APPLY DYNAMIC SYSTEM RATING AS A PROACTIVE WAMPACS

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Our agenda

Improving power-grid capacity

- Congestion and renewable-curtailment relief
- GETs system benefits

Static line ratings

Dynamic System Rating WAMPACS

- Dynamic line ratings (DLR)
- Dynamic power rating (DPR)
- Optimal power-flow controllers (OPFC)

Implementing a DSR WAMPACS

What DSR provides to operators and to EMS

Simulation results

Congestion / renewable-curtailment relief needed now

National Renewable Energy Laboratory grid capacity must triple to achieve zero carbon by 2035

US consumers paid $21 billion USD in congestion costs in 2022

More than 1.4 terawatts of renewable energy projects are stuck in interconnection queues

Europe to reduce greenhouse-gas emissions by at least 55% by 2030 and source 40% energy from renewables

Australia has 67 GW of renewable energy projects cannot connect because of congestion

Grid-enhancing technologies (GETs) system benefits

Situational awareness for safer, real-time operation

Asset deferral, to give time to implement longer-term solutions

Increased grid resilience

Asset health monitoring

Static line ratings

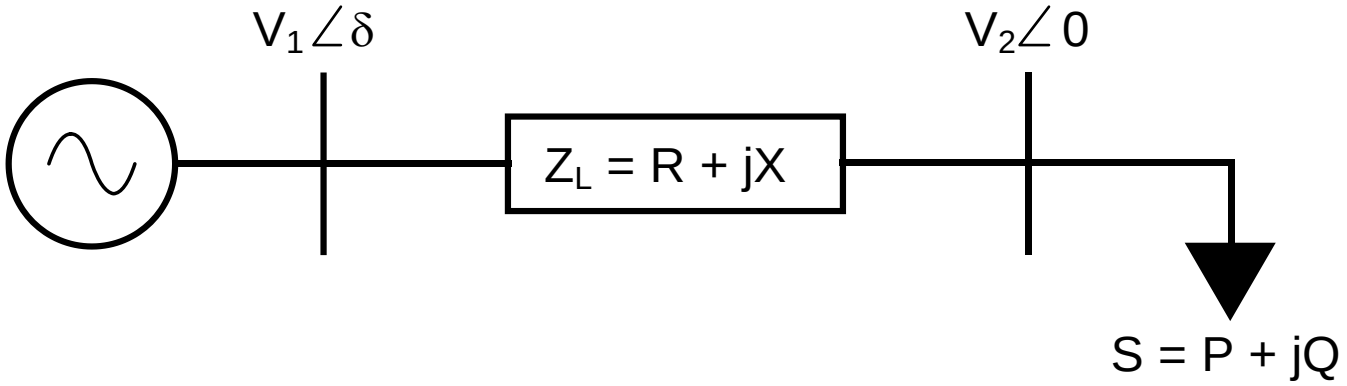
Maintain safe operating conditions on power lines from generation to loads

IEEE 738 “IEEE Standard for Calculating Current Temperature Relationship of Bare Overhead Conductors”

Conservative assumptions

- Static weather conditions
- Average wind speeds and direction
- Average ambient temperatures
- Solar conditions for summer and winter

Cannot take advantage of favorable conditions



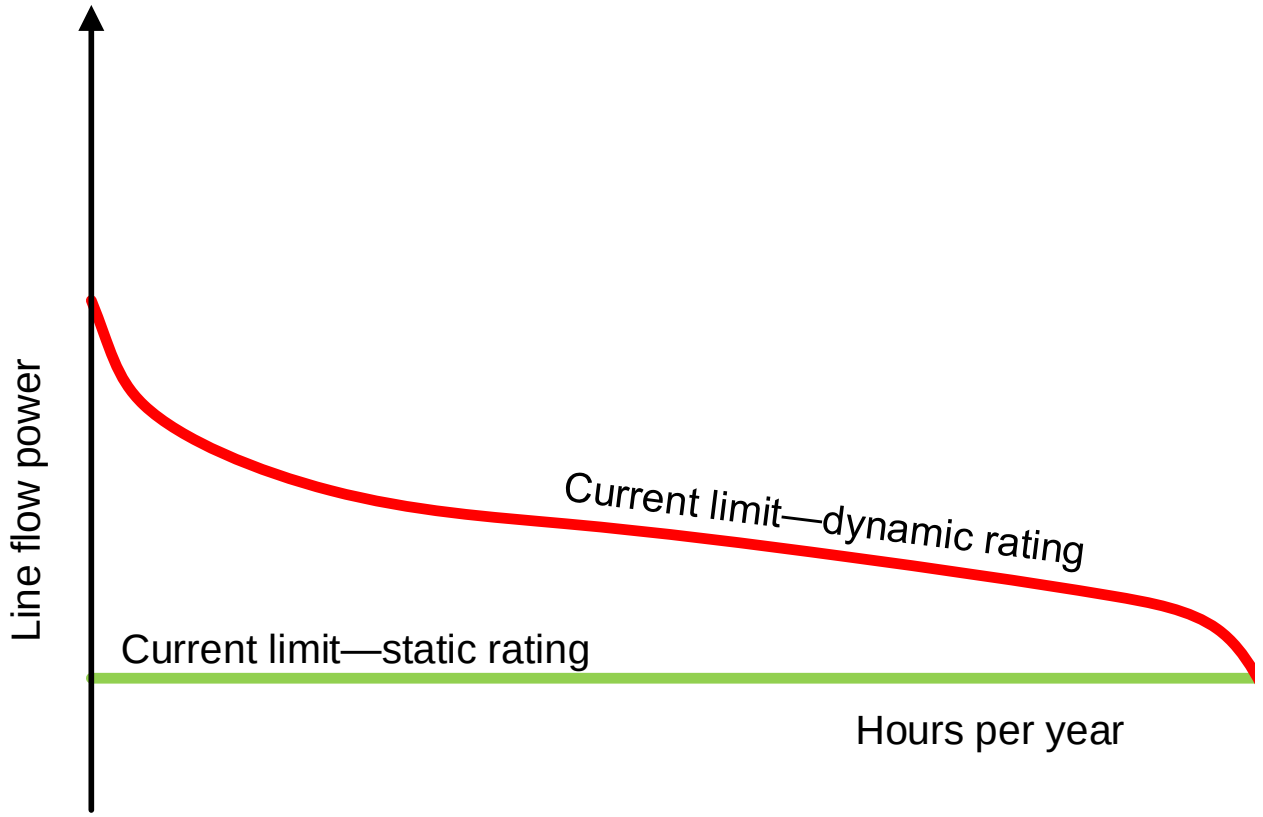
Dynamic line rating (DLR)

Thermal line capability

Sensor and computational analysis

Computational fluid dynamics

Increases line power flow



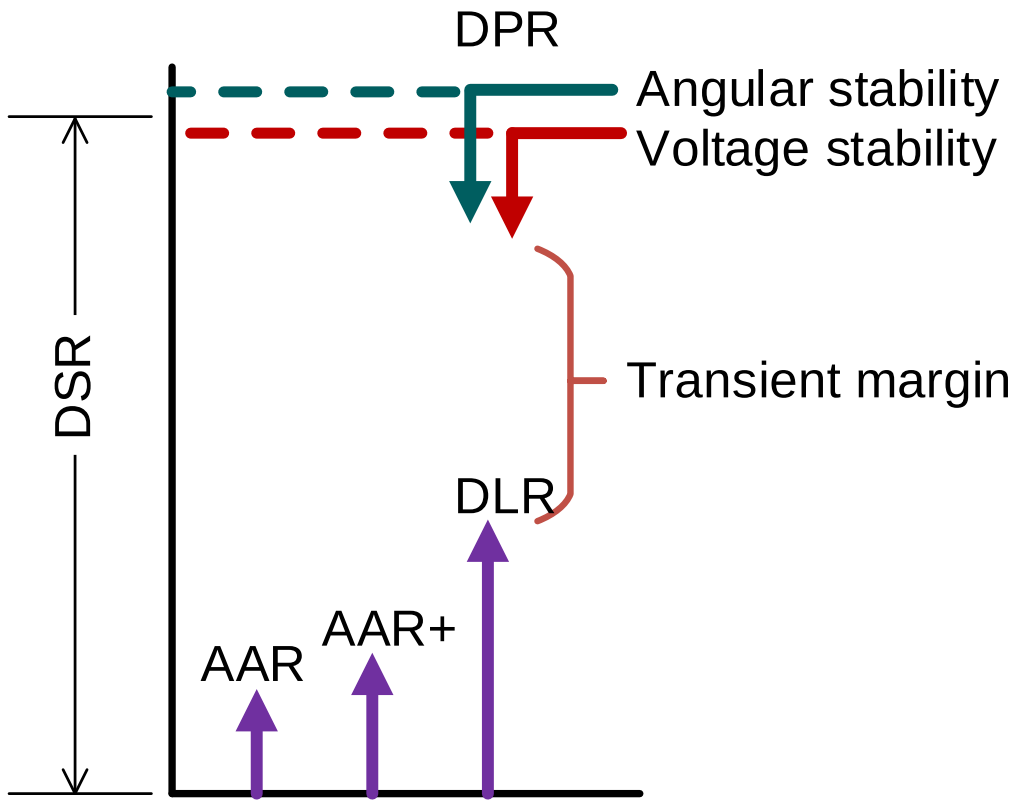
Dynamic system rating DSR = DLR + DPR

Dynamic line ratings (DLR)—thermal

Dynamic power rating (DPR)

- Angular stability
- Voltage stability

Optimal power-flow controls (OPFC)



Dynamic power ratings (DPR); angular stability

$$P_{E1}(\delta) = \frac{V_1 \cdot V_2}{X_{T1}} \cdot \sin\delta = P_{M1} \cdot \sin\delta$$

where

P_{E1} is electrical power

P_{M1} is mechanical power

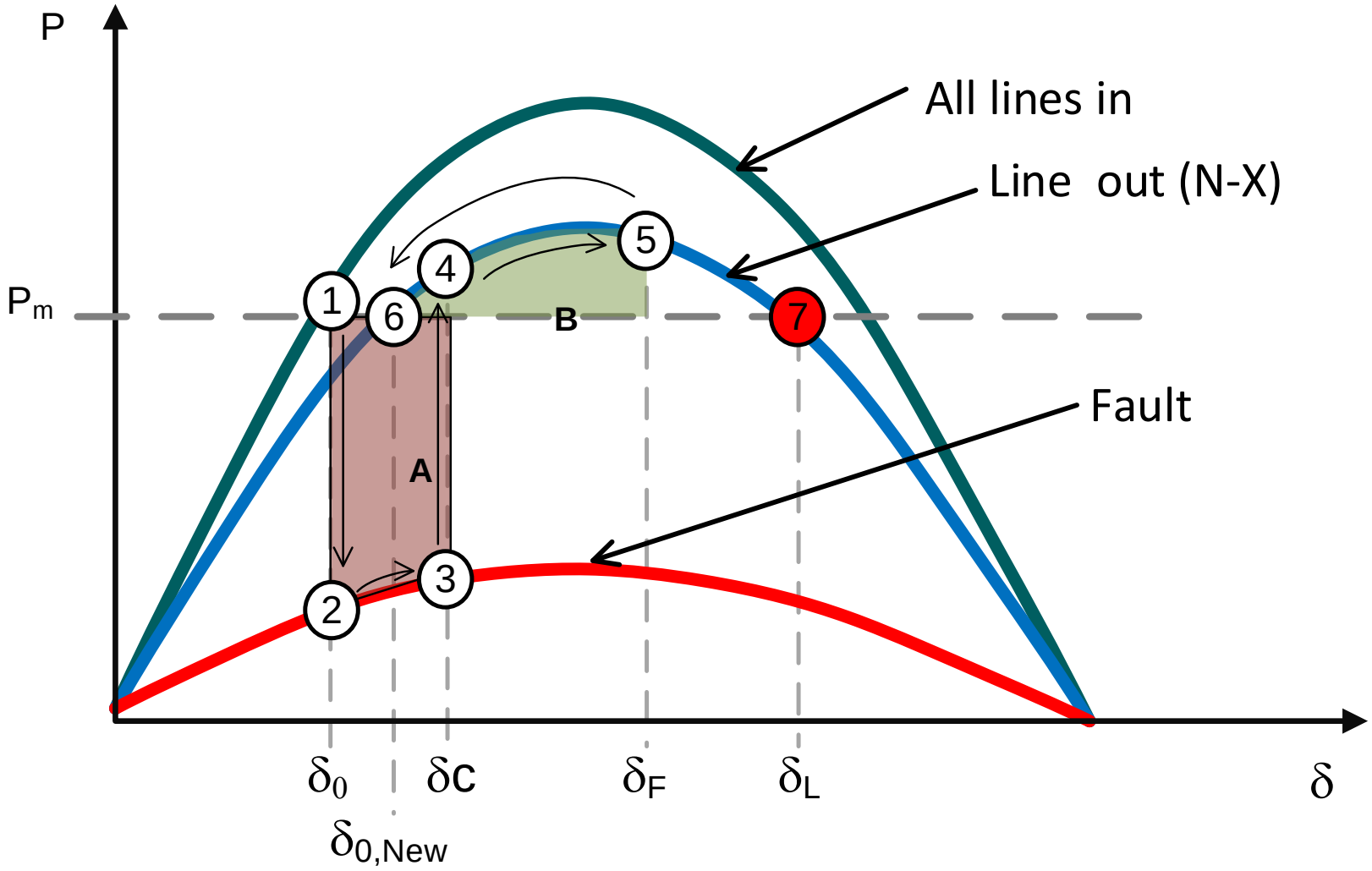
V_1 is transmitting line-terminal voltage

V_2 is receiving line-terminal voltage

X is line Impedance (neglect resistance R)

sin δ is sine of the line angle

Dynamic power ratings (DPR); equal power criterion



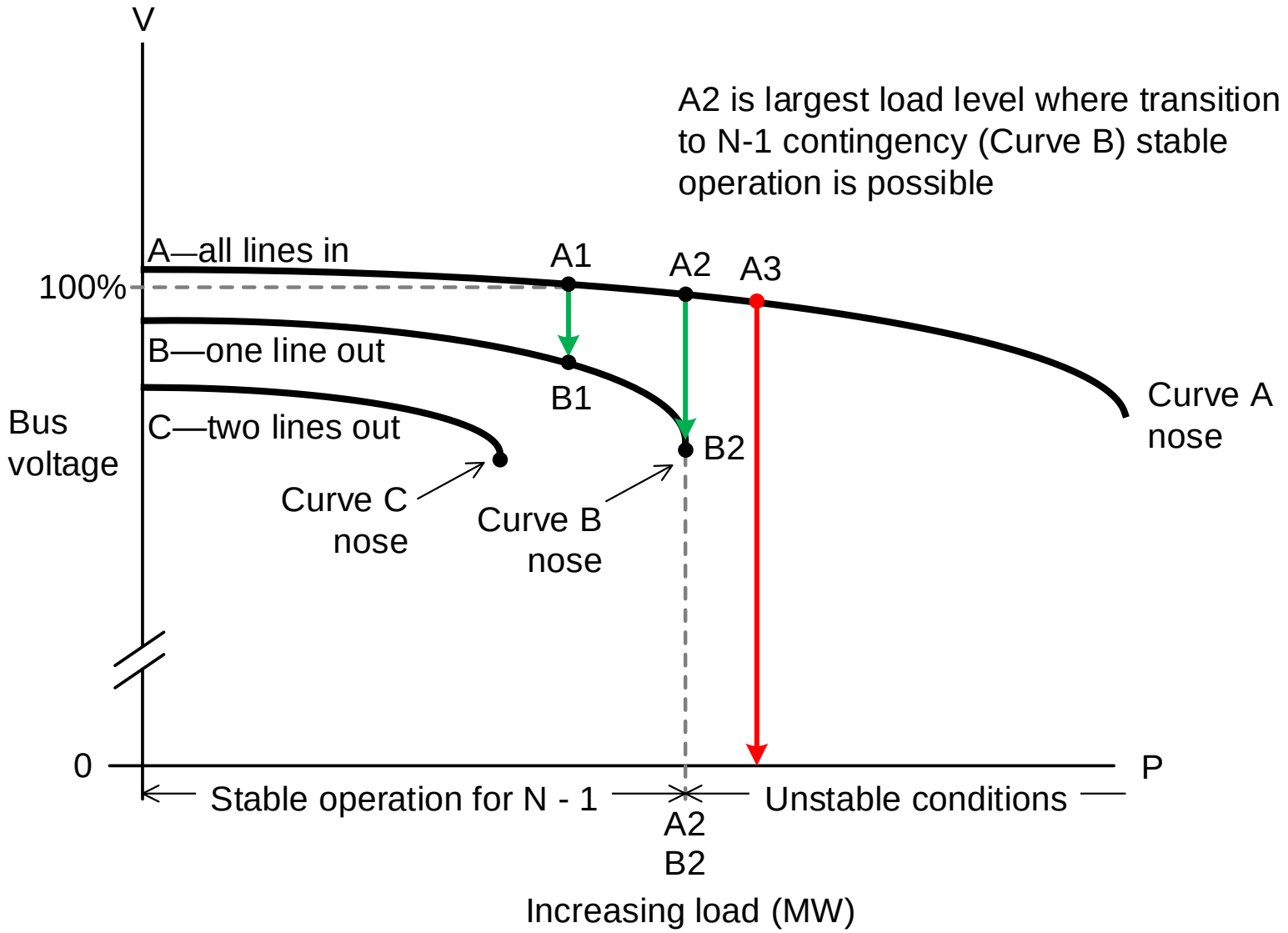
Dynamic power rating (DPR); voltage stability

$$P + jQ = V_2 \cdot \left(\frac{V_1 \angle \delta - V_2}{R + jX} \right)^*$$

$$P = \left[(V_1 \cos\delta - V_2) \cdot \frac{R}{R^2 + X^2} + V_1 \sin\delta \cdot \frac{X}{R^2 + X^2} \right] \cdot V_2$$

$$Q = \left[(V_1 \cos\delta - V_2) \cdot \frac{X}{R^2 + X^2} - V_1 \sin\delta \cdot \frac{R}{R^2 + X^2} \right] \cdot V_2$$

Dynamic power rating (DPR) nose curves



Optimal power-flow control (OPFC)

Adjust localized resources

Shunt-connected devices change V1 and V2

Series-connected devices change jX

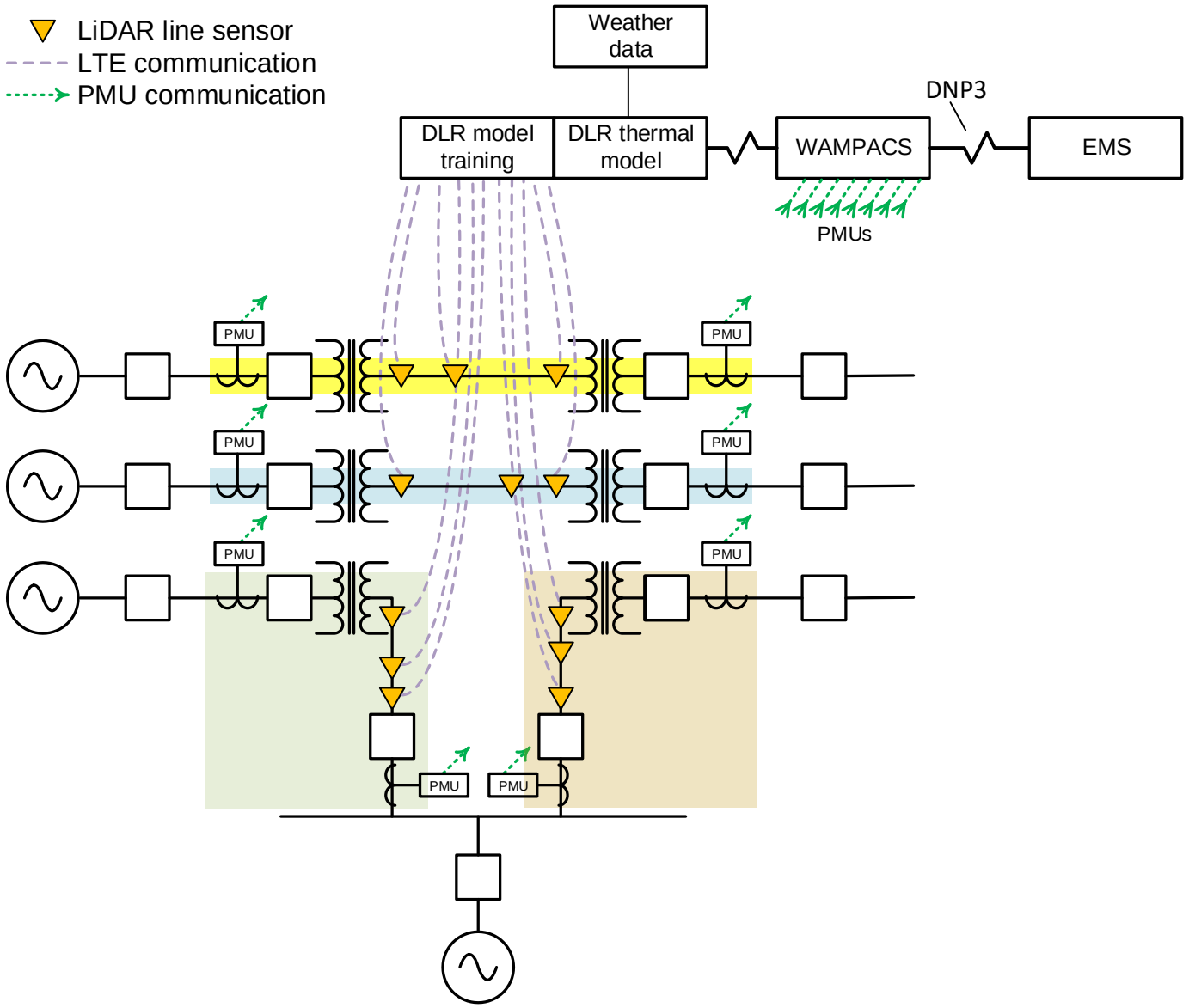
Phase-shifting transformers change δ

$$P_{E1}(\delta) = \frac{V_1 \cdot V_2}{X_{T1}} \cdot \sin\delta = P_{M1} \cdot \sin\delta$$

$$P + jQ = V_2 \cdot \left(\frac{V_1 \angle \delta - V_2}{R + jX}\right)^*$$

Shunt connected change voltages V1 and V2	Series connected change impedance jX
Static VAr compensators (SVCs)	Fixed, series-compensation capacitors
Synchronous condensers SSCs	Static synchronous series compensators (SSSC)
Static synchronous compensator (STATCOM)	
Shunt capacitors	
Load-tap-changing transformers	
Phase-shifting transformers control phase angle δ	

Implementing proactive DSR WAMPACS



What DSR provides to operators and to EMS

Information on power-transfer limits per line in a power corridor

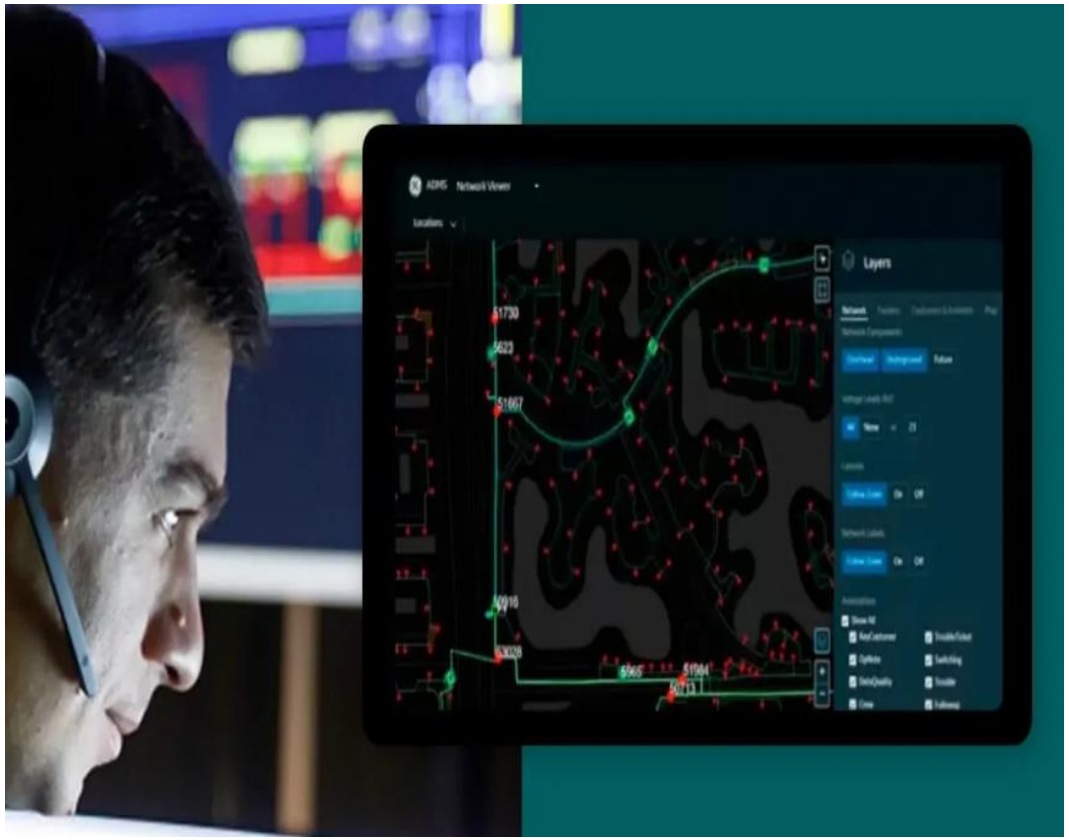
DLR (thermal) and DPR (angular and voltage stability) for each line

Worst-constraint limit

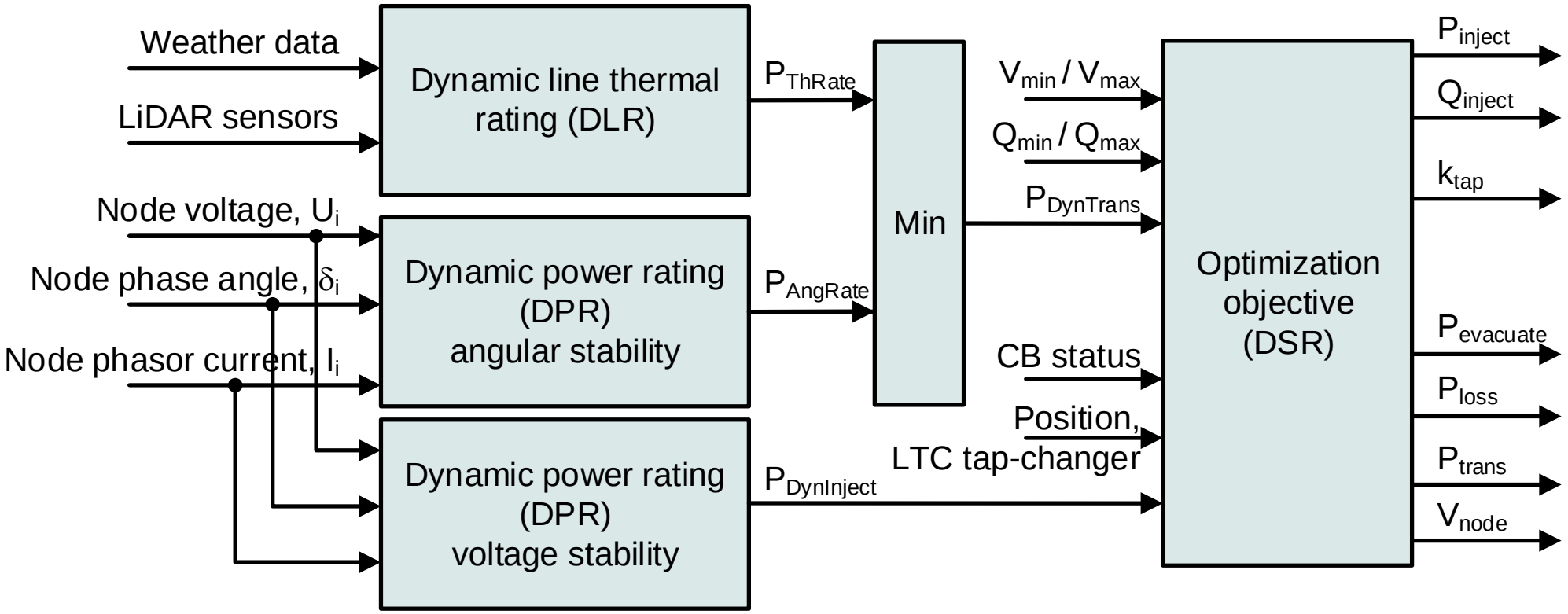
Operator suggestions for control of power-flow elements to optimize energy transfer, changing operating schedule (redispatch)

Commands for operator confirmation (e.g., L1 West Terminal: raise LTC two taps)

Direct control of power-flow elements where fast response is needed (e.g., Bus 3: SVC to 3MVAr)



Simulation results



Benefits of DSR

Enables more power transfer across a line

Fosters use of the least-cost marginal power from renewable sources

Accelerates interconnection of renewable assets

Reduces congestion and curtailment

Enhances grid resilience

Increases situational awareness

Supports asset health insight

Conclusions

Traditional WAMPACS used static ratings and state estimation

Now, proactive WAMPACS employs dynamic system rating (DSR)

DSR combines dynamic power rating (DPR) voltage / angle calculations to supplement thermal dynamic line rating (DLR)

Real-time calculation and contingency analysis redirects and redispatches power flow

Maximum safe power flow occurs on lines and load buses in PMU monitored area

DSR WAMPACS relieves grid congestion and curtailment


GE VERNOVA