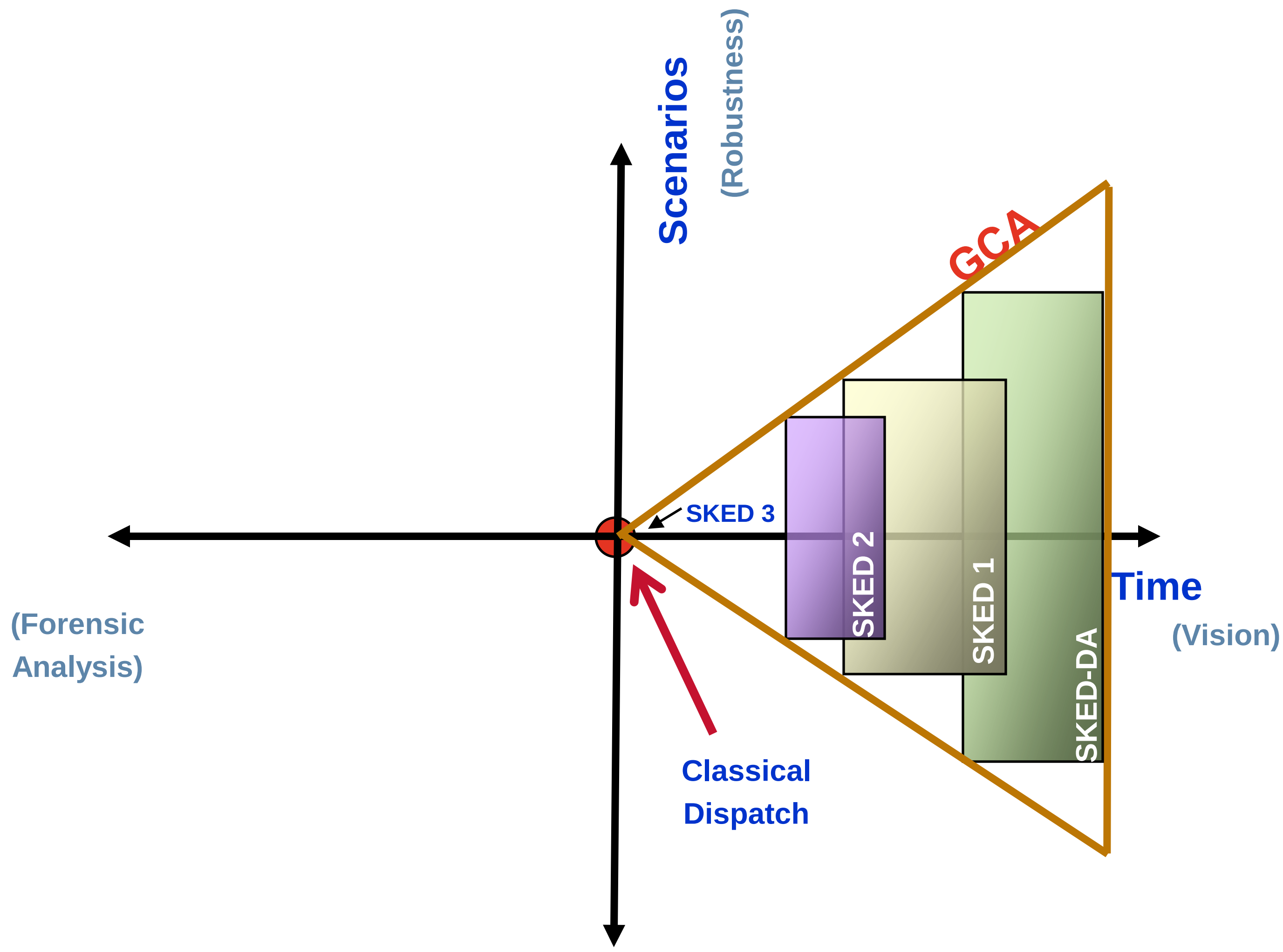
- COP has the repository of all operating plans in a multi-stage decision process.
- Each stage in the decision process generates a set of schedules that are reflected in its corresponding COP (COPi)
- The aggregated results from the multi-stage decision process are captured in the total COP (COPt), which is the merged outcome of the individual COPi's.
- A COP contains quantities (e.g. MW generation level) being scheduled over different Operating Intervals.
- Operator interaction is typically with COPt



Benefits of COP

- **Holistic forward-looking view of operating plan**
- **Modular SKED**
  - **Multiple SKEDi's are coordinated using subordinate COPi's which are synchronized into the overall COPt.**
  - **This removes the need for individual SKED applications to communicate with each other directly.**
- **Flexible design with high availability:**
  - **SKED's may be added, removed and/or modified with minimal impact on the other SKEDs and COPs.**
  - **Ensures high availability for the mission critical real-time GCA SKED functions. Failure of any one or more SKED components will cause smooth degradation of, instead of abrupt service interruptions to, real-time dispatch instructions.**
  - **Intrinsic flexibility enables low-risk, cost-effective business process evolution.**

Dimension Coverage in Smart Dispatch/GCA Applications



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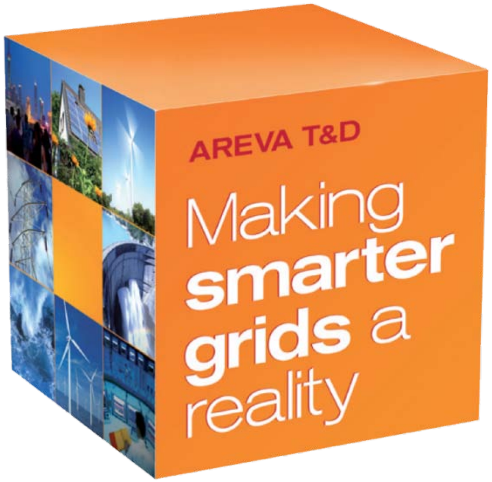
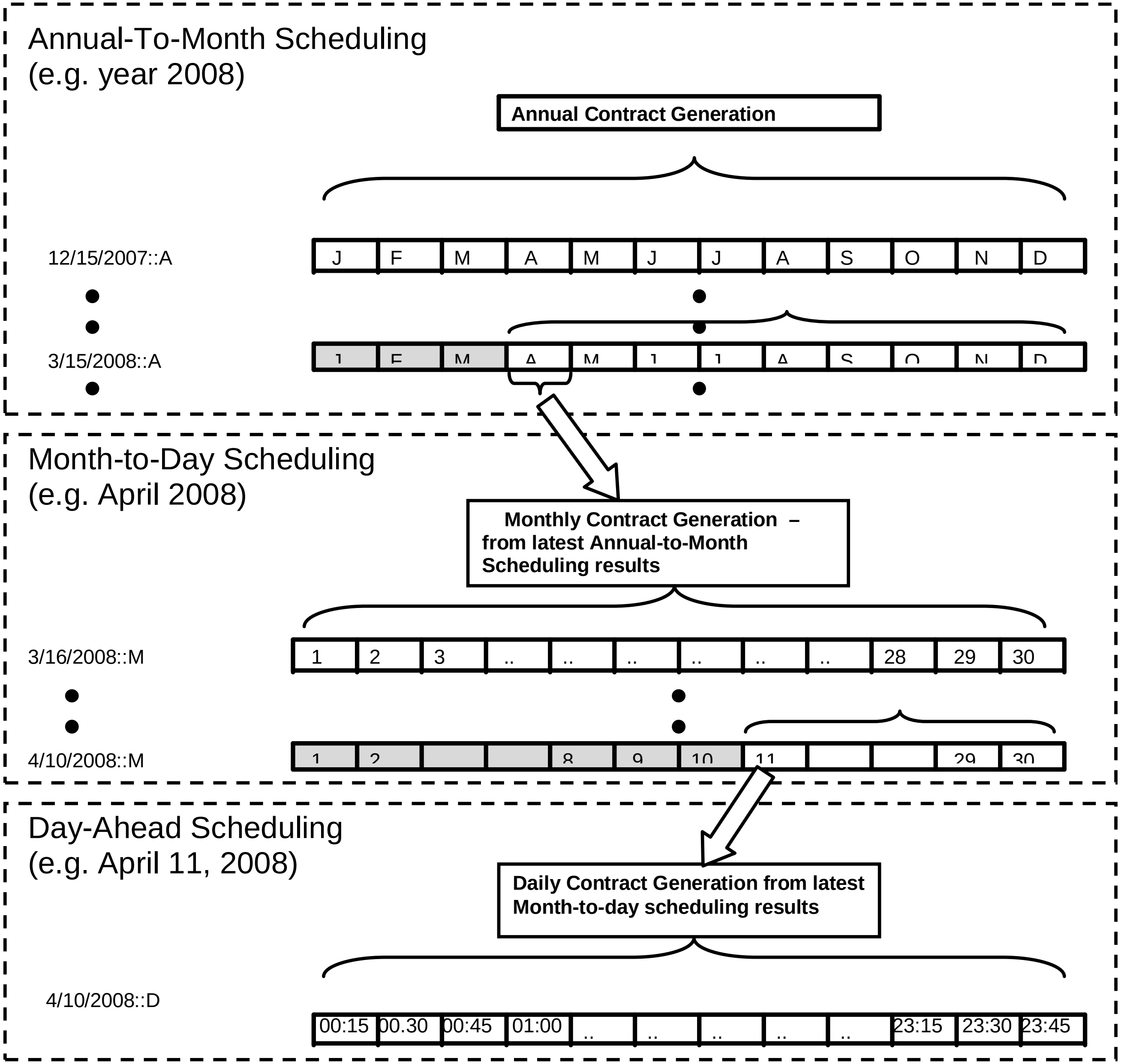


Practical Applications of COP: An Example

- NCG (North China Grid) applies the concept of COP to build a unified scheduling framework.
- Scheduling processes range from annual planning to real-time dispatch.
- NCG generation scheduling processes:
  - Rolling forward scheduling monthly contract generation based on annual contracts.
  - Rolling forward scheduling daily contract generation based on monthly contracts.
  - Day-ahead quarter-hourly generation schedule
  - Rolling forward intra-day GCA SKEDs.
- COP streamlines the business processes.

North China Grid Generation Scheduling Coordination



Conclusions

- Discussed the vision and the challenges of Smart Dispatch in the context of control center's operations for the evolving smart grid environment.
- Presented the framework of Smart Dispatch
- Proposed a new dispatch system (GCA)
  - Cope with the increasing amount of uncertainties
  - Provide a better holistic and forward-looking view of system conditions and generation patterns and help system operators to make better decisions.
- An example to apply COP is given.
- GCA is deemed critical for the success of efficient power system operations in the near future.

Thank you!