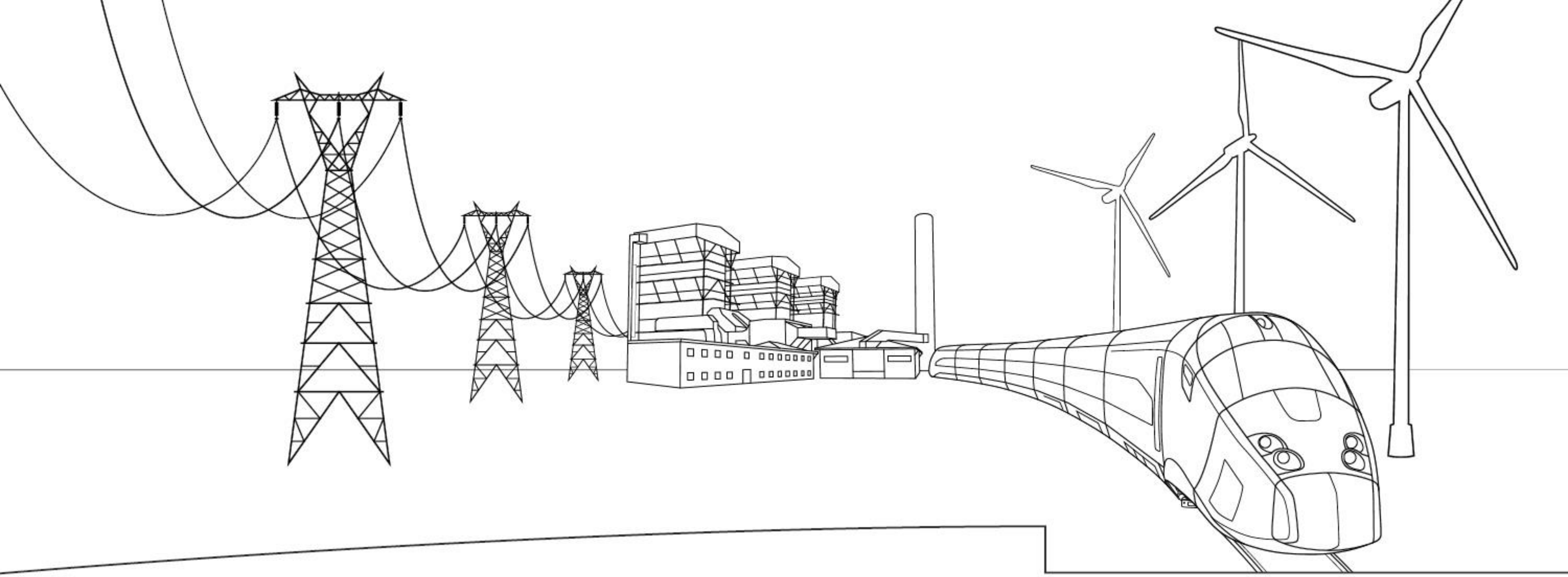

Online Dynamic Assessment of Transmission Ratings for Transmission Constraint Management in Power System and Market Operations

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Shaping the future

CIGRE GOTF Symposium: October 11-13, 2015

Outline

- Introduction
- Transmission Constraint Management in Smart Dispatch
- Dynamic Line Ratings (DLR)
- Adaptive Transmission Rating (ATR)
- Combining DLR and ATR
- Conclusions

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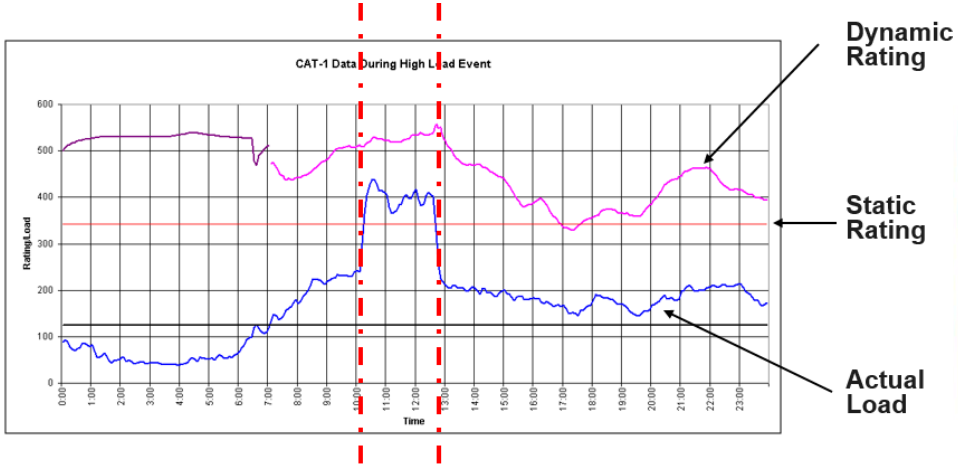
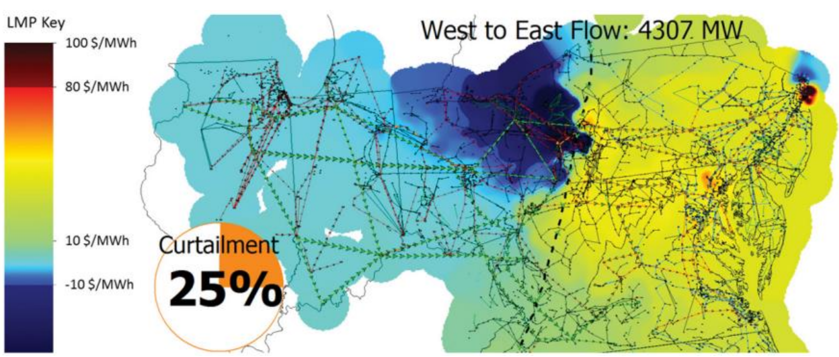
Introduction

- Regional transmission organizations are heavily reliant on *security constrained* unit commitment (SCUC) and economic dispatch (SCED) to optimally dispatch their energy resources.
- Transmission of electric power has traditionally been limited by conductor thermal capacity defined in terms of a *static line rating* which is based upon “near” worst-case weather and pre-load conditions.
- More accurate assessment of transmission flow limits will
  - impact the efficiency of system and market operations.
  - help to integrate clean energy into the power grid.





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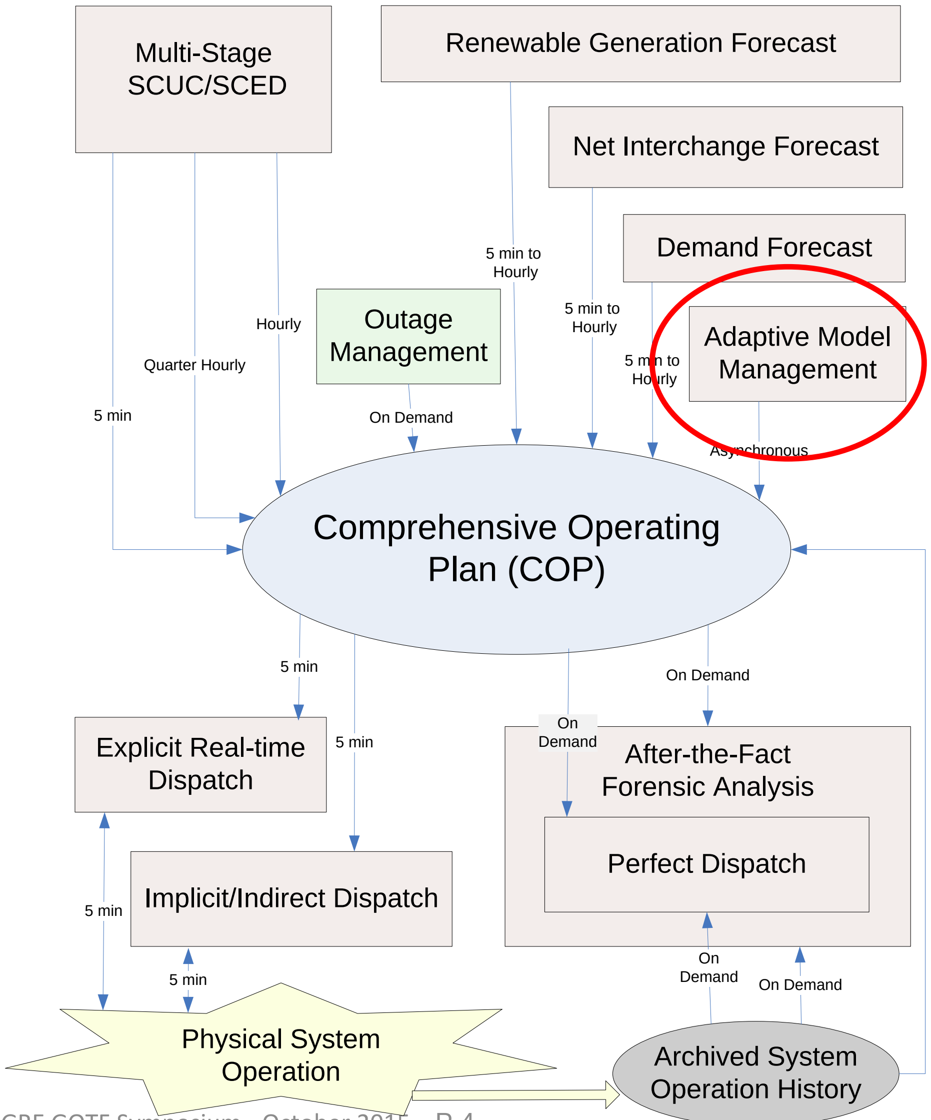
Alstom's Smart Dispatch Solution Overview



- Multi-stage SCUC/SCED
- Outage management
- After-the-fact forensic analysis (perfect dispatch)
- Renewable generation forecasting
- Net interchange forecasting
- Demand forecasting
- Adaptive Model Management
  - Adaptive generator modeling
  - **Adaptive constraint modeling**

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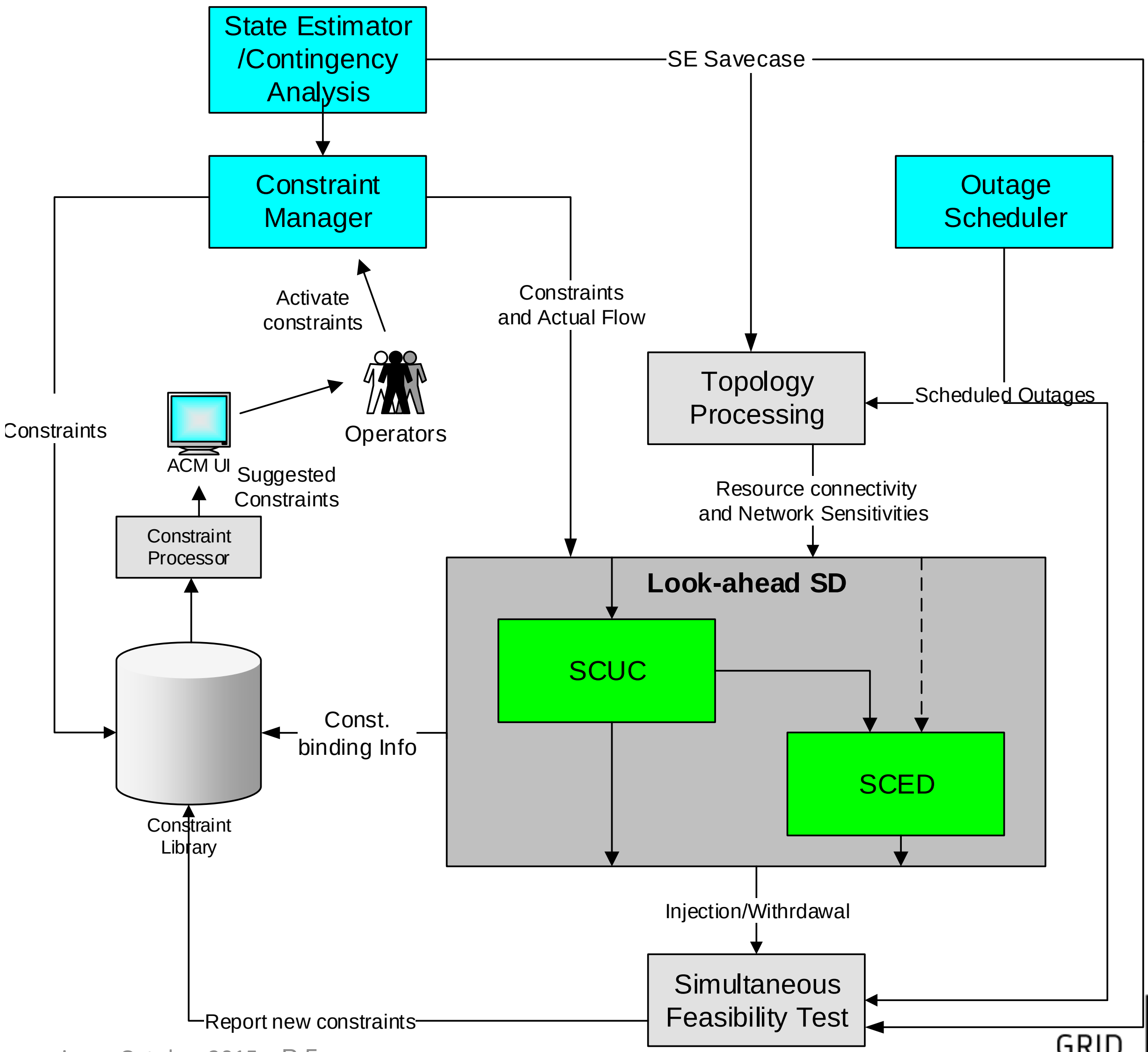
Transmission Constraint Management



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Transmission Constraint Model

- Grid base-case and contingency transmission constraints are modeled in the following form in SCUC/SCED:

$$\sum_i a_{l,i}(P_i - D_i - d_i \times FD) \le L_l^{\max}$$

where

P_i : decision variables for generation dispatch at bus *i*;

D_i : decision variables for load dispatch at bus *i*;

FD : fixed demand;

d_i : the load distribution factor for fixed demand;

$a_{l,i}$: the sensitivity of constraint *l* with respect to bus *i;*

$L_l^{\max}$: the grid security limit for constraint *l.*

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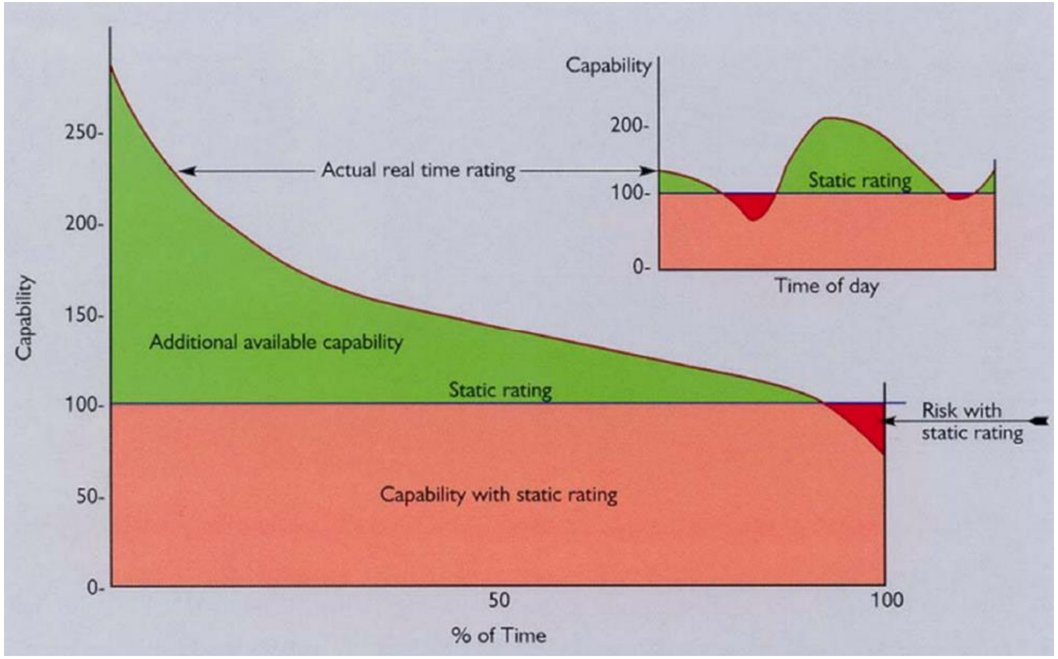
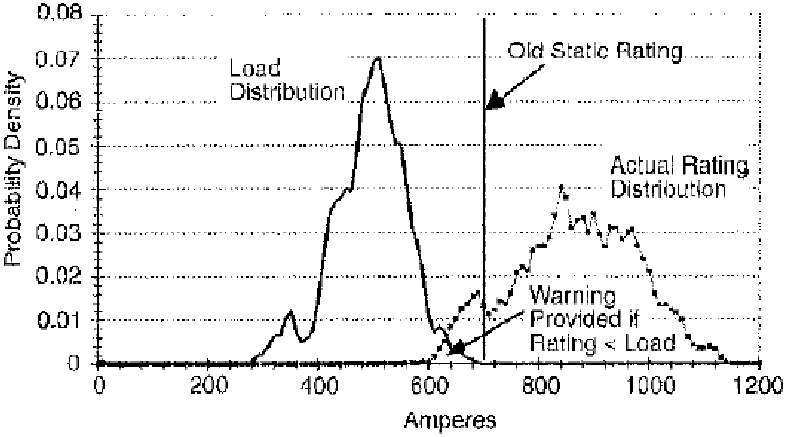
Dynamic Line Ratings

- DLR enables significant amount of additional transmission capacity (Ampacity)
- DLR eliminates the risk in static rating



CAT-1 Transmission line monitoring system. The Valley Group. Available at http://www.nexans.be/eservice/Belgiumen/ fileLibrary/Download_540145282/US/files/valley%20group_CAT-1.pdf



Dynamic thermal ratings realize circuit load limits
Douglass, D.A. ; Lawry, D.C. ; Edris, A.-A. ; Bascom, E.C.
Computer Applications in Power, IEEE
Volume: 13 , Issue: 1

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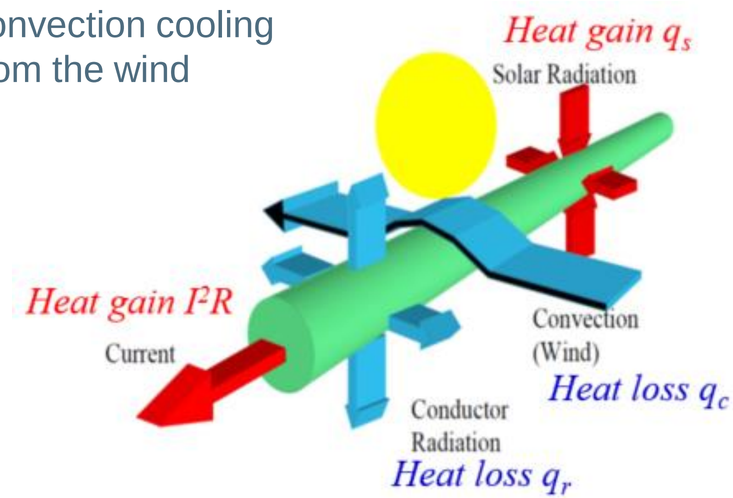
Calculation of Line Capacity

- Steady-state Heat-balance Equation:

$$I^2R(T_C)+q_s=q_r(T_C,T_A)+q_c(T_C,T_A,V_s,V_D),$$

joule heat from the current — radiation from the sun — radiation from the conductor — convection cooling from the wind



where

T_C : line conductor temperature;

T_A: ambient temperature;

V_S: wind speed;

V_D: wind direction.

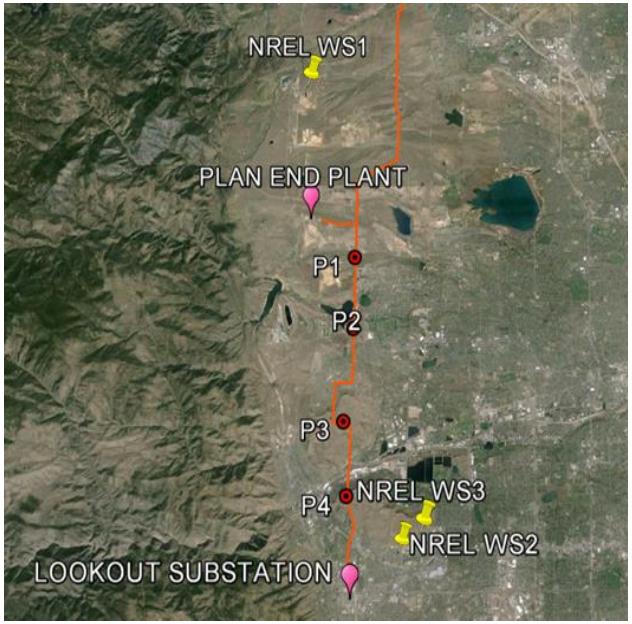
- Maximum Permissible Current:

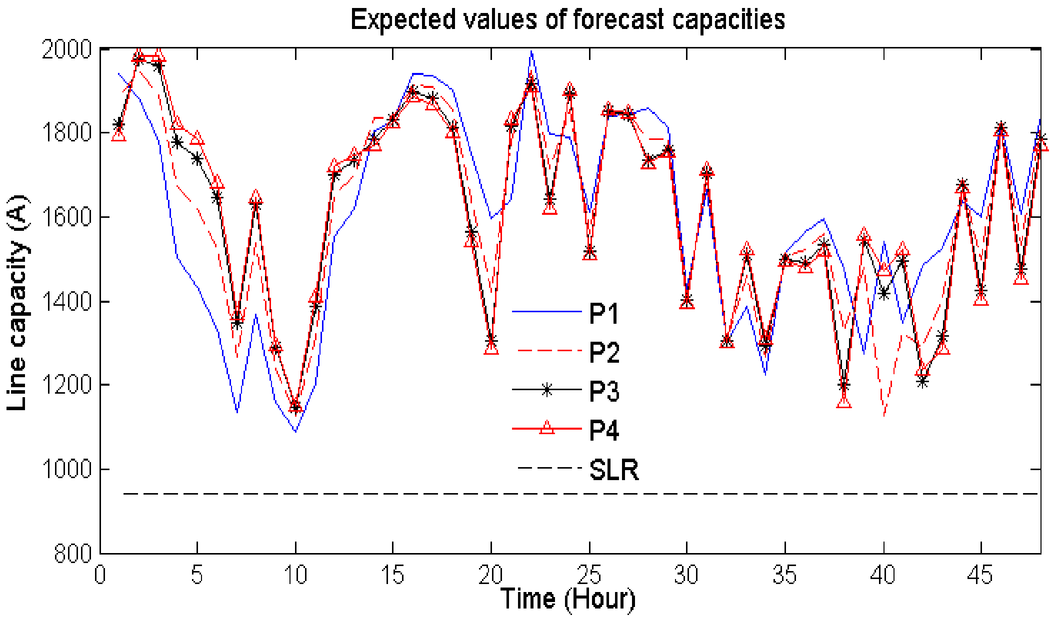
Max. operating temperature

$$I_{\max}=\sqrt{\frac{q_r(T_C^{\max},T_A)+q_c(T_C^{\max},T_A,V_s,V_D)-q_s}{R(T_C^{\max})}}$$

DLR Calculation Example

- A 230 kV transmission line between Lookout substation and Plan End power plant in Colorado is adopted for the case study.
- Four spans (P1, P2, P3 and P4) are selected. Among them, P1, P2 and P4 are in a North-South line direction while P3 is in West-East direction.





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Adaptive Transmission Ratings

- Post-contingency thermal transmission constraints are based on transient Emergency Ratings of lines and transformers:

Post contingency flow ≤ Emergency Rate

- Emergency Rate is typically a static parameter and equals to Long-Term Emergency (LTE, 4 hours) or Short-Term Emergency (STE, 15 min) rate
- $STE \geq LTE$ → Which rate $Rate(time)$ to use?
- Adaptive Transmission Rate (ATR) concept intends to adaptively select Emergency ratings by accounting for the post-contingency dispatch and pre-contingency conductor loading

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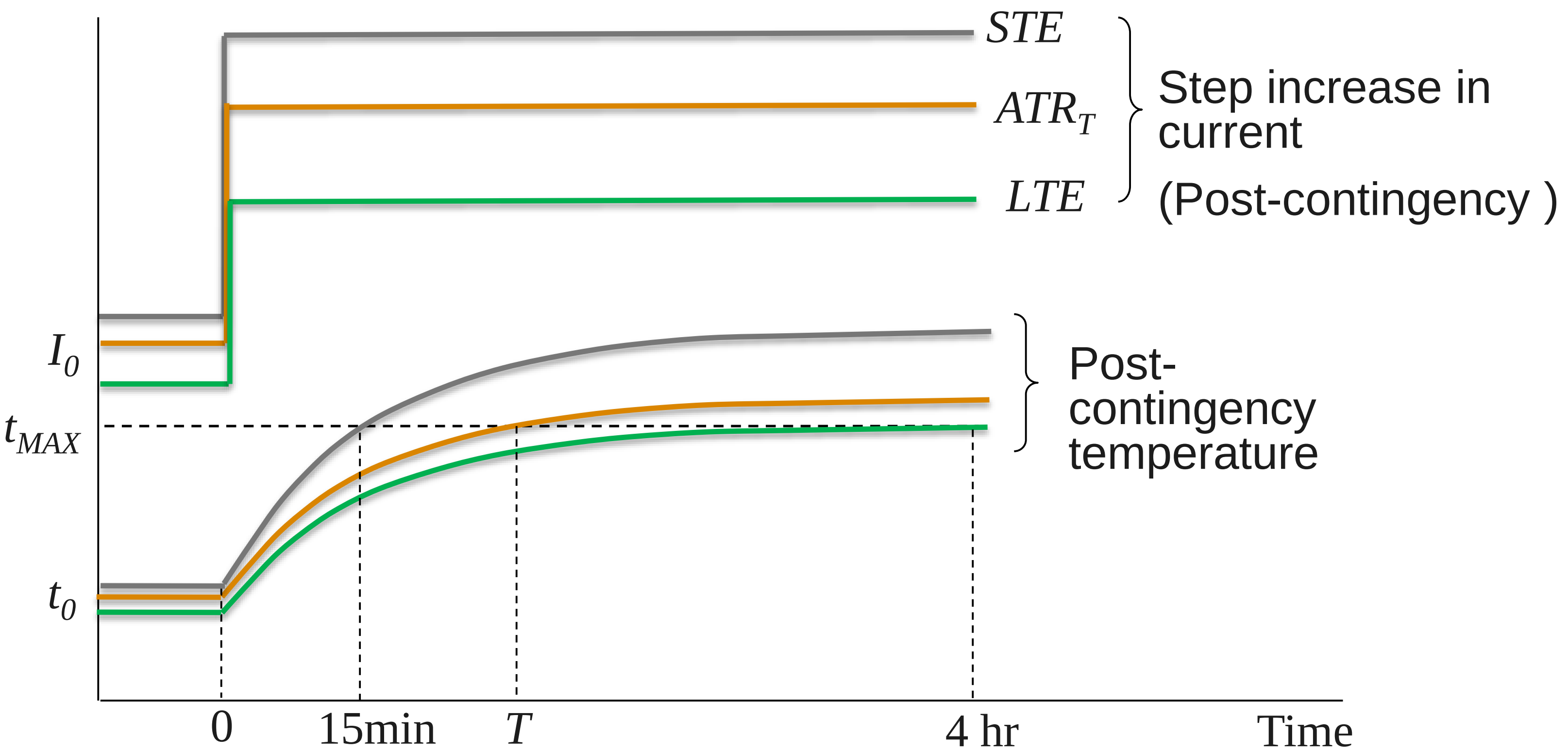
Definition of Emergency Transient Rate

IEEE 738-1993 standard: “The transient thermal rating is that final current that yields the maximum allowable conductor temperature (t_{MAX}) in a specified time (T) after a step change in electrical current from some initial current (I_0).”



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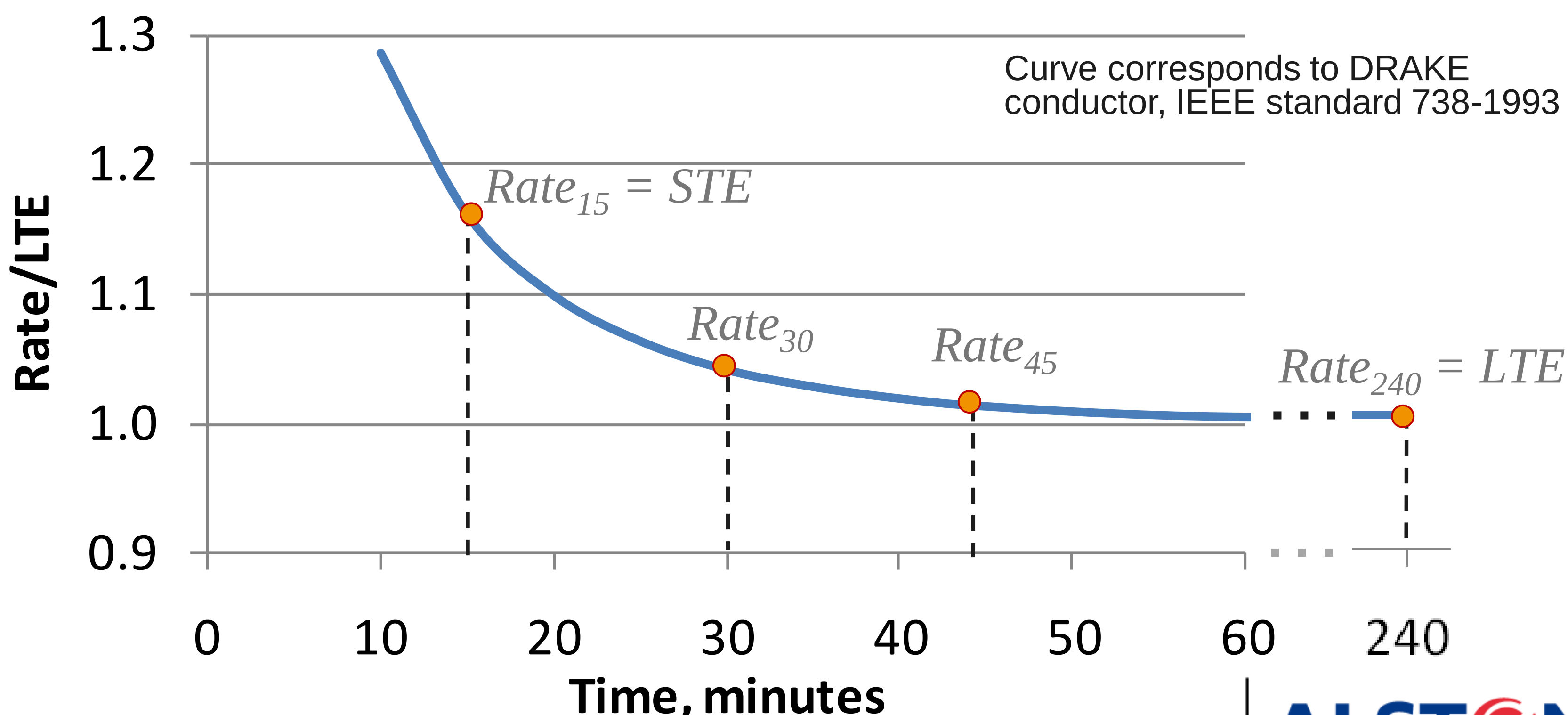
Rate(time) Characteristic

- *Rate(time)* is a physical characteristic and can be developed for each line by using the same methods as for calculation of *STE* and *LTE*
- Any point on a curve can be used as an Emergency rate



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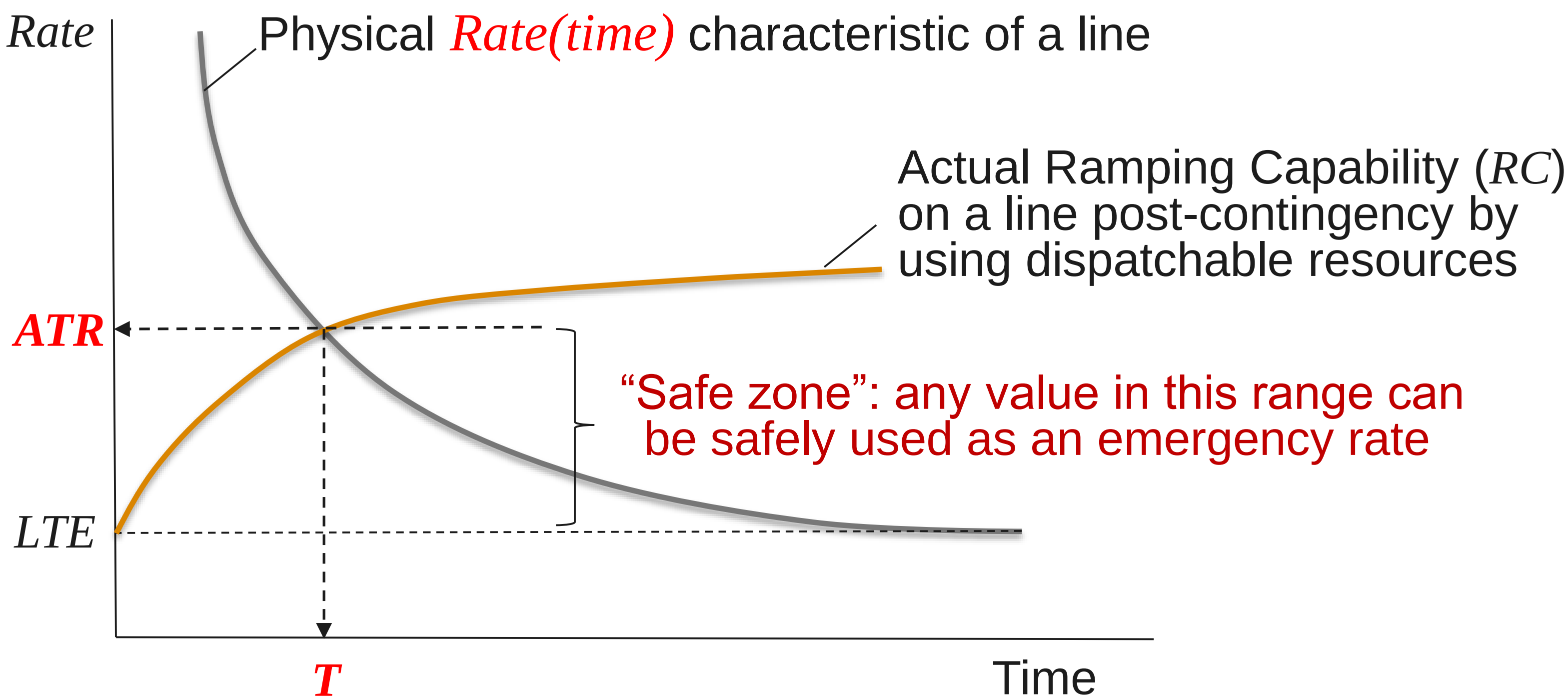
Solution of ATR

- *ATR* is obtained as the solution of the following equation

$$Rate(time) = LTE + RC(time)$$



- Conservative reduction of *ATR* range: $LTE \leq ATR \leq STE$

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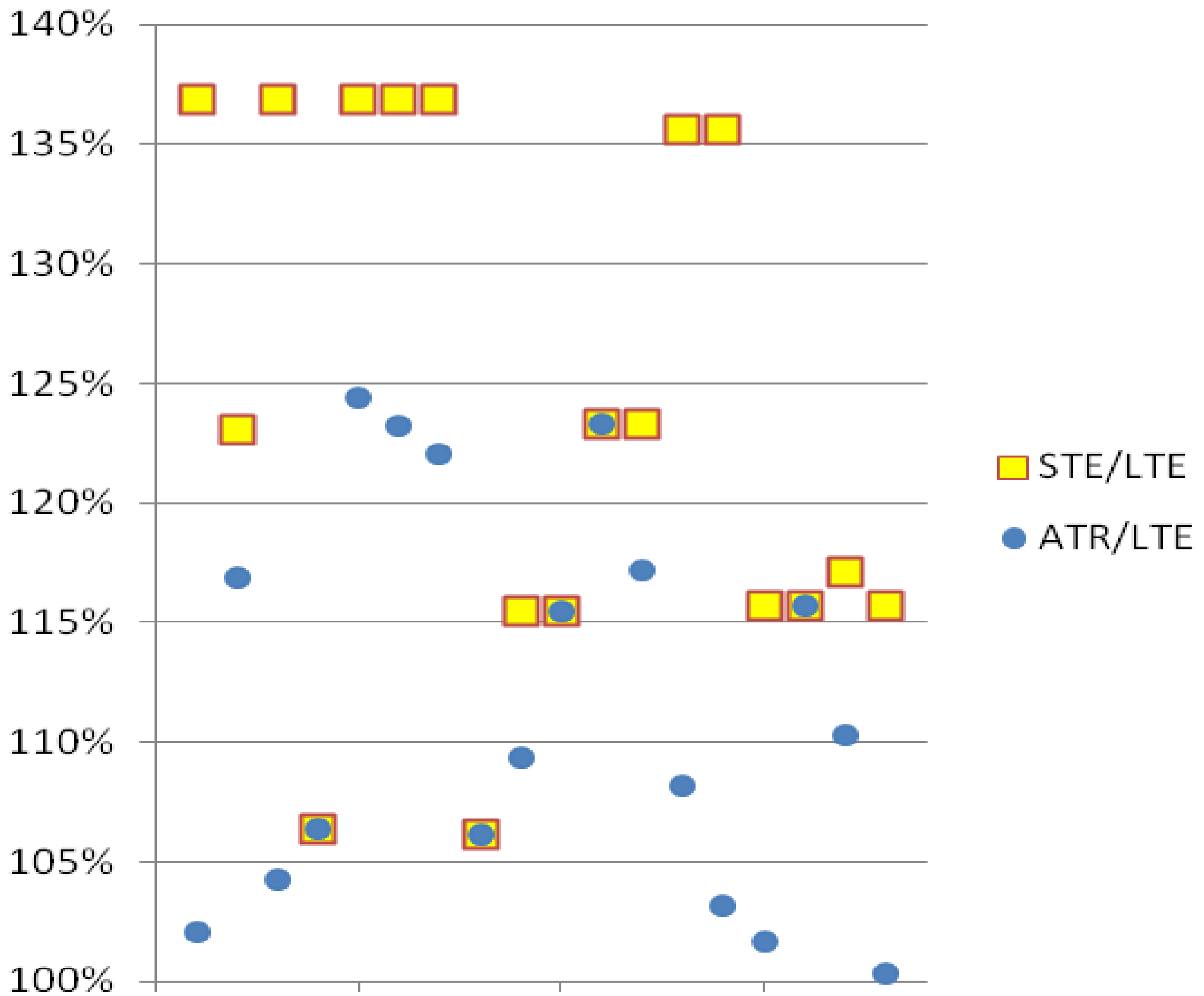
ATR Values for Real-Time binding constraints



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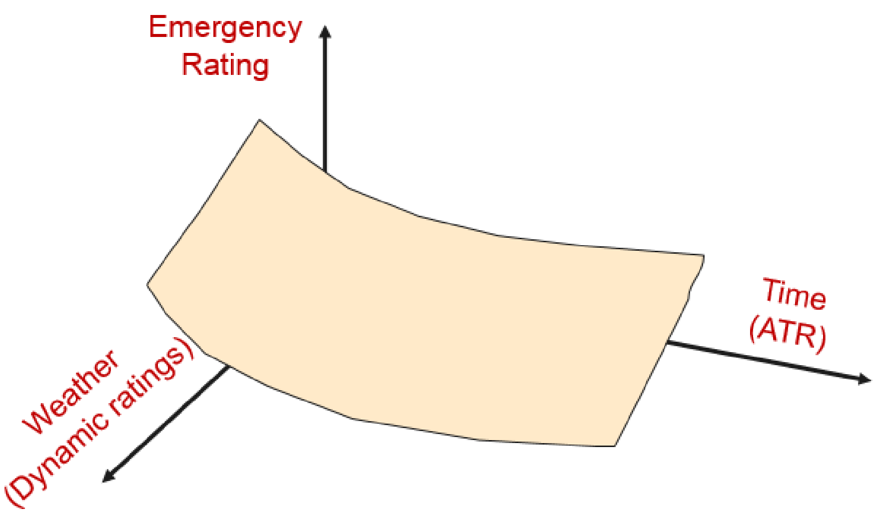
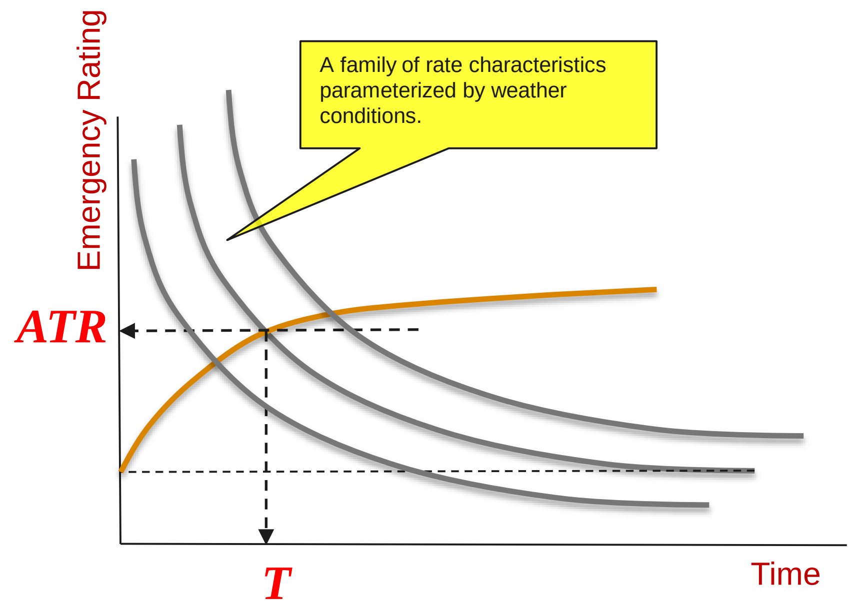
Combining DLR and ATR

- Dynamic line ratings and adaptive transmission ratings are two different unique concepts and each can more accurately assess the actual rating of a transmission line.
- DLR and ATR complement each other and can be treated independently.





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Conclusions

- Transmission constraint management for RTOs is reviewed.
- DLR can significantly improve the economic efficiency of both real-time and day-ahead markets by reflecting the change in ambient weather conditions to determine the ratings of key transmission elements.
- Adaptive Transmission Ratings (ATR) can increase utilization of power system transfer capabilities by 10-15% without deterioration of system reliability.
- DLR and ATR can be combined to achieve even less conservative but yet secure ratings for transmission lines.

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Q&A

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