Remedial Action Schemes (RAS) to Quickly and Affordably Connect New Generation and Large Loads

MAKING FULL USE OF TRANSMISSION CAPACITY

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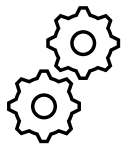
Summary and Outline

Definition* of a Remedial Action Scheme (RAS): a control system that allows power to flow up to the full capacity of a transmission line, rather than holding some "headroom" on transmission for contingencies

- RAS achieve full utilization of transmission by actively responding to monitored contingencies with automated changes in generator output or load consumption (or system reconfiguration)

Benefits: By enabling full utilization of transmission, RAS allow for faster, more cost-effective connection of large loads and urgently needed new generation



Reliability: RAS increase reliability, but they add operating complexity and have limits; RAS deployment and use must be carefully managed, and greater dependence on RAS may require more staff and better tools

- Properly managed RAS can increase reliability by providing more tools for post-contingency response
- "Limited-use RAS" are simpler; however, other RAS are limited in deployment scale due to complexity

Jurisdictional review: Trends in dependence RAS vary widely worldwide, with CAISO leading growth in US

- Some parts of the U.S. are expanding use of RAS in pursuit of the benefits (e.g., CAISO), while others are decreasing RAS in order to simplify operations (e.g., much of the Eastern Interconnection).
- Some international jurisdictions have long experience relying heavily on RAS (e.g., Australia, Alberta)

In CAISO, RAS enabled 21,000 MW of new renewables to connect

According to CAISO's RAS Guideline:
*"**RAS is a commonly considered alternative**"* and *"**RAS can normally be implemented much more quickly**"*

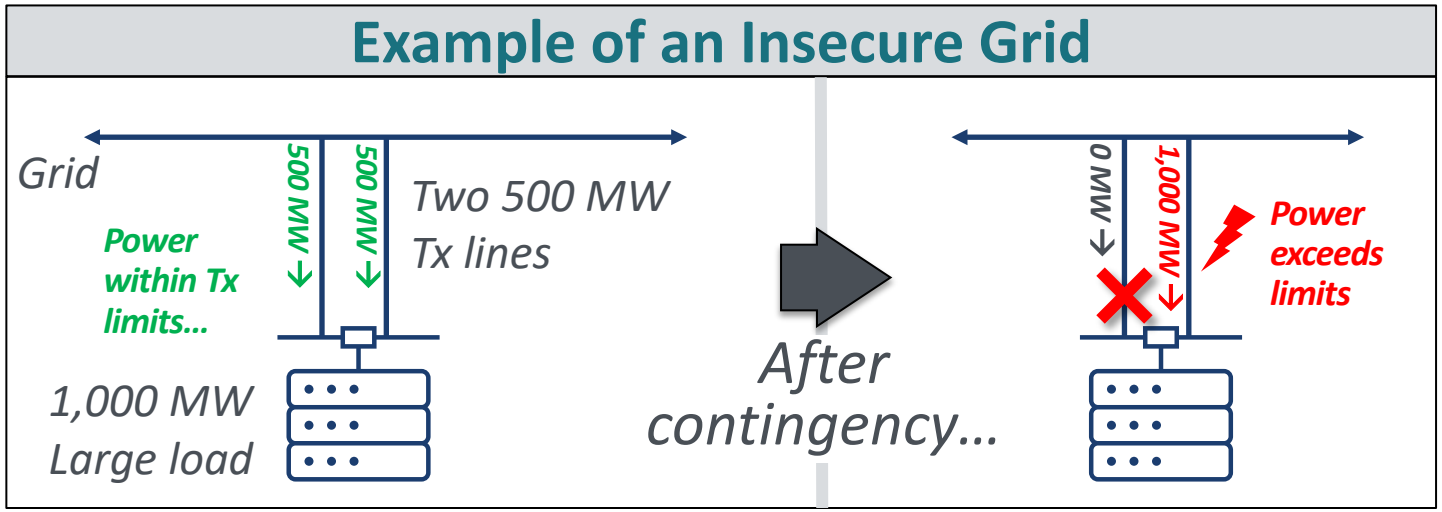
* NERC defines a RAS as: *"A scheme designed to detect predetermined System conditions and automatically take corrective actions that may include, but are not limited to adjusting or tripping generation (MW and Mvar), tripping load, or reconfiguring a System(s)."*

Security Against Contingencies: Key Concepts in Grid Operations

The grid is vulnerable to **contingencies** (a sudden loss of a generator or transmission line)

Power flows immediately change in response to a contingency, which can cause **overload** of a transmission line, which would then trip offline, potentially triggering a cascade of such failures

Grid operators therefore must take steps to ensure post-contingency conditions do not cause overloads—this is called **grid security**

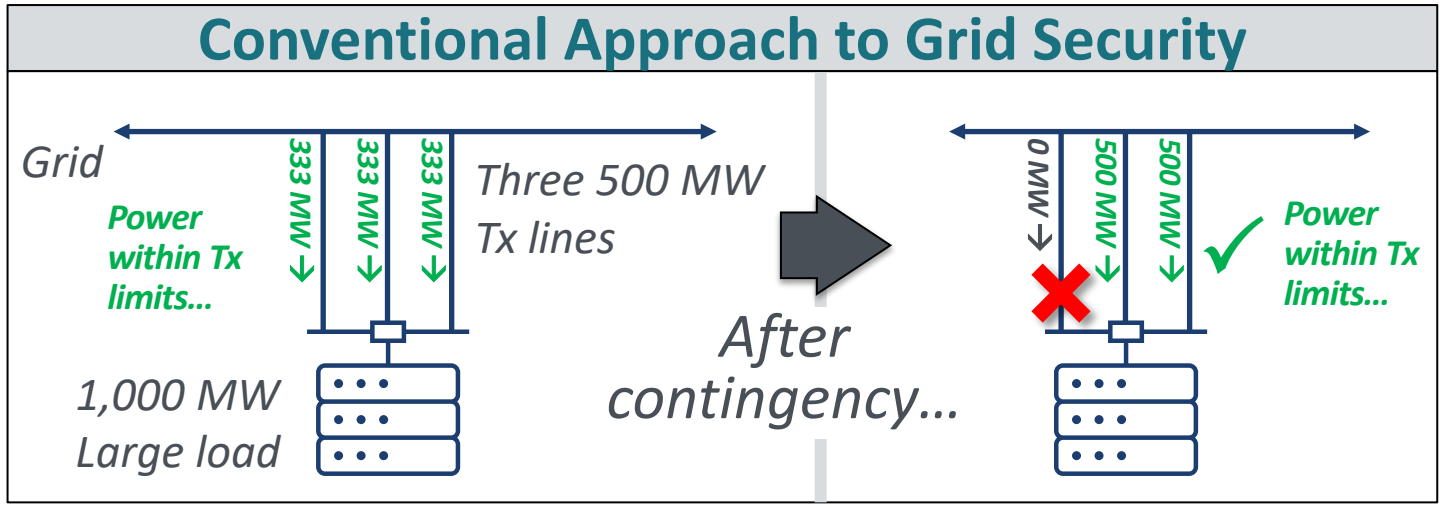


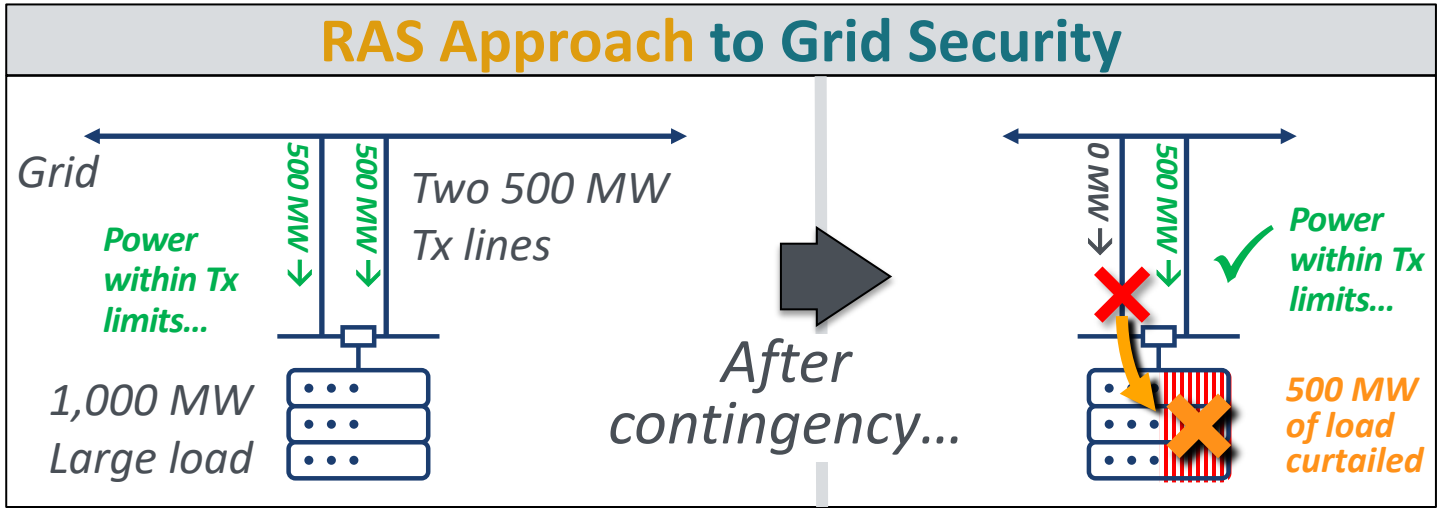
A RAS Uses Controls to Unlock Transmission Headroom that Normally Needs to be Held for Contingency

Two ways to achieve security:

- **Conventional grid operations:** Hold headroom on transmission lines to **accommodate extra power** that would flow after a contingency

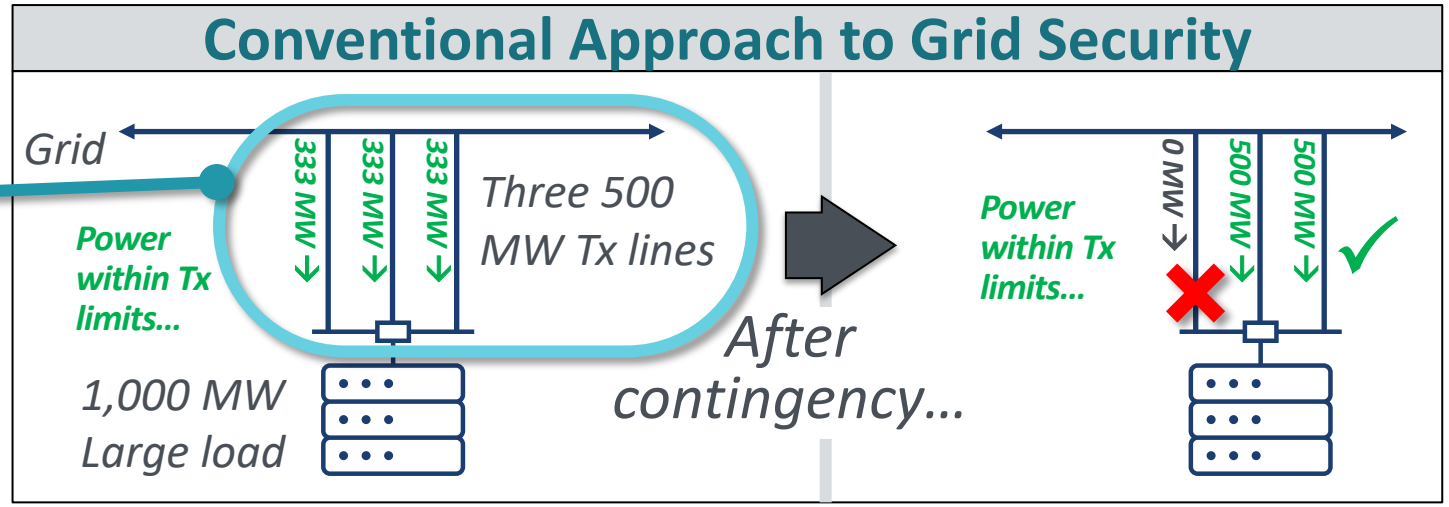
- **RAS Approach:** Use a pre-programmed controller to immediately adjust generation or load MW after a contingency in order to **prevent extra power** that would otherwise flow



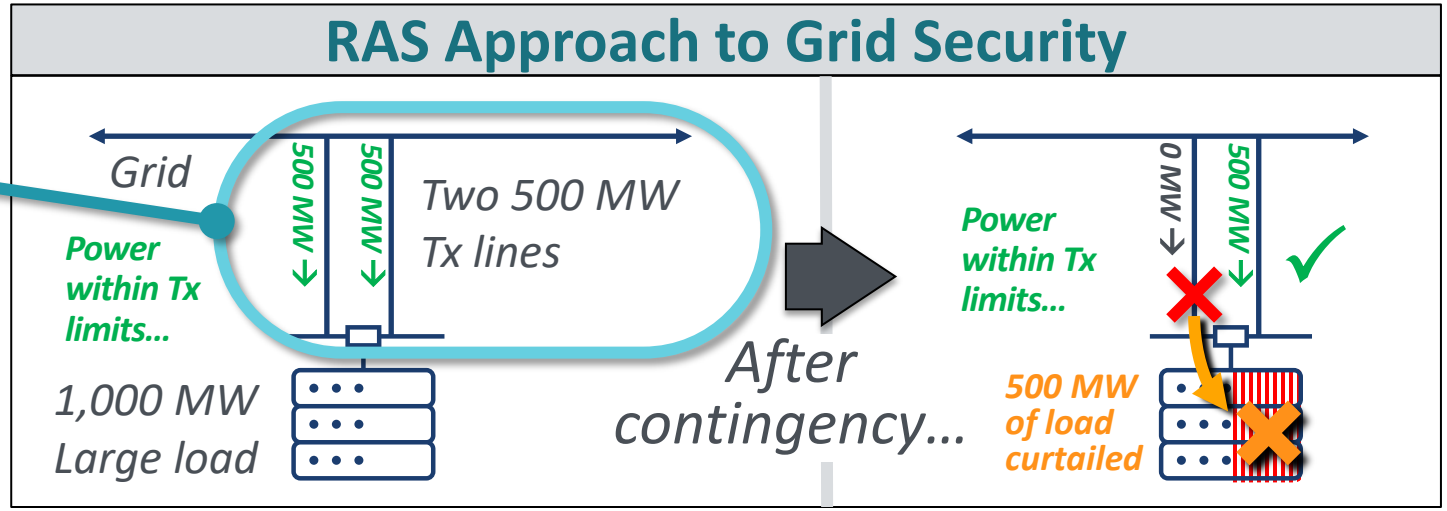


A RAS Uses Controls to Unlock Transmission Headroom that Normally Needs to be Held for Contingency (cont'd)

The conventional approach requires excess, underutilized transmission

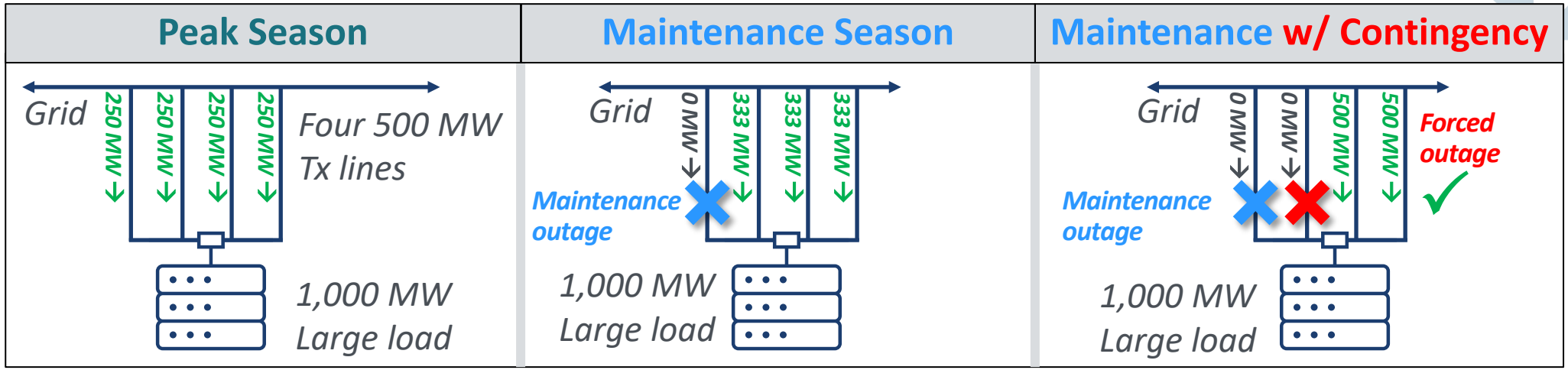


Because RAS does not need to hold headroom on transmission, it can fully utilize line capacity with actual power flows (and avoid building a 3rd line)

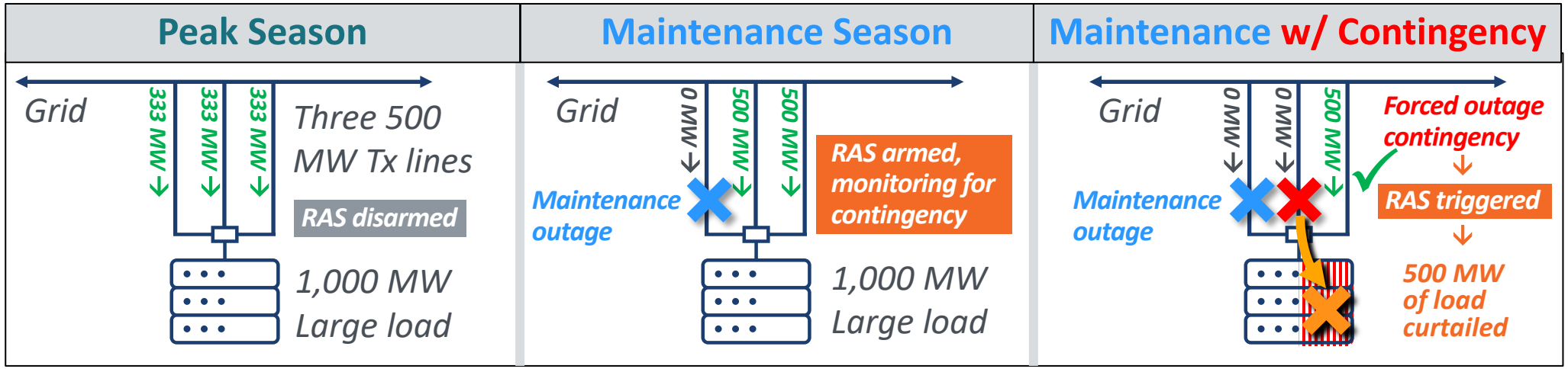


Maintenance Season Planning—Conventional vs. RAS: RAS Armed in Maintenance Season

Conventional approach plans for N-1-1, requiring a fourth line for maintenance season → more excess, underutilized transmission



RAS approach: avoids fourth line, RAS not needed during most of the year, only armed during maintenance season

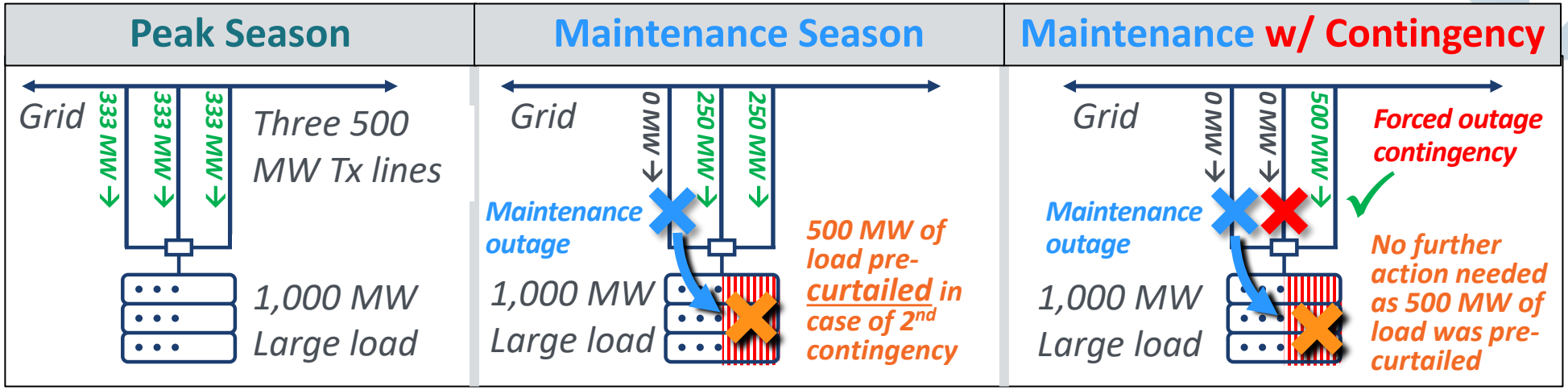


Maintenance w/ Flexible Loads: Curtailment of Non-RAS Flexible Load is Certain, RAS Curtailment Only Occurs if Needed After Contingency

Flexible load approach without RAS

→ *Certain Curtailment*

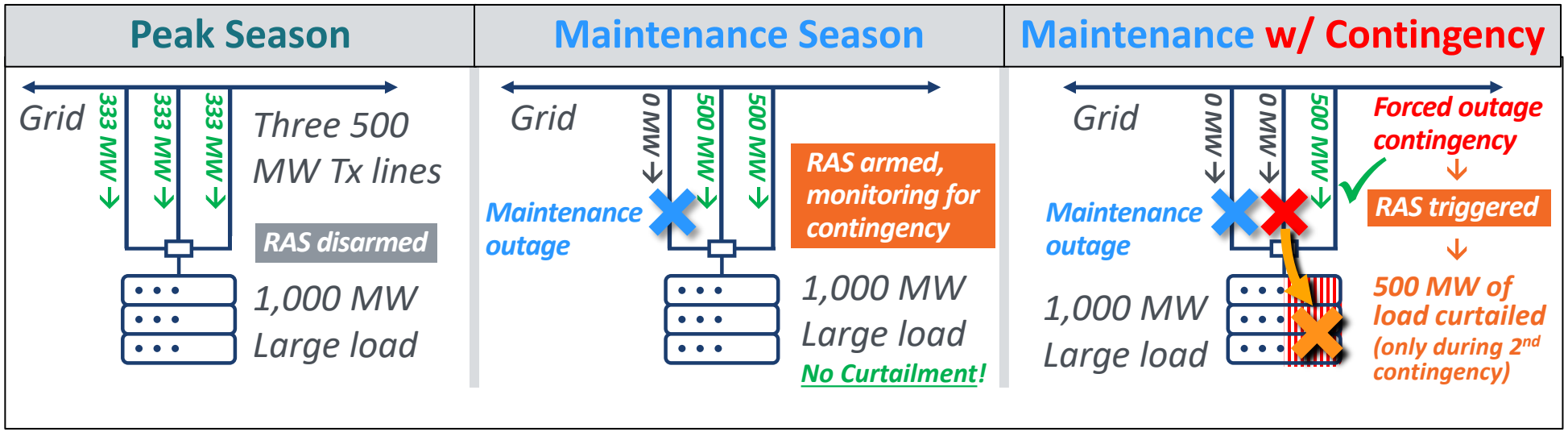
Flexibility avoids fourth line, but curtailments throughout weeks-long maintenance season are certain



RAS approach to flex (same as prior slide)

→ *Unlikely Curtailment*

Avoids fourth line, but curtailment only needed during 2nd Tx outage (very unlikely) when RAS is armed (during maintenance season)



Potential RAS Use Cases for Faster Interconnection

Accommodate connection of a new large load during outage season, when some transmission lines are out of service

- Such a site would be conventionally secure during most of the year, but a load-curtailment RAS (such as shown on the prior slide) can be installed and armed during outage periods (days or weeks)

Limit transmission withdrawals at a new large load site co-located with new generation

- A large load site can limit withdrawals by relying on co-located generation; in case one unit at the co-located generation facility fails, a power flow relay at the point of interconnection can automatically reduce the load to limit withdrawals, limiting any impact on the grid
- Such a relay is sometimes called a RAS, but because it monitors and controls non-public facilities it is often referred to simply as a relay

Use storage for a RAS instead of load curtailment

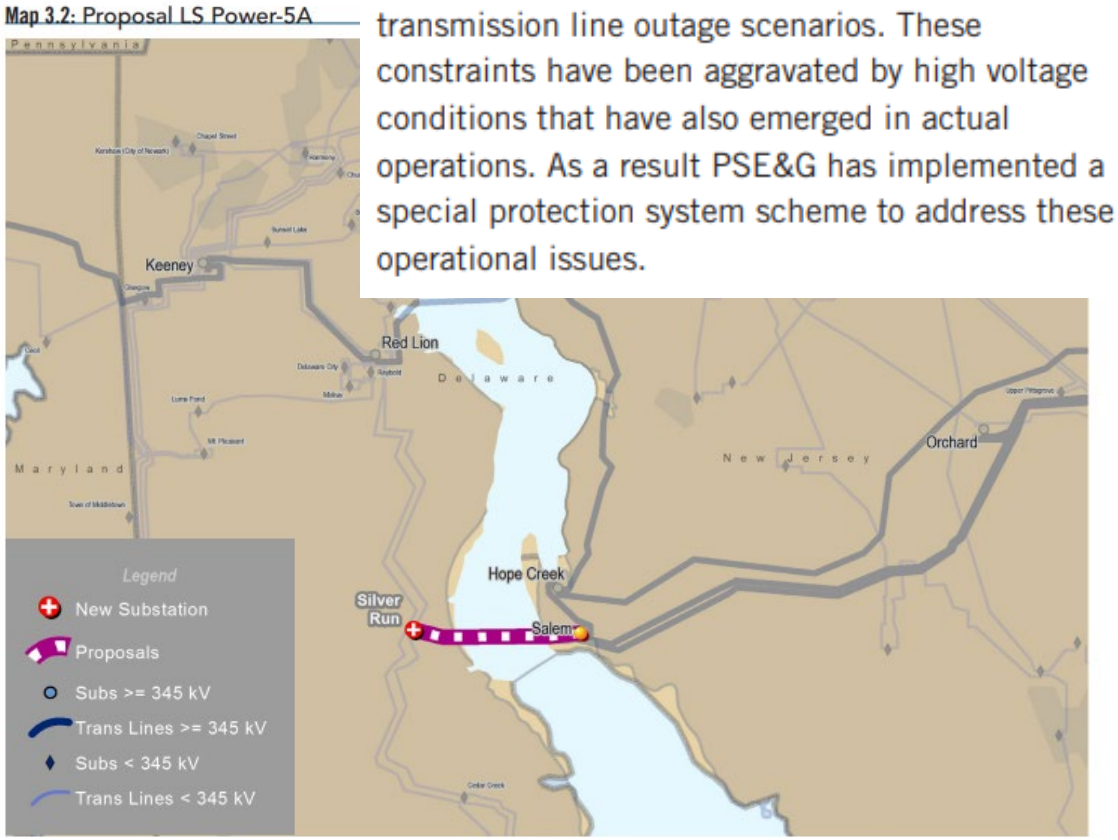
- Co-located storage (front-of-the-meter or behind-the-meter) can be used for instantaneously reducing net inflows in lieu of load curtailment
- This use case could be combined with the other use cases above such that co-located storage operates as a normal market asset during non-outage season, but a RAS-support asset during outage season

Example of a Large Transmission Upgrade to Retire a RAS

- Starting in 1987, PJM/PSEG used the "Artificial Island (Salem) Cross Trip Scheme" Special Protection Scheme (old term for RAS) to manage transient stability limits
- In 2013, PJM sought to use transmission planning to eliminate the complexity associated with the Artificial Island SPS and associated Operating Guide
- In 2015, after a competitive planning process, PJM recommended a $275 million collection of transmission upgrades (including the new Silver Run transmission line under the Delaware River) to avoid the need for the SPS
- In 2020, the Silver Run line was completed, and the Artificial Island SPS was modified accordingly

Artificial Island Operating Guide

Historically, Salem and Hope Creek generation output has been constrained by dynamic and transient stability limitations, particularly under transmission line outage scenarios. These constraints have been aggravated by high voltage conditions that have also emerged in actual operations. As a result PSE&G has implemented a special protection system scheme to address these operational issues.

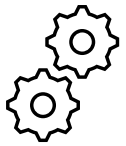


Source: PJM, Artificial Island Project Recommendation White Paper, July 2015

Benefits and Reliability Considerations of RAS

RAS are beneficial because they:

- Allow generators to connect more quickly, before (or instead of) network upgrades
  - Alleviate capacity crunch, add reliability, ease prices
  - If permanently avoiding network upgrades, this reduces cost
- Allow large loads to connect more quickly, before (or instead of) network upgrades
  - Achieve national objectives, economic growth
  - If permanently avoiding network upgrades, reduces cost



RAS can add complexity to reliability operations:

- Properly managed RAS can increase reliability by providing more tools for post-contingency response, but they can add complexity
- "Limited impact RAS" are those that avoid complexity and can generally be added without concerns
- To ensure that complex and poorly designed RAS cannot cause reliability concerns, CAISO and grid operators in Australia and Europe have established supportive RAS guidelines and standards
  - E.g., CAISO requires that RAS be "simple and manageable"
  - Best practice is to avoid strong interactions among RAS, using them in separate zones of influence
- RAS requires careful management in planning/ops to ensure response supports reliability

For further discussion, see: Pfeifenberger, et al, Unlocking America's Energy: How to Efficiently Connect New Generation to the Grid, August 2024, pages 59 - 60

Jurisdictional Review of RAS

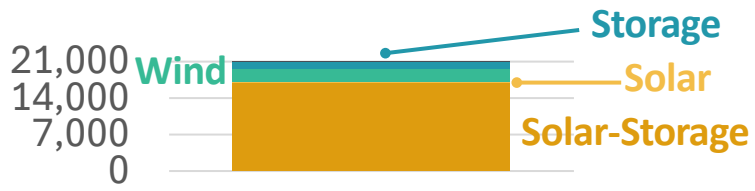
California ISO

- CAISO analysis shows RAS enabled 21,000 MW of new renewables (with 16,000 MW of "firm" capacity) to connect (below)
- According to CAISO's RAS Guideline:

*"**RAS is a commonly considered alternative** to building new infrastructure in an effort to keep costs down when integrating new generation into the grid and/or addressing reliability concerns under multiple contingency condition"*

*"**RAS can normally be implemented much more quickly** and at a much lower cost than constructing new infrastructure. In addition, **RAS can increase the utilization** of the existing transmission facilities, make better use of scarce transmission resources **and maintain system reliability**."*

New Gen Enabled by RAS in CAISO



AEMO

- AEMO has rigorous RAS management as detailed in the RAS Guideline. There they state:

*"**There is an … increasing number of RASs** across the NEM…Such schemes can **improve asset utilisation**, network access for generating systems, integrated resource systems and loads, reduce the impact and severity of events, and aid with recovery from such events."*

- AEMO recognizes that RAS deployment is growing, increasing the need for management and tools:

*"…**new generation projects are increasingly observed to propose remedial action schemes (RASs)** to manage non-credible contingencies. While these schemes add complexity, they also bring benefits of minimising costs and deferring the need for further investment in primary plant that would otherwise be required"*
2025 General Power System Risk Review Report, page 6, 33-34.

- AEMO uses RAS-like schemes to connect large loads ahead of network upgrades (see e.g., Appendix A2 to the Transition Plan for System Security, page 108, discussion of Deer Park)

aeso

- AESO reports that it *"…**makes extensive use of Remedial Action Schemes (RAS)** … **These RAS are designed to ensure that grid reliability is maintained** following a contingency or system disturbance by administering automatic corrective actions."*
- WECC (of which AESO forms part) reported in 2022 that *"These schemes [i.e., RAS] have become more common primarily because they are usually less costly and quicker to permit, design, and build than other alternatives such as major transmission lines and power plants."*

Potential Policy Directions

- Adopt global best practices in RAS growth and management

- Incorporate advancements in RAS management technology

- Among TOs, share experiences with RAS for accelerating connection of large loads

?

Appendix

Remedial Action Schemes (RAS)

NERC defines a RAS [or Special Protection Scheme (SPS)] as:

> *"A scheme designed to detect predetermined System conditions and automatically take corrective actions that may include, but are not limited to adjusting or tripping generation (MW and Mvar), tripping load, or reconfiguring a System(s)."*

Practically, a RAS:

- Is series of pre-planned, automatically-triggered actions on the grid to address a specific contingency and maintain system security
- Is typically "armed" when certain system conditions are present (e.g., flows on an element are close to full capacity on normal ratings), "arming" involves notifying parties that participate in the RAS that they need to be ready for automatic corrective action

Each RAS is owned by a "RAS-entity," which can be a transmission owner, generation owner, or distribution provider

New or updated RAS must achieve regional approval as governed by NERC Standard PRC-012-2, which requires:

- Each RAS to include technical documentation of studies demonstrating the effectiveness of the RAS to solve the identified system condition
- Documentation that the RAS meets minimum operating criteria, including that the failure of a single component of a RAS will not cause voltage overloads or cascading outages
- A specified set of minimum review criteria for regions reviewing RAS

NERC also developed reporting and testing requirements associated with RAS:

- Each RAS-entity needs to report on the operation or failure of a RAS within 120 days (or alternate timeline as agreed with region)
- Regions must evaluate each RAS once every five years
- Each RAS must be tested once every six years
- RAS-entities are obligated to implement corrective action plans to address issues identified by the region

Notes and Sources: SPS and RAS are equivalent terms which were originally distinct in NERC standards. NERC, *Glossary of Terms Used in NERC Reliability Standards, February 27, 2026, pp. 43-44.*

RAS Role in U.S. System Planning

Key
Permanent RAS Allowed With Load Shed
RAS Allowed as a Temporary Solution
Permanent RAS Allowed With Restrictions

ISO/RTO	Current Understanding of RAS Planning	Comments
CAISO (WECC)	RAS can be selected over building upgrades, but it must be designed for a post-contingency response and cannot shed firm load if associated with new generator interconnection. Voluntary interruption of firm load is allowed if paid for by the generator.	Unclear whether load shed restrictions apply to large load interconnection. CAISO also limits load shed to 250 MW after a single contingency.
ERCOT	RAS can be considered to resolve a performance deficiency only if the deficiency is expected to be temporary (<5 years), regional planning always considers a no-RAS case to identify upgrades to eliminate RAS	Standards appear designed to eliminate all RAS as soon as possible, seen as bridge to upgrades or band-aid for longer-term deficiencies with end in sight
ISO-NE	RAS can only be used to mitigate “design or operating criteria contingencies” when the contingency is two adjacent circuits on a multicircuit tower, confined to a limited local area, or applied to a facility that is already out of service	Load interruption guidelines have been proposed but not implemented. Unclear whether RAS are intended to be temporary, as RAS can operate for the “life of the associated project or until system changes make it unacceptable or unnecessary.” RAS are allowed to mitigate extreme contingencies.
MISO	RAS can be "considered" as substitutes for required upgrades but are not automatically assumed to resolve issues and should be temporary	The criteria for evaluation of a RAS in lieu of an upgrade is not clear, but the ability to propose a RAS is clearly permitted
NYISO	RAS can be created to address temporary conditions, including project delays and unavailability, and are applied in the event of severe outages and contingencies. RAS are not proposed in lieu of permanent upgrades.	Standards state that RAS (SPS) should be evaluated for complexity and the consequences of incorrect operation. RAS can be used to protect the system after a severe outage or extreme contingency.
PJM	RAS can be included as part of a corrective action plan in conjunction with upgrades but cannot shed load	Unclear whether RAS are intended to be temporary, not specifically noted as in other planning criteria; PJM has worked to remove RAS in planning
SPP	“Extended Use” RAS can be a substitute for network upgrades if no other upgrades are required through other processes, can shed a max of 200 MW of load and 600 MW of generation	Temporary (30-month) RAS are also allowed in association with a specific planned upgrade. Other mitigation plans must be considered before use of an extended use RAS. Zones can set specific load shed limits for a RAS but must be approved by SPP, default is 200 MW.