Enhancement of Dispatch by Utilization of Adaptive Transmission Rates (ATR)

ISO New England

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Formulation of the Problem

- 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 and LTE values can be fixed or temperature dependent - "Dynamic rates"
- $STE \geq LTE$ → Which rate to use?

Formulation of the Problem, cont

- *STE* rate in dispatch is used only if loading can be reduced below *LTE* within 15 min post-contingency
- None of the Control Room tools provide estimation on how quickly loading can be reduced post-contingency
- Typically Operator has to use more conservative *LTE* rates in dispatch resulting in more then necessary restrictive transmission constraints
- Adaptive Transmission Rate (ATR) concept intends to adaptively select Emergency ratings by utilizing the post-contingency system ramping capabilities and pre-contingency conductor loading

Transient Emergency Rate

Rate = Function of (Time, Weather, Load)

Post-contingency time frame for which a rate is defined

Pre-contingency temperature (current) of conductor

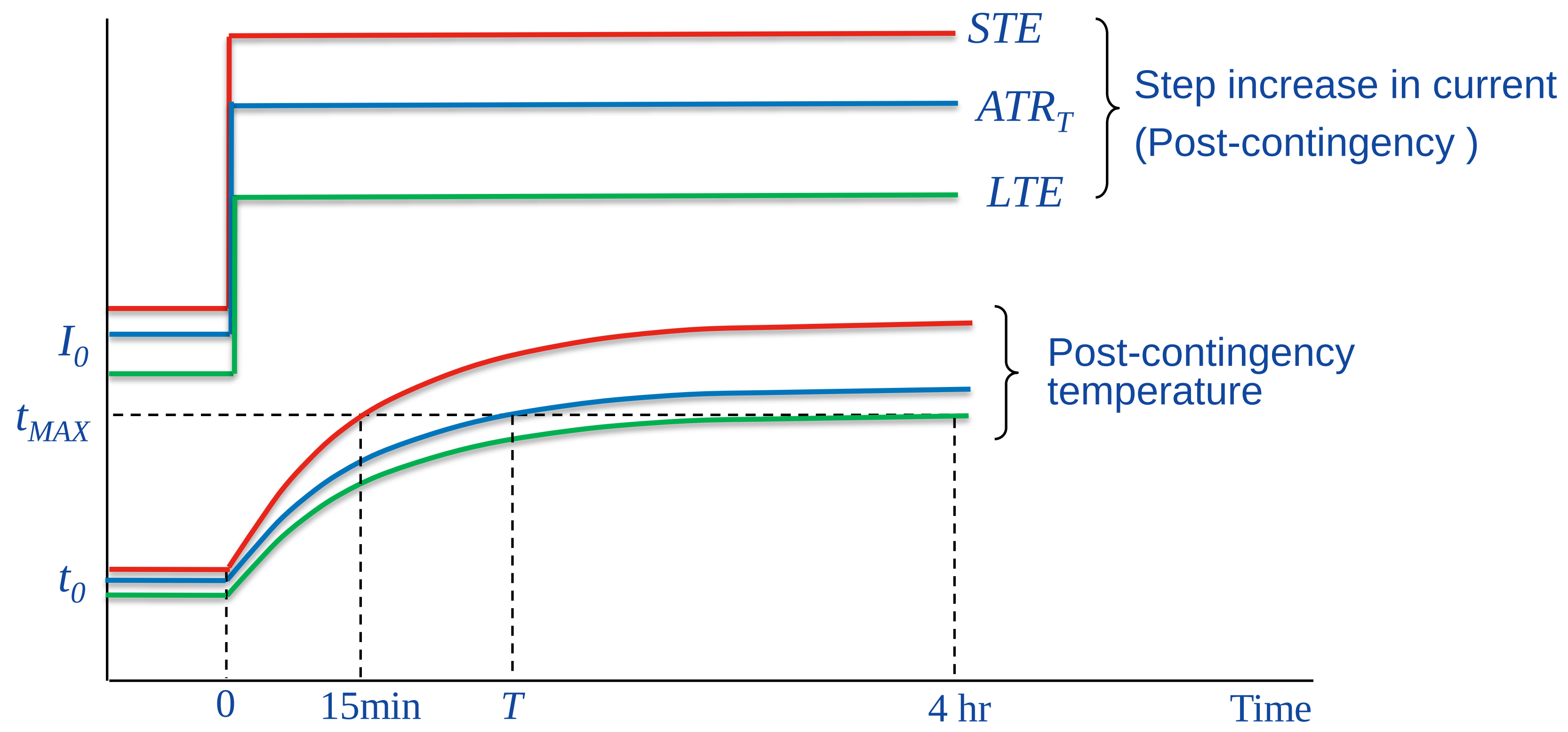
Cooling conditions:

Not considered in ATR

Impact of Post-Contingency Time on Conductor Rating

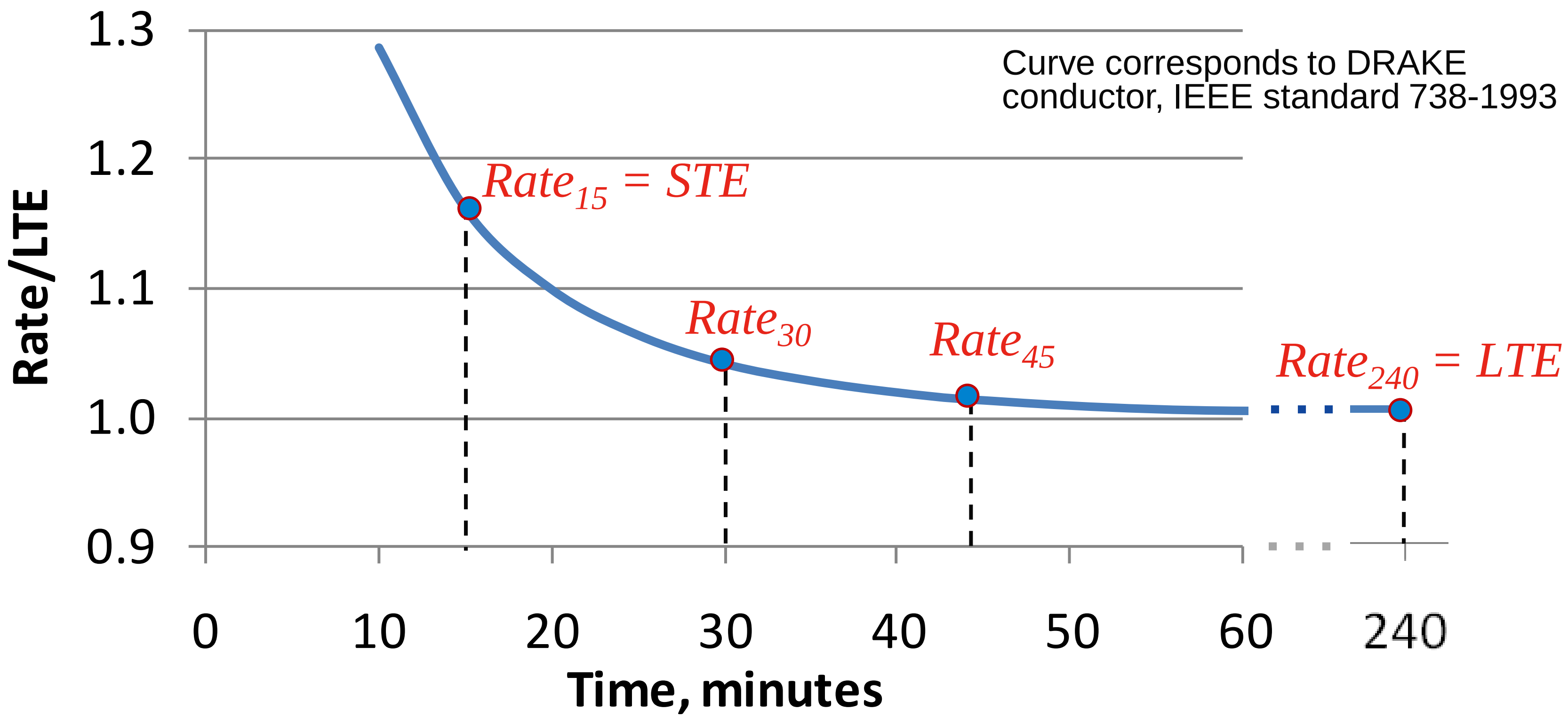
Definition of Emergency Transient Rate

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).”



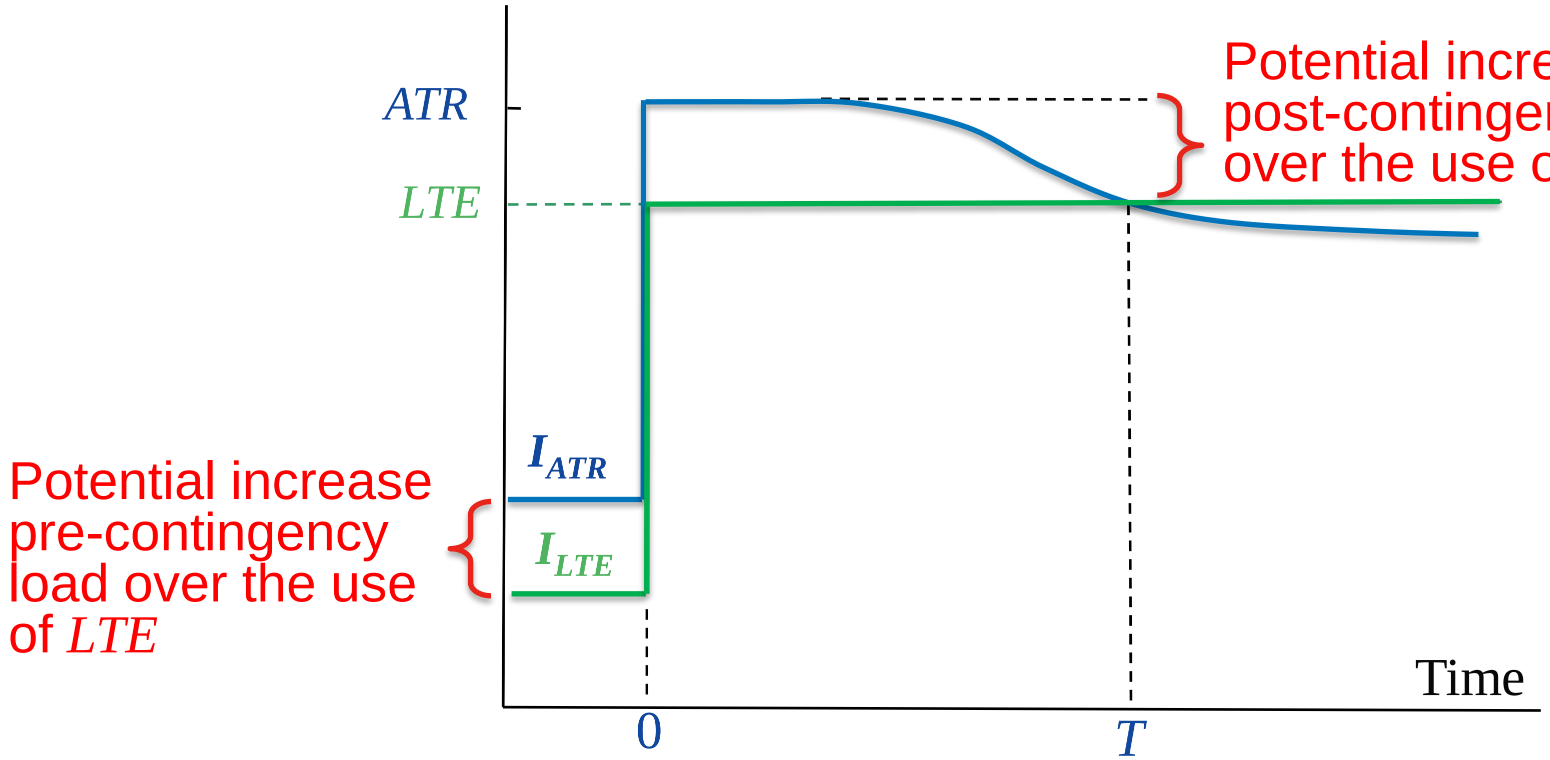
Rate(time) characteristic

- *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



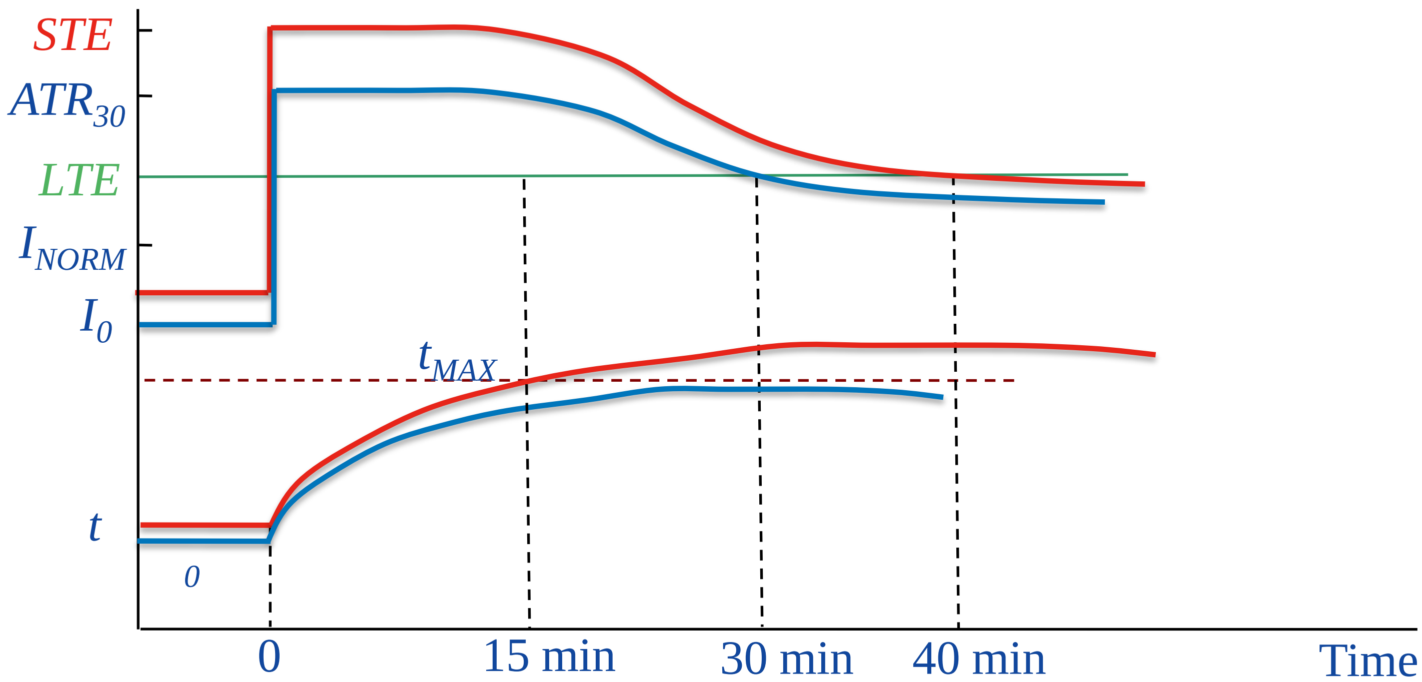
Introduce Adaptive Transmission Rate (ATR)

ATR of a line is the maximal post-contingency loading on that line, which can be reduced below *LTE* within *T* minutes by using available dispatchable resources



Example: Current/Temperature dependencies

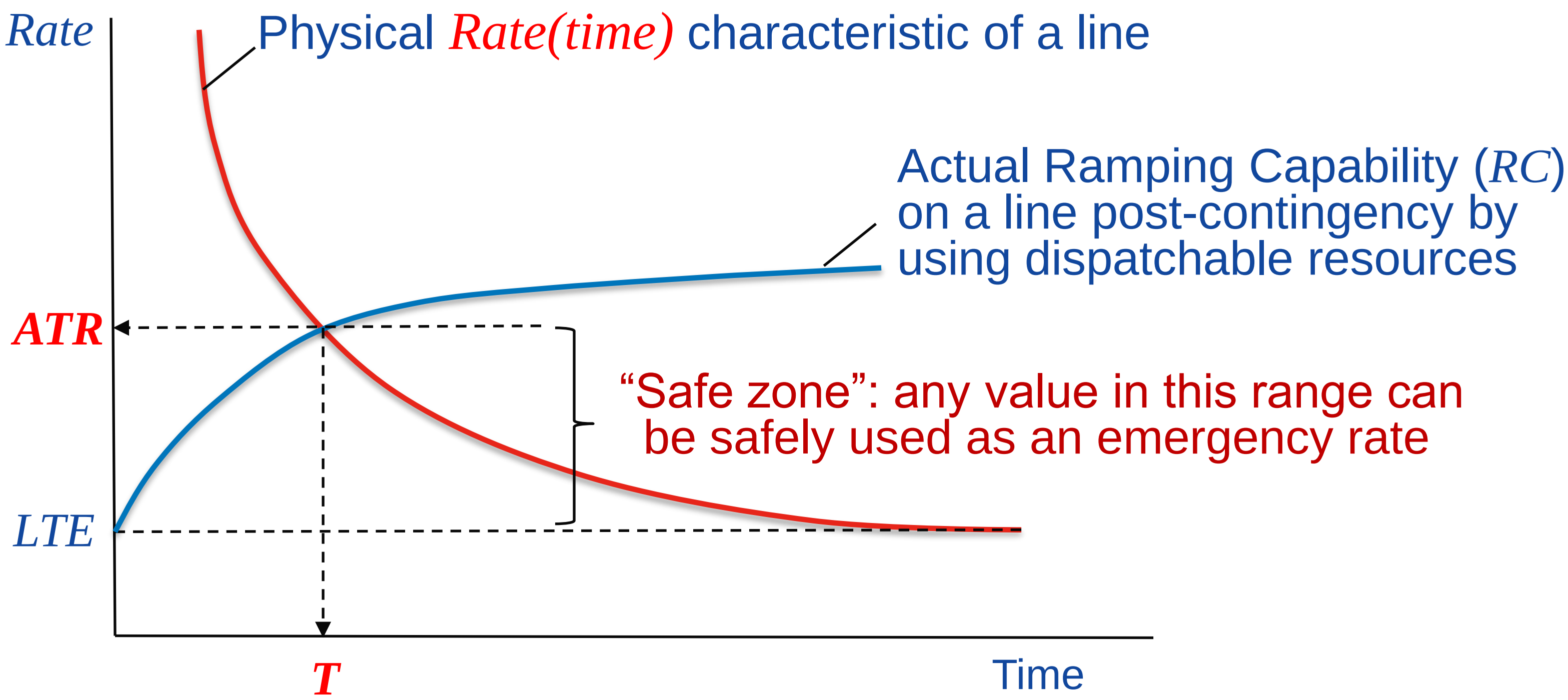
- Let dispatch use *STE* and system needs 40 min to reduce load below *LTE*: line temperature exceeds t_{max} in 15 min
- Let ATR_{30} be the maximal loading per ATR definition: dispatch up to ATR_{30} guarantees line temperature below t_{max}



How to Get ATR?

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

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



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

Ramping Capability calculation: *RC(time)*

- *RC* is the change in MW flow in a line of interest over time as a result of actual economic dispatch after contingency
- *ATR* and *RC* are calculated on-line for each line loaded above *LTE* according to the results of Contingency Analysis
- There are two ways of *RC* calculation
  - Simplified - by using Shift Factors of dispatchable resources
  - Accurate - by using modified Economic Dispatch

Simplified *RC* calculation

- Few minutes after contingency generation dispatch is aiming mainly to relieve overloading above Normal ratings on a line/lines of interest
- Sensitivities (Shift Factors (SF)) of dispatchable resources with respect to the power flow in the line of interest can be used for approximate *RC* estimation

$$RC(t) = \min_{m}\left(\sum_{i} Ramp_i \cdot x_i \cdot SF_i^m \cdot t\right)$$

$$P_{\min,i} \le Ramp_i \cdot x_i \cdot SF_i^m \cdot t + P_i^0 \le P_{\max,i}$$

Where: m index of critical contingency

Ramp is unit's ramping capacity MW/min

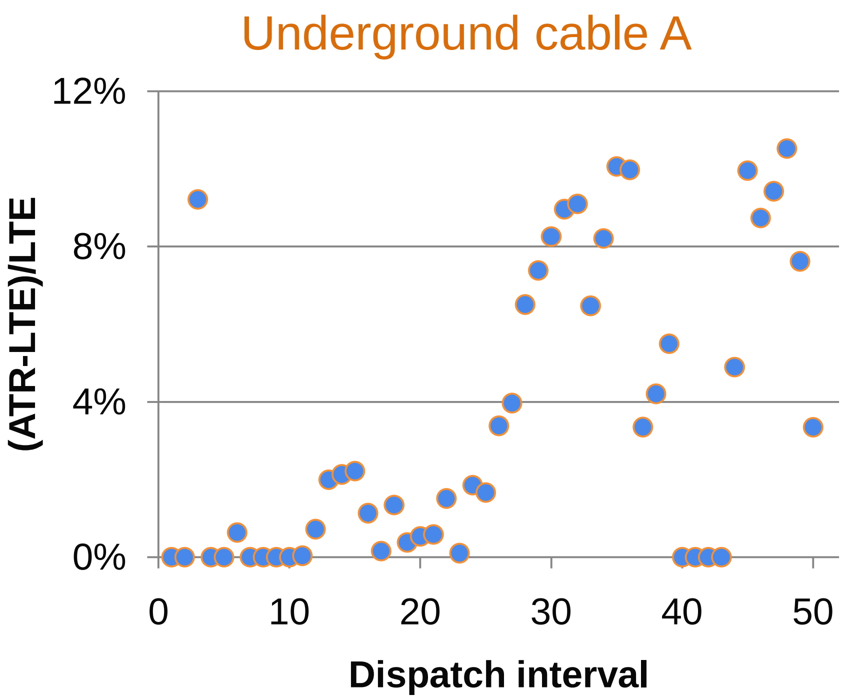
$x_i \in \{-1, 0, 1\}$ unit's dispatch direction

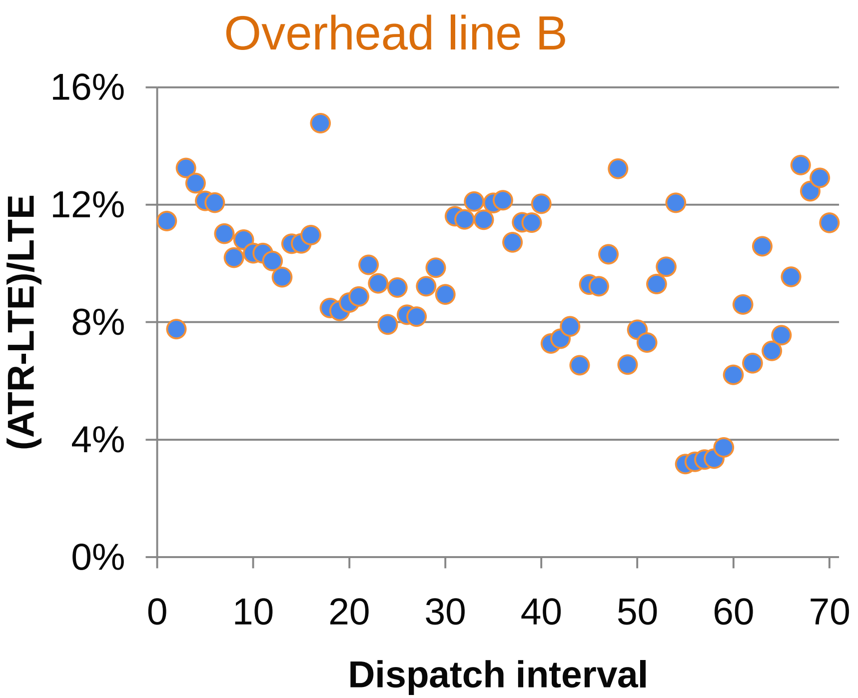
Accurate *RC* calculation

- The same SCED procedure, which is used for dispatch, will be used for *RC*
- RC is calculated for each critical contingency m causing loading above *LTE* on the line of interest
- For critical contingency, calculate $RC(t)$ as the MW flow change in the line of interest by SCED for different look-ahead time intervals 15, 30, 45 and 60 minutes
- $RC(t) = \min_{m}(RC^{m}(t))$

Example: Use of ATR for Real-Time

Increase of *ATR* over *LTE*. All dispatch intervals for Jan-Apr 2010, where lines A and B were binding constraints based on *LTE* rates



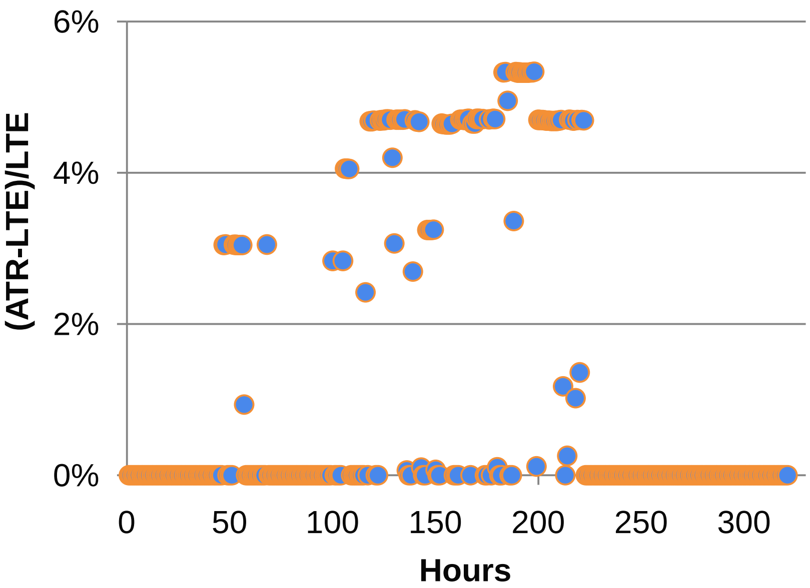


ATR allow increasing post-contingency loading up to 10-15%

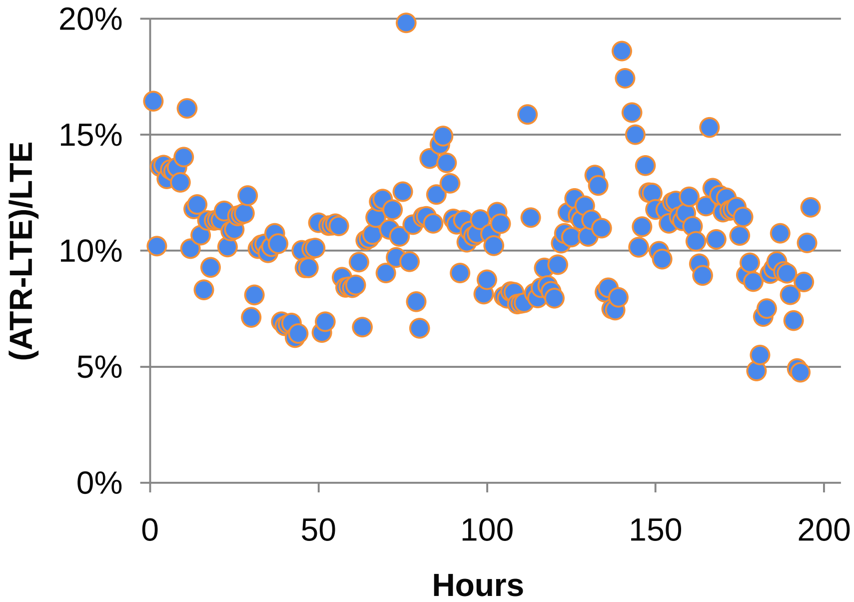
Example: Use of ATR for Day-Ahead

Increase of *ATR* over *LTE*. All hourly cases for Jan-Apr 2010, where lines A and B were binding constraints based on *LTE* rates

Underground cable A



Overhead line B



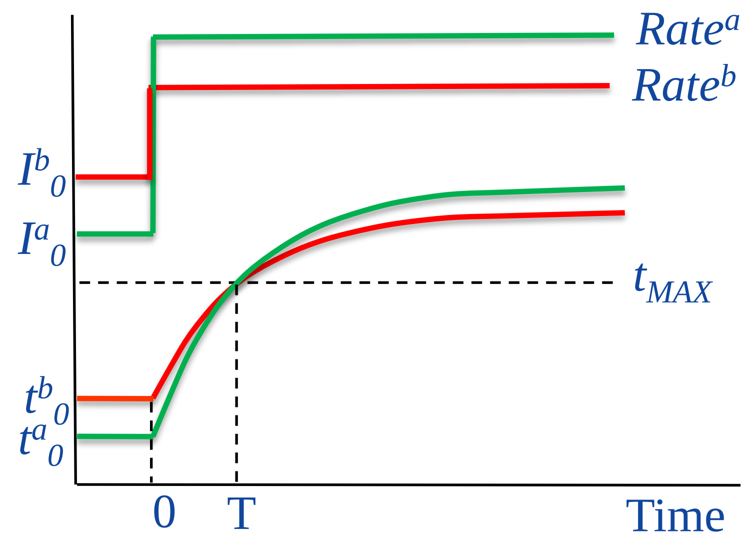
ATR allow increasing post-contingency loading up to 15-20%

Impact of Initial Load of Conductor

How initial load impacts *Rate*?

- *Rate =f(Pre-contingency load)*
- The lower the initial load is the higher is *Rate* value

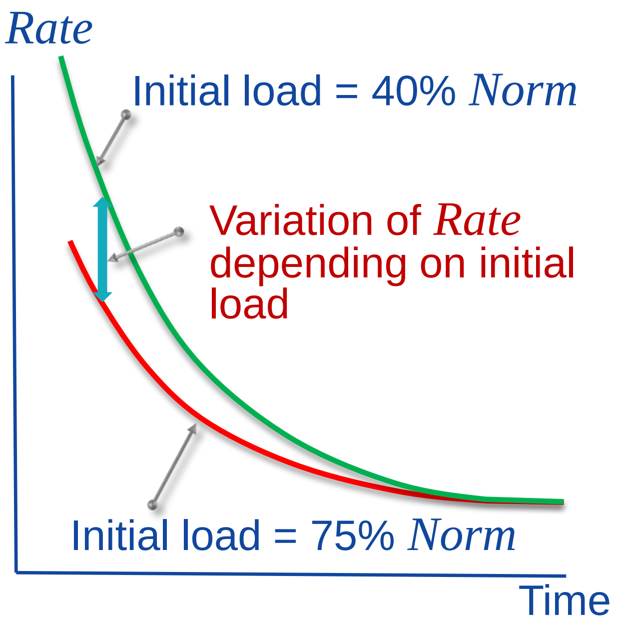
  $I^a_0 < I^b_0 \rightarrow Rate^a > Rate^b$



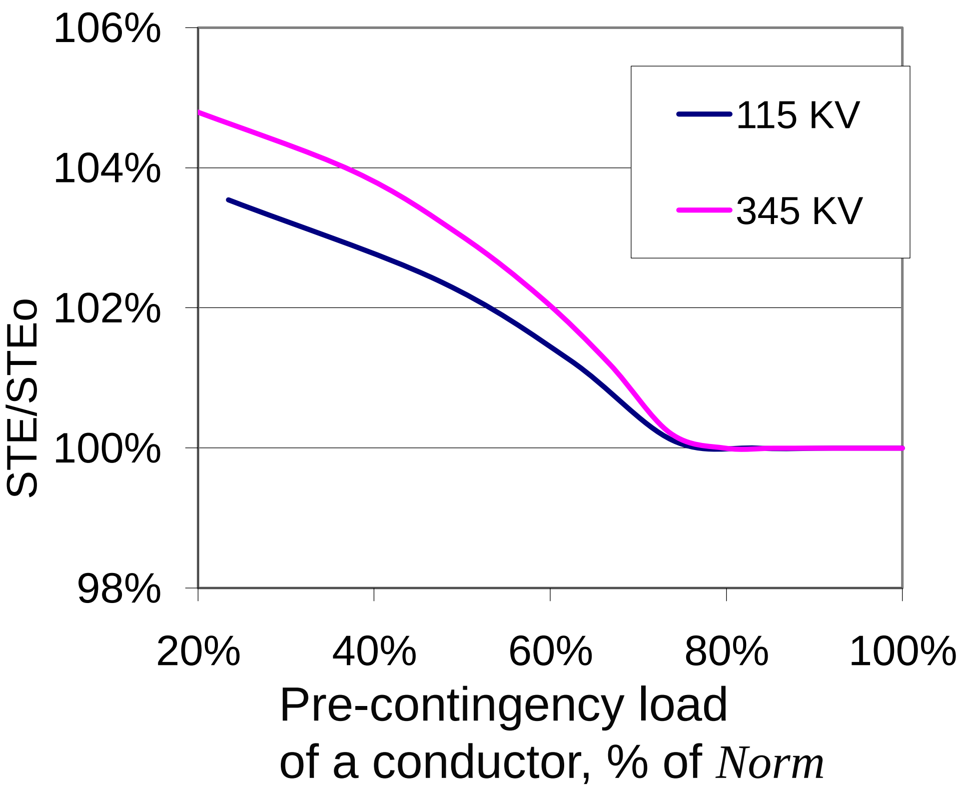
- Typical assumption for pre-contingency loading of a conductor is 75% of *NORM* rate
- Real time loading often is less than 75% and that opens an opportunity to recalculate *Rate* according to actual loading of conductor

Change in *Rate(Time)* characteristic

Rate(Time) adjustment per pre-contingency load by standard IEEE technique



Variation of *STE* rate for overhead conductor



Impact of initial loading on ATR

- *Rate(Time)* curve could be adjusted according to available at ISO historical data on conductor load. Pre-calculated nomograms or IEEE recommended techniques can be used

- Required time of pre-contingency loading
  - Overhead lines : about 1 hr
  - Underground cables : 2-10 hrs

Expected increase in *Rate* value

	Overhead conductor	Underground cable
STE	up to 4-5%	up to 5-10%
$ATR_{T=30min}$	up to 1-2%	up to 3-8%

Applicability / Implementation of ATR

ATR benefits

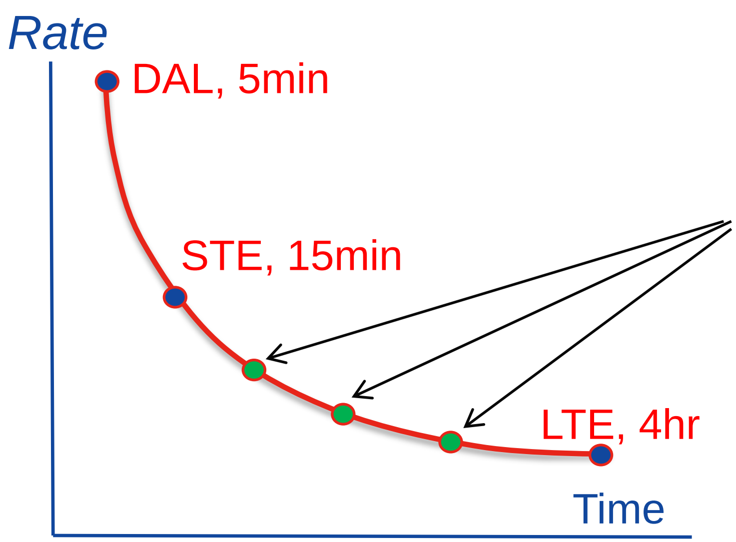
- Increased utilization of power system transfer capabilities without deterioration of system reliability
- Reduction of electricity production cost. ATR allows enforcing transmission constraints in dispatch at the maximal but safe load level
- Simplify the system operator’s job by providing additional information on maximal emergency rates that could be safely applied to existing system conditions

Smart accounting of the system conditions allows to increase line loading up to 10-15% without deterioration of reliability

Applicability of ATR

Process	Applicability of ATR
Real Time Operation	Yes, most efficient
Day Ahead Market	Yes
Short Term Outage Coordination	Possible
Long Term Outage Coordination	Possible
Planning	No

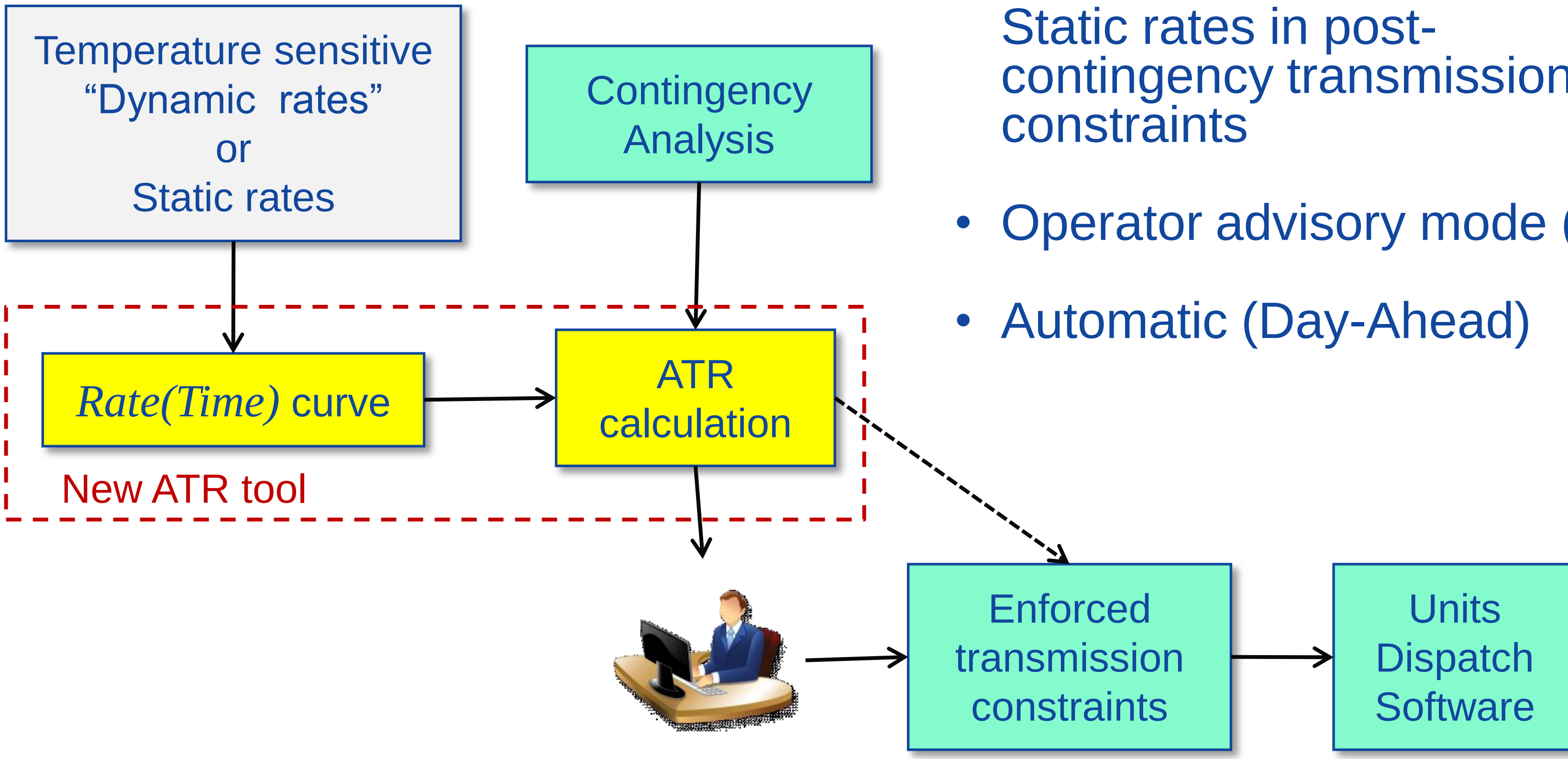
How to get *Rate(time)* characteristic?



- Transmission Owners (TOs) should develop them
- Additional rates at 30, 45 and 60 min are need for creation of credible *Rate(time)* curve

- Additional rates can be also estimated by using available *STE* and *LTE* and typical *Rate(time)* dependence for overhead and underground lines. That needs to be agreed with TOs

Use of ATR in dispatch



- *ATR* to be used instead of Static rates in post-contingency transmission constraints
- Operator advisory mode (RT)
- Automatic (Day-Ahead)

Implementation

- ATR is the new concept proposed by ISO-NE in 2008
- Engineering expertise by Transmission Owners has approved the ATR concept
- ATR tool can be a useful, standard feature of any Market Systems and to be implemented by the Market Management System vendor
- ISO-NE currently develops a prototype of ATR tool
- More details can be found in the paper: Maslennikov and Litvinov “Adaptive Emergency Transmission Rates in Power System and Market Operation”, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 24, NO. 2, MAY 2009, pp. 923-929.

Thank you

Questions