Coal Generation Retirement and Load Serving Capability in Colorado

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GridNumerics™

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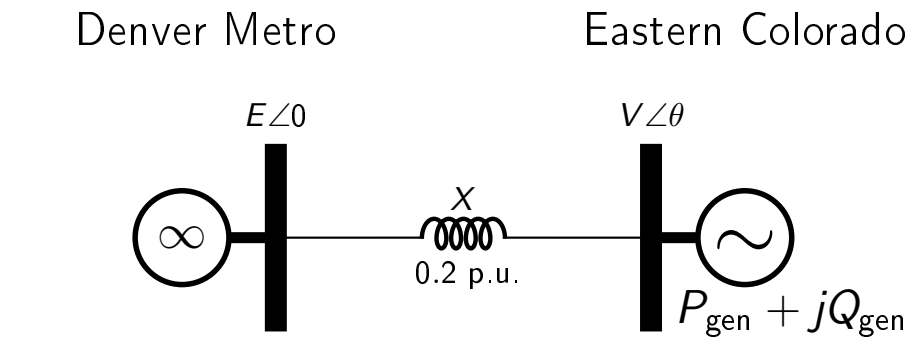
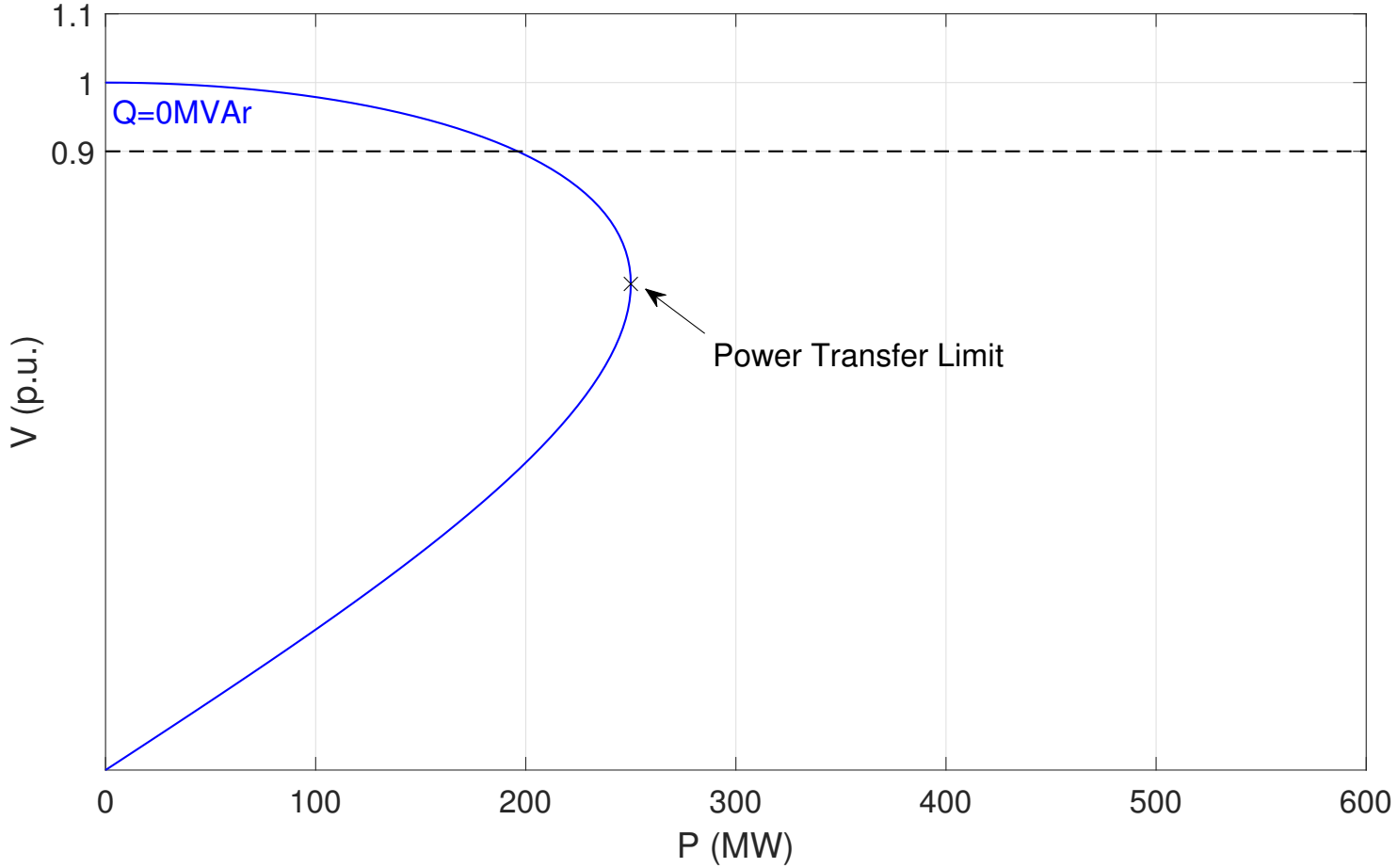
Outline

- Power Transfer in a Radial Path
- Power Transfer between Regions: An Illustrative Example
- Power Transfer between WECC and Colorado: Study Results
- Grid Numerics Platform

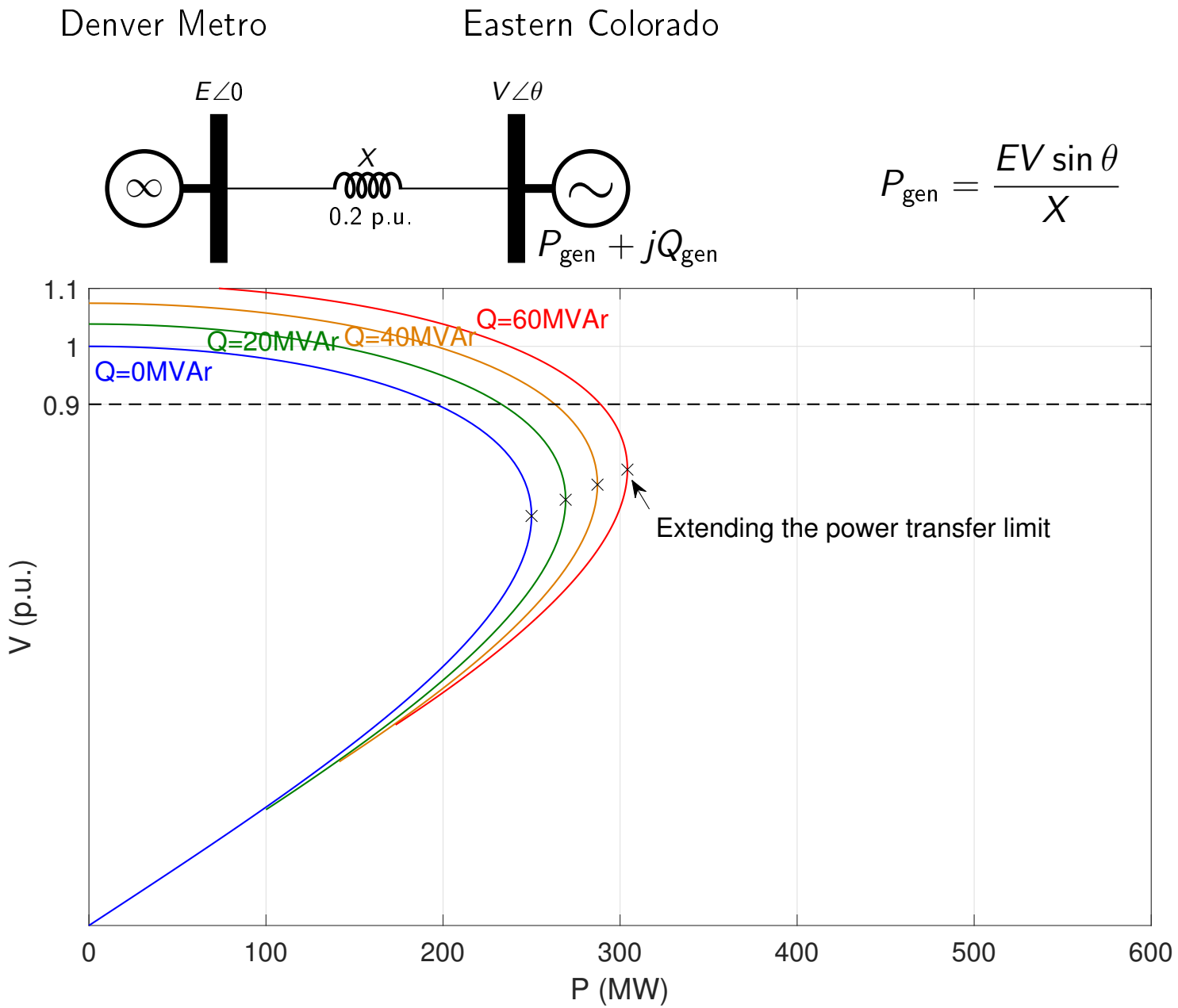
Power Transfer: Radial Path



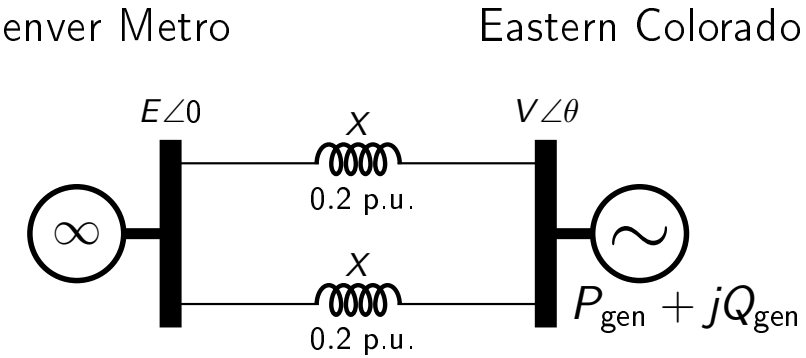
$$P_{gen} = \frac{EV \sin\theta}{X}$$



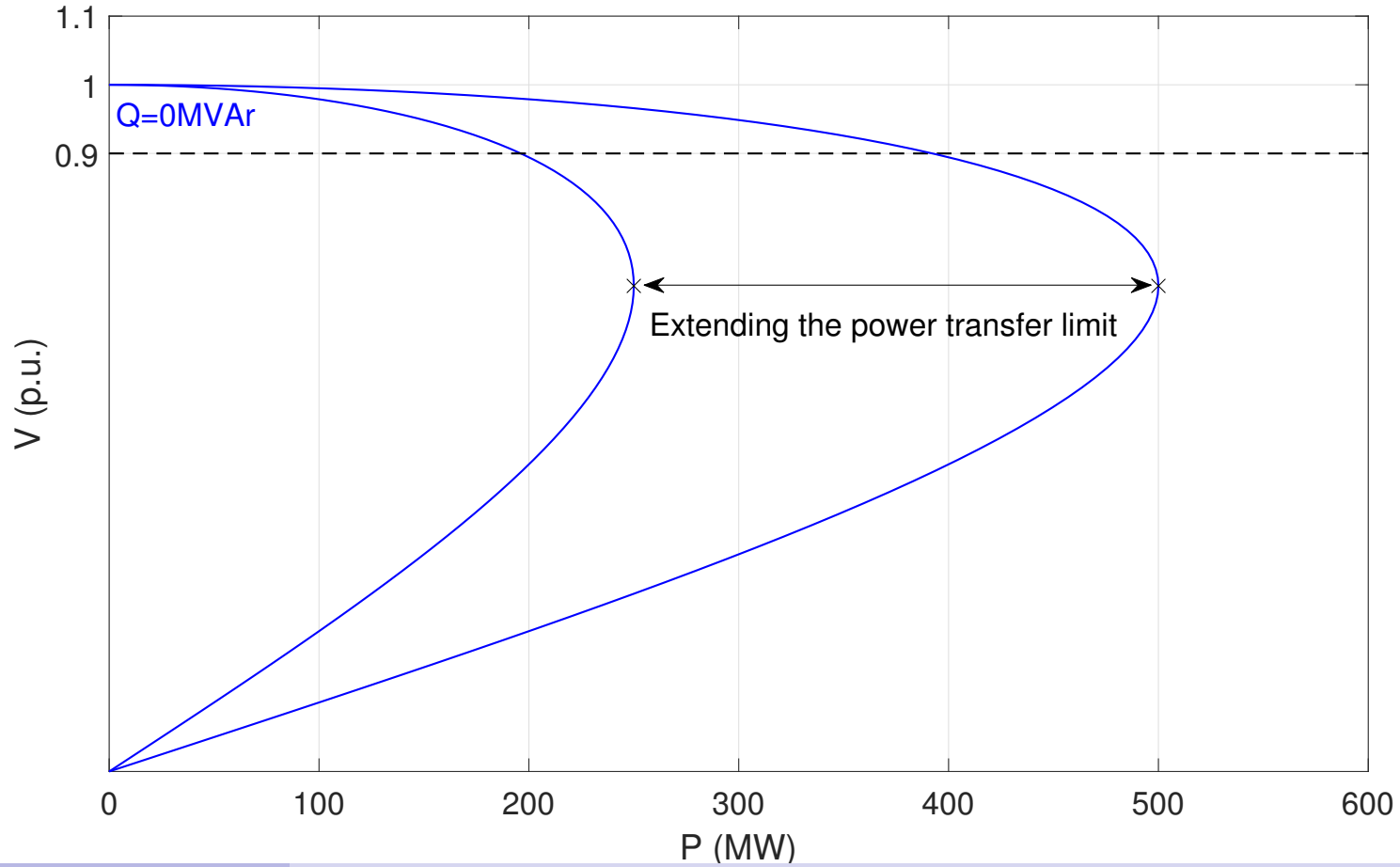
Power Transfer: Reactive Compensation



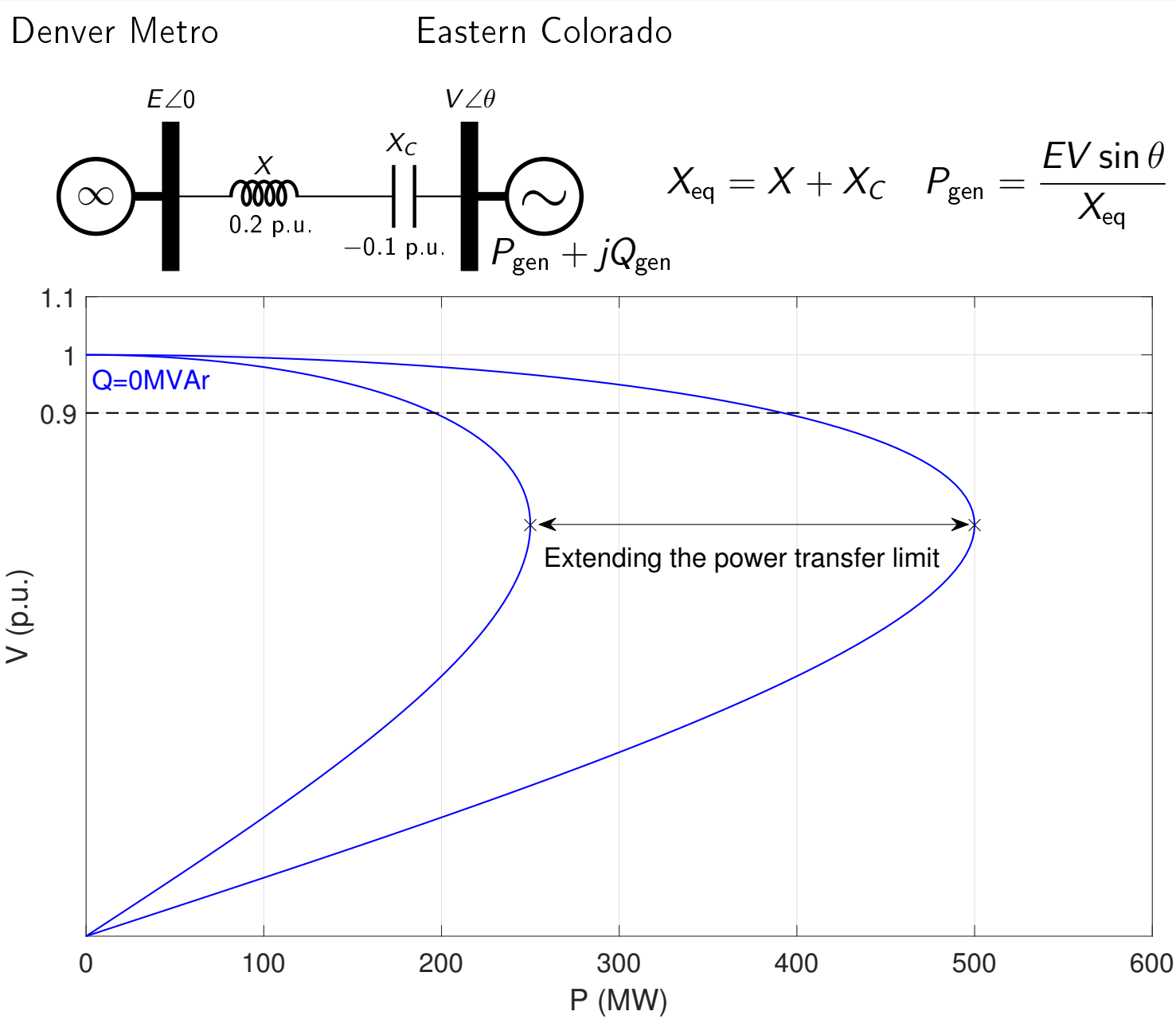
Power Transfer: Building New Lines



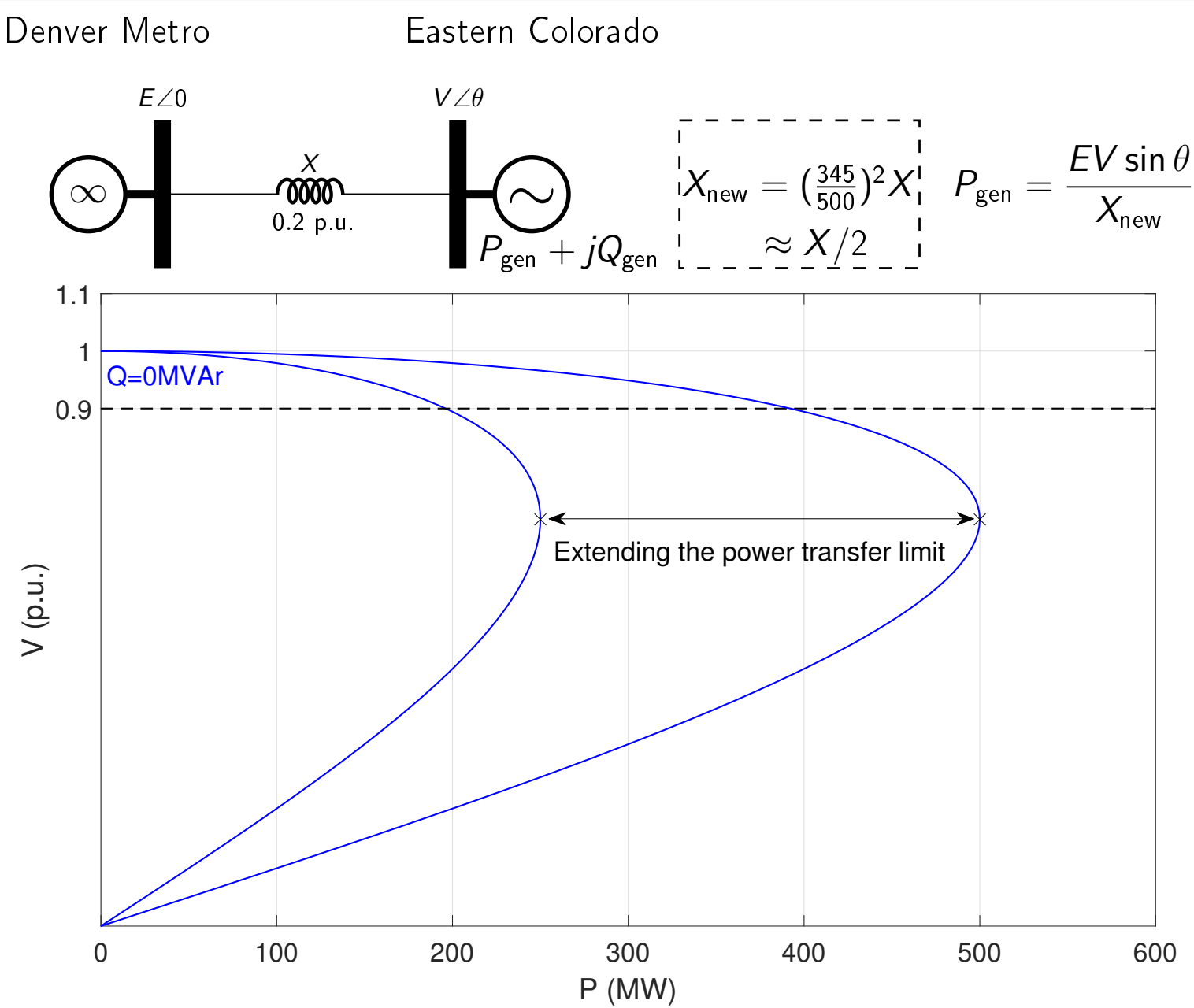
$$X_{eq} = X/2 \quad P_{gen} = \frac{EV \sin\theta}{X_{eq}}$$



Power Transfer: Series Compensation



Power Transfer: Choosing Extra High Voltage



Enhancing the Power Transfer Capability

1. Build new transmission lines
2. Series compensation
3. Increase the base operating voltage from 230 to 345 or even 500kV

Injecting reactive power is not a solution and could destabilize the system!

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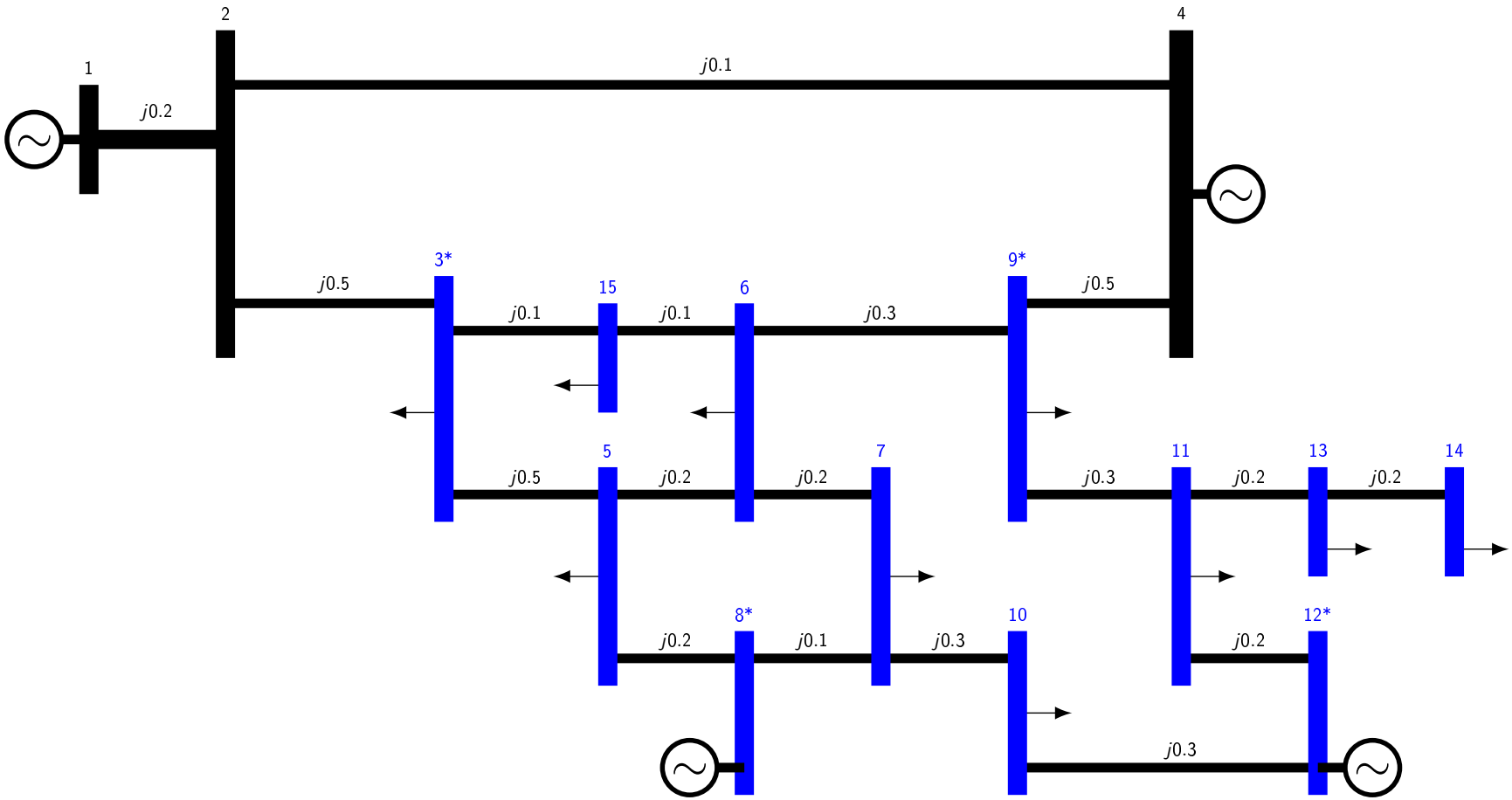
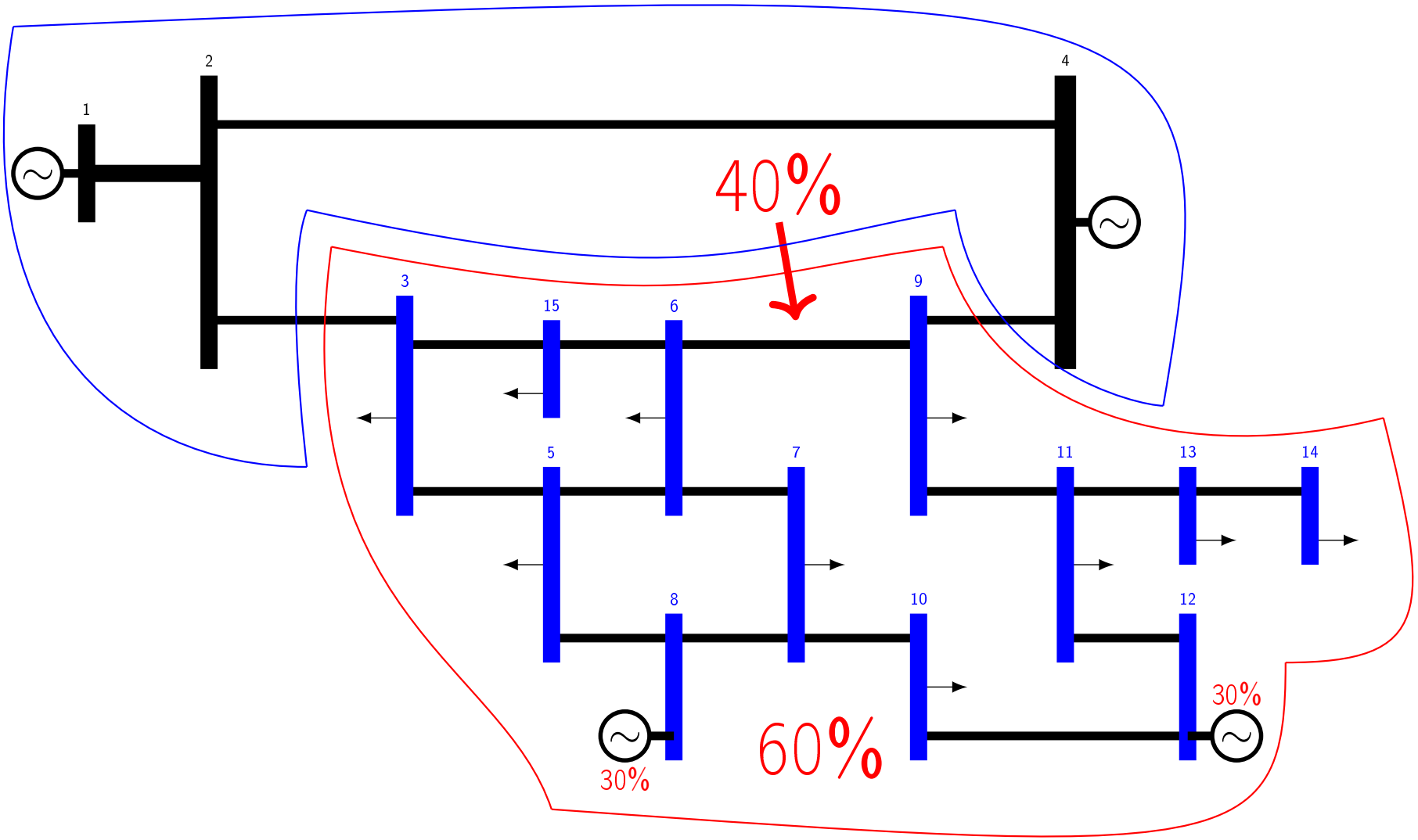
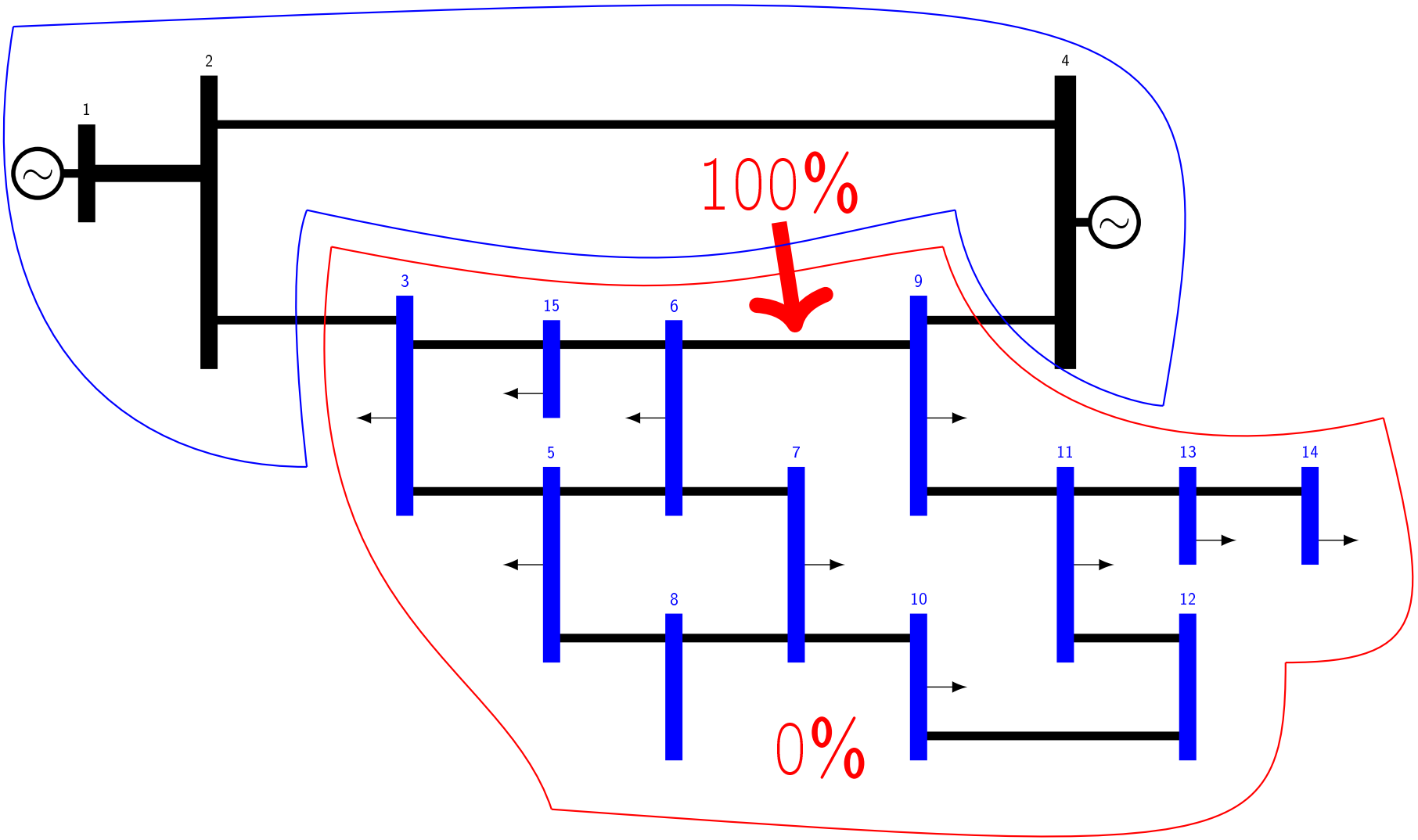
Inter-regional Power Transfer: An Example



Dispatch Scenario 1: 60% local, 40% from outside

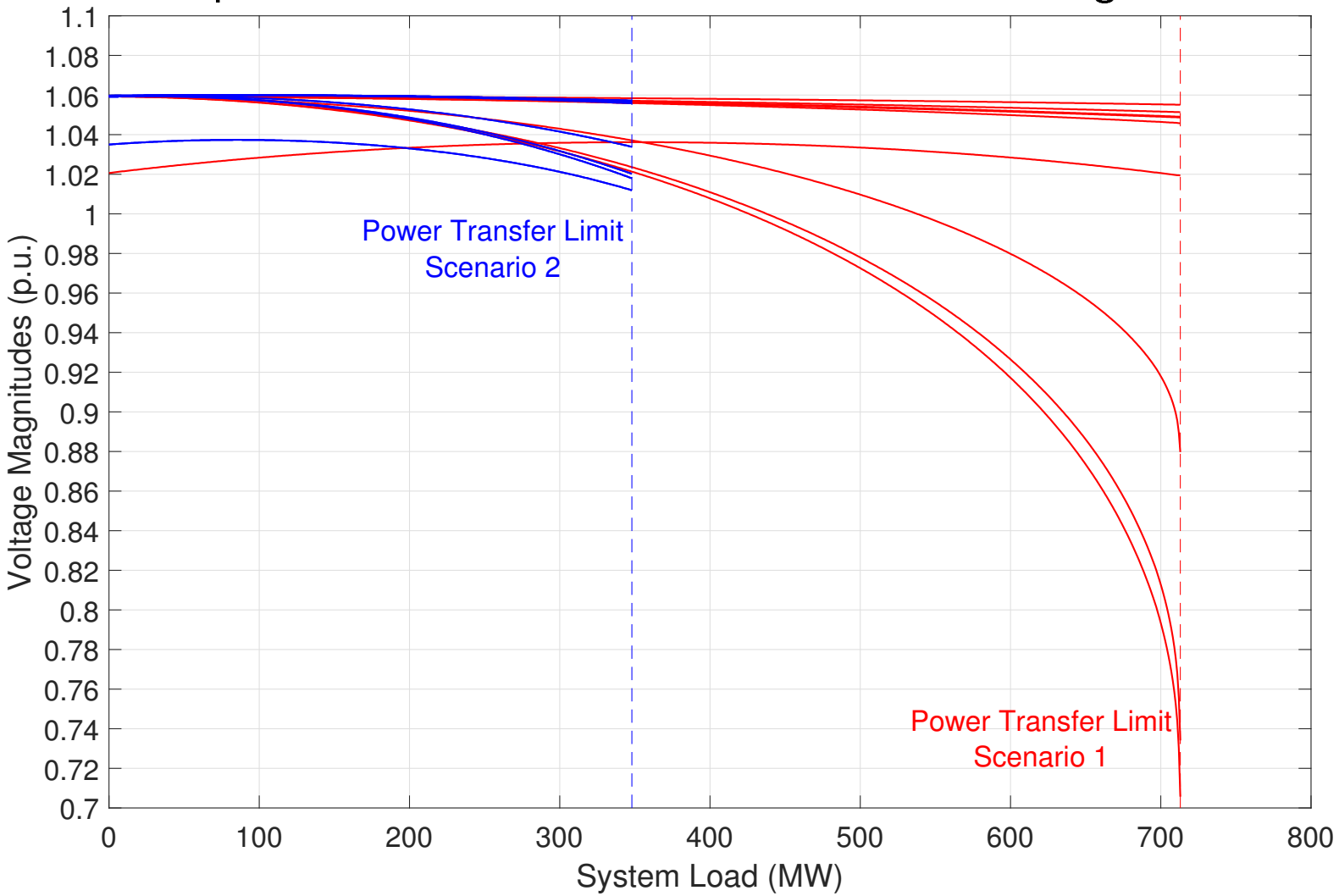


Dispatch Scenario 2: 0% local, 100% from outside



Power transfer limit can occur at normal voltages

In Scenario 2 all the voltages are in the range of $1.01 - 1.06$ p.u. at the power transfer limit, i.e. at 350MW of loading.



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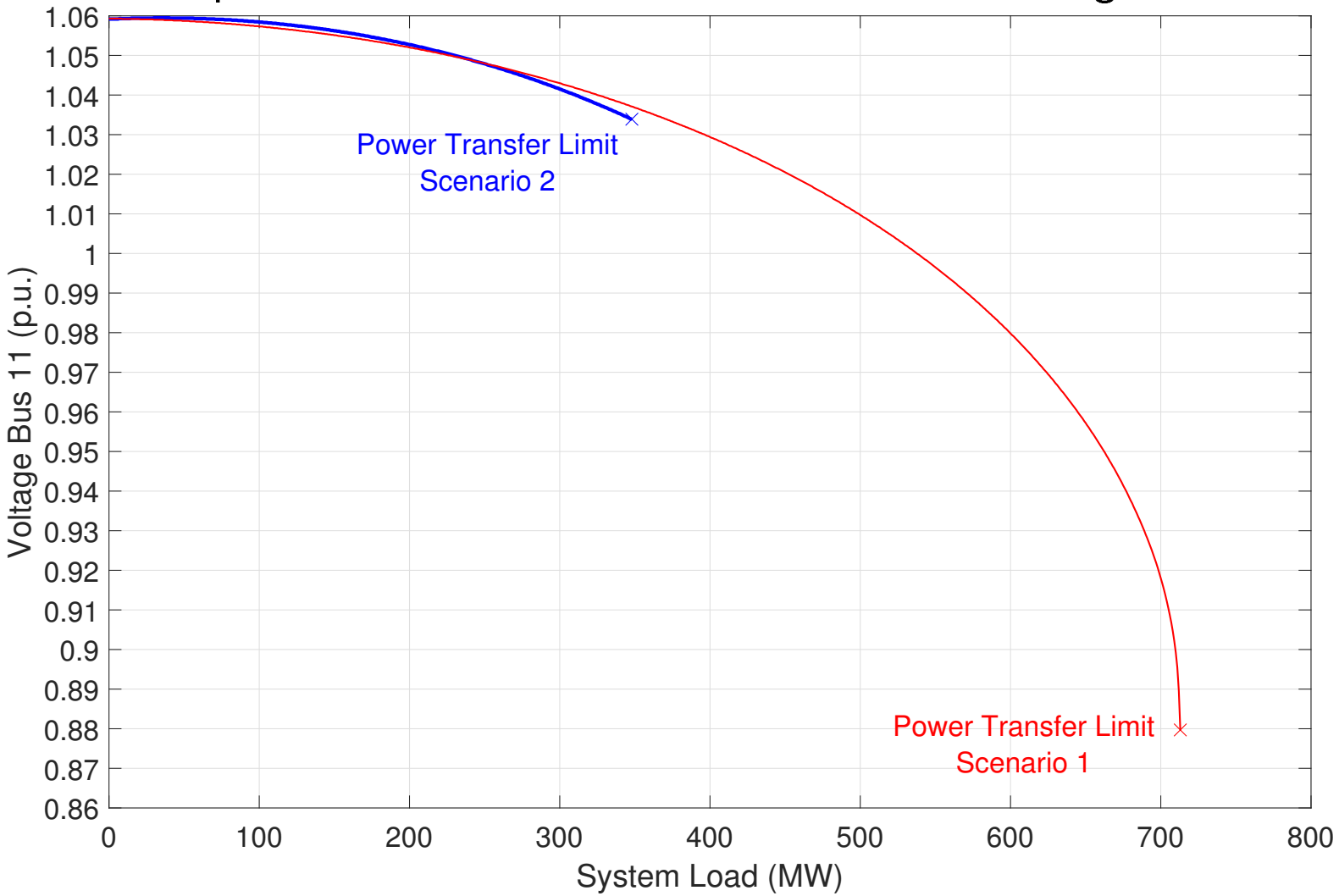

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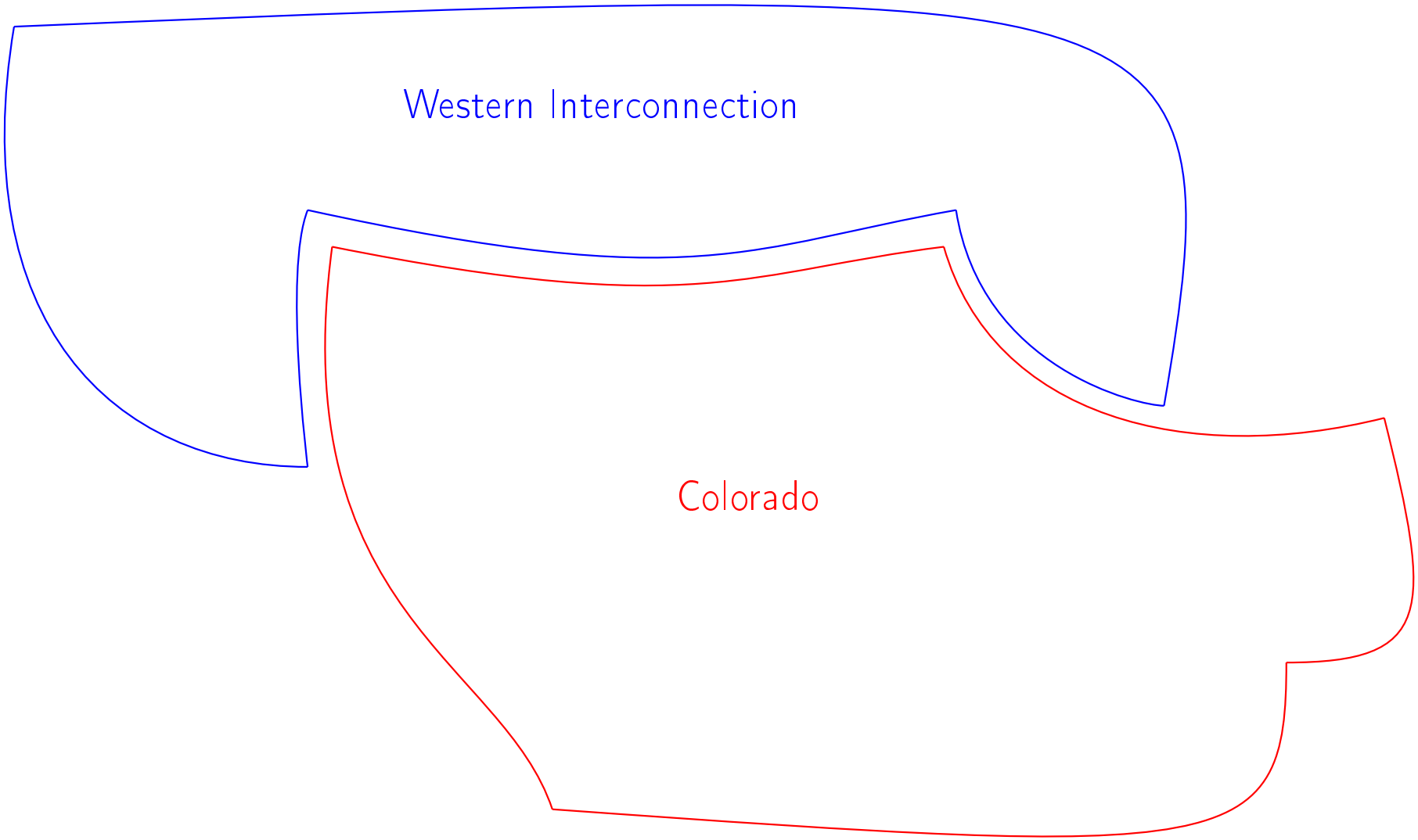
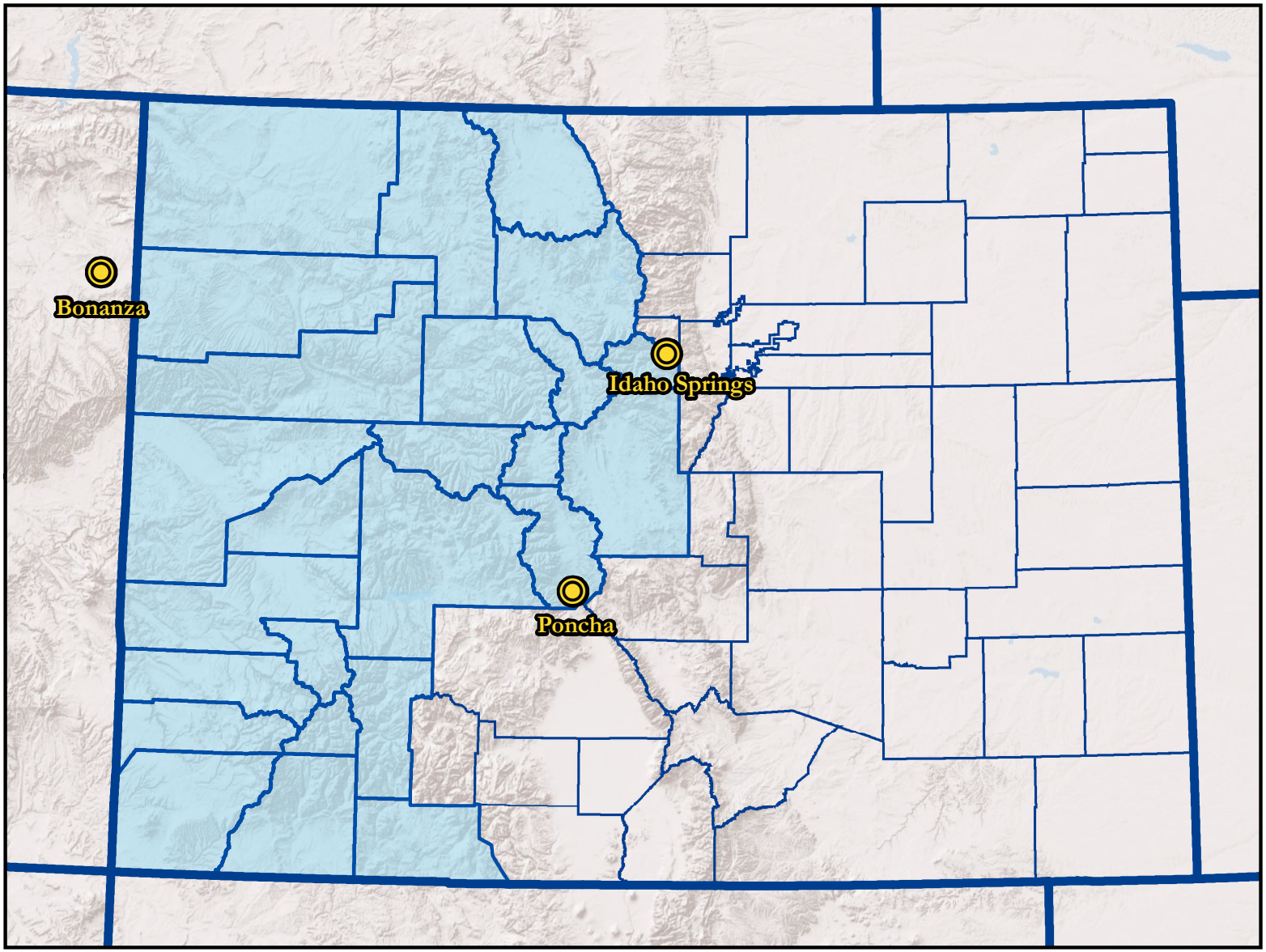
Power Transfer between WECC and Colorado



Western Colorado



Methodology

Contrast the load serving capability of the grid in Western Colorado before and after the retirement of Craig 1,2&3 and Hayden 1&2 units:

- Craig 1: 470MW
- Craig 2: 470MW
- Craig 3: 478MW
- Hayden 1: 202MW
- Hayden 2: 285MW

Roughly 1900MW of coal generation in NW Colorado is to be retired.

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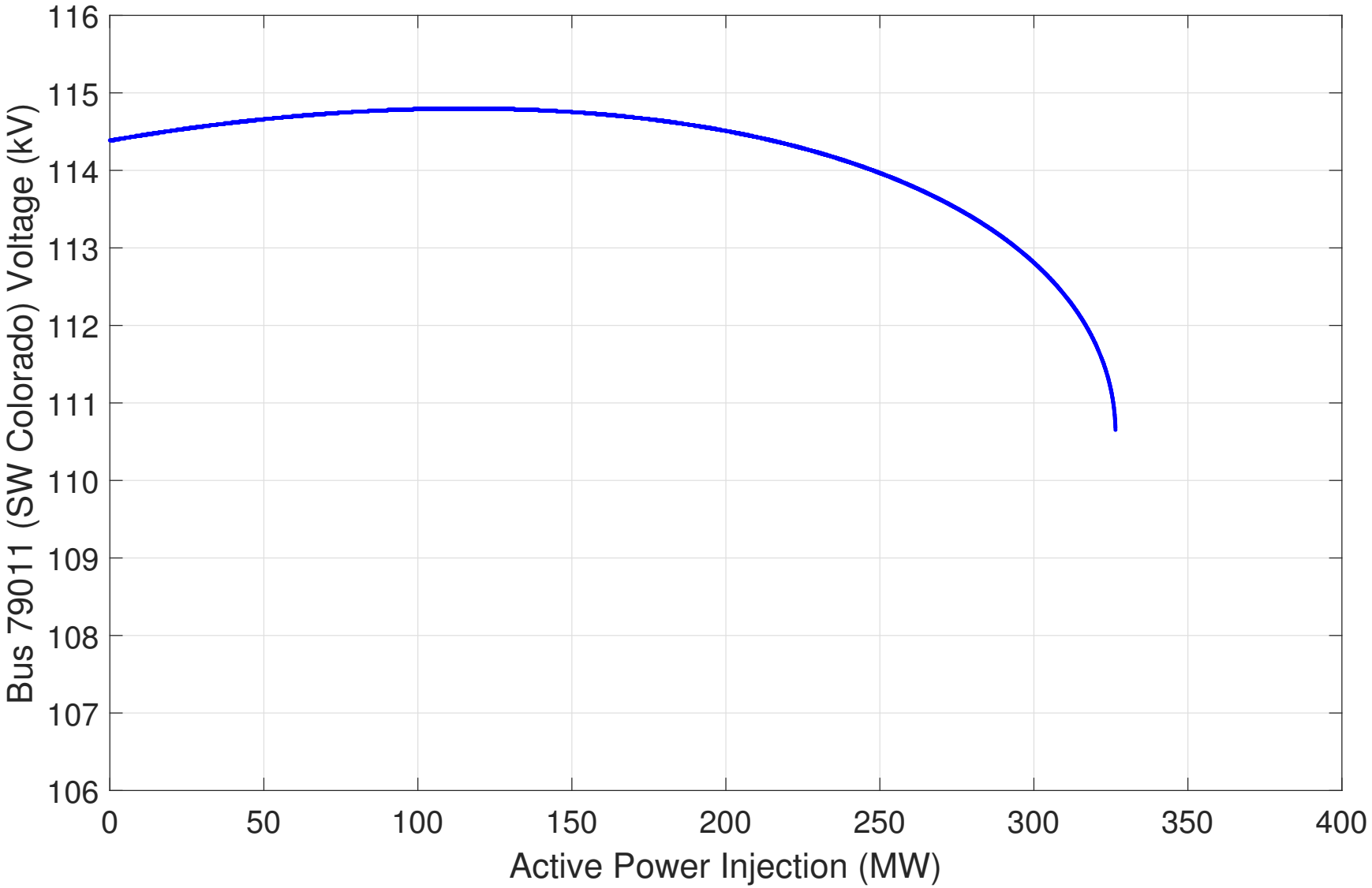
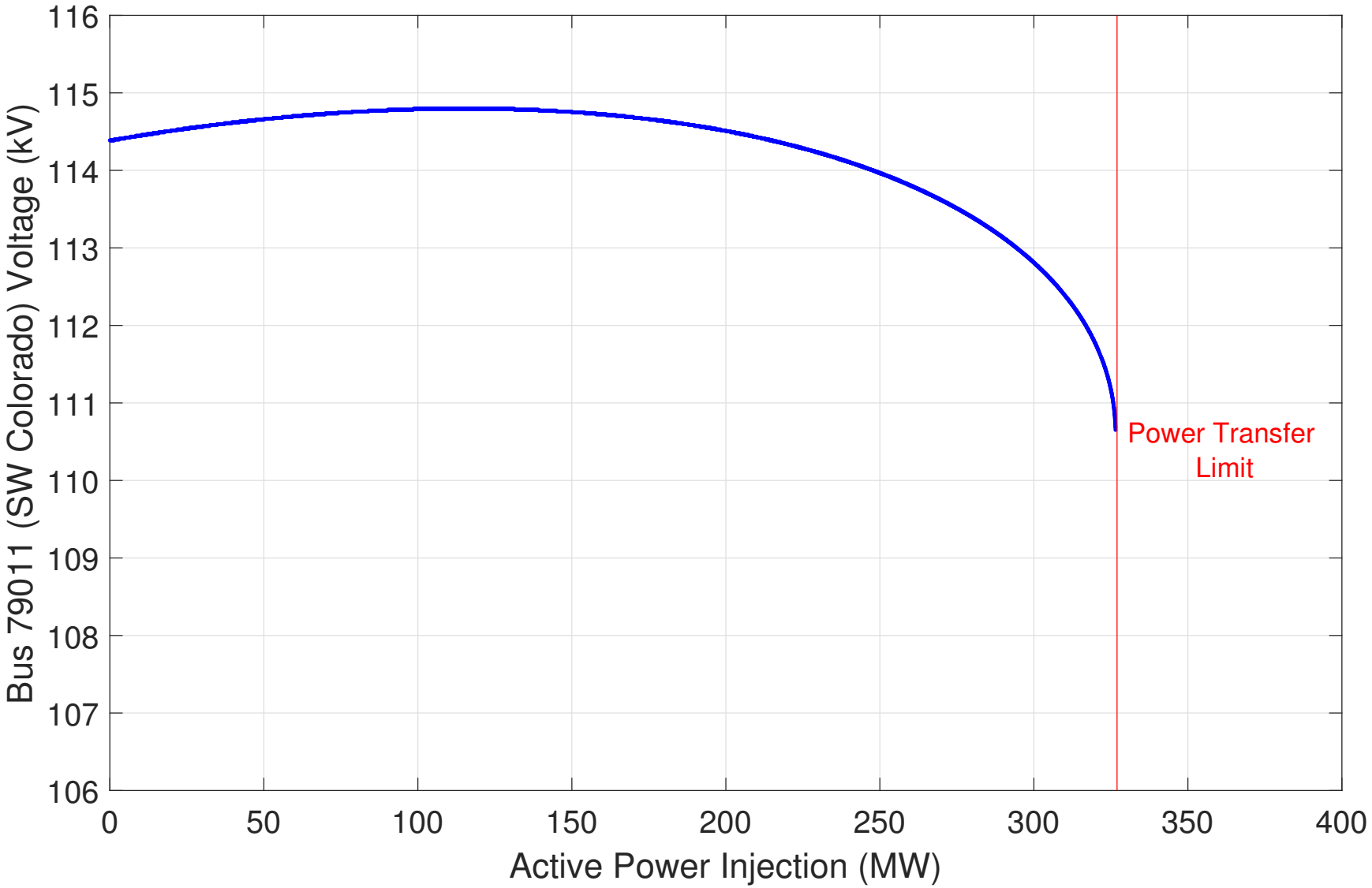
Roughly 1900MW of coal generation in NW Colorado is to be retired.

But how to develop an objective and meaningful metric for load serving capability? A metric that can model and anticipate previous power transfer limit events in the West Coast or Texas?

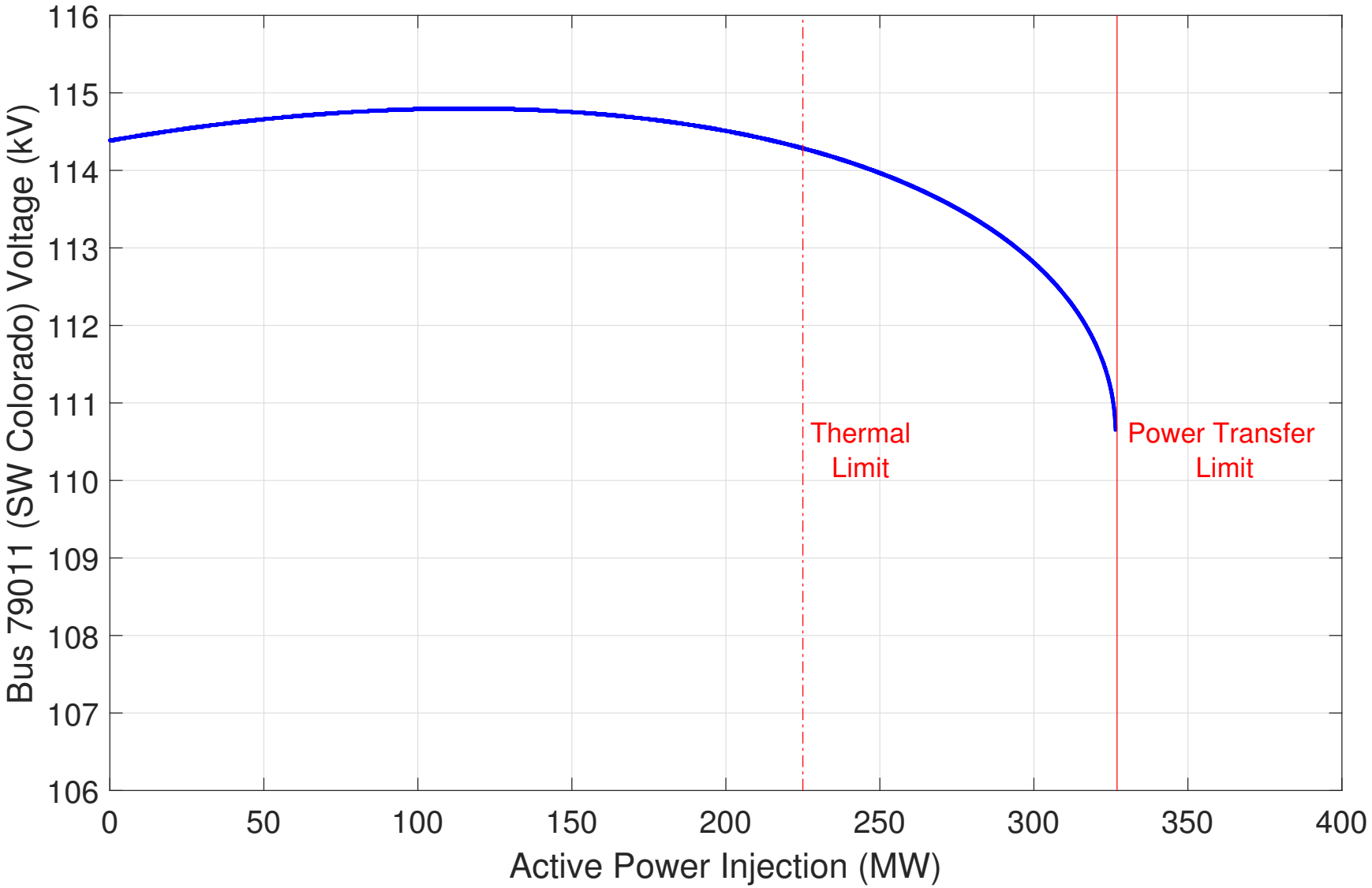
PV Curves: Classical approach with limited usefulness



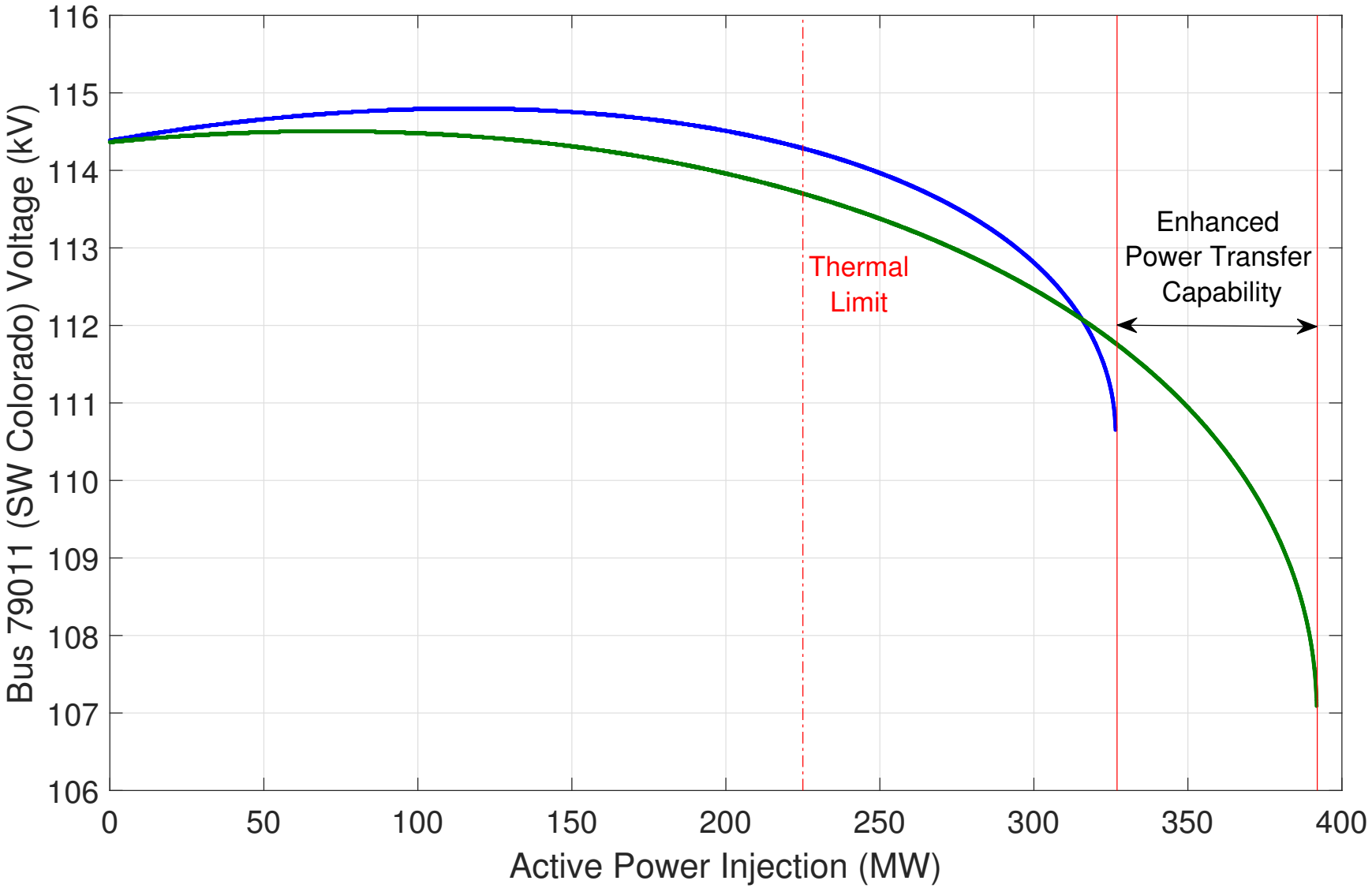
PV Curves: Classical approach with limited usefulness



Thermal limits encountered well before power transfer limits



Mitigation irrelevant with thermal limits already encountered



A more sensible approach: **Composite Load Serving Capability**

Stress the system by increasing generation and load *simultaneously* at *multiple* nodes until reliability issues, either thermal or transfer limits, are encountered:

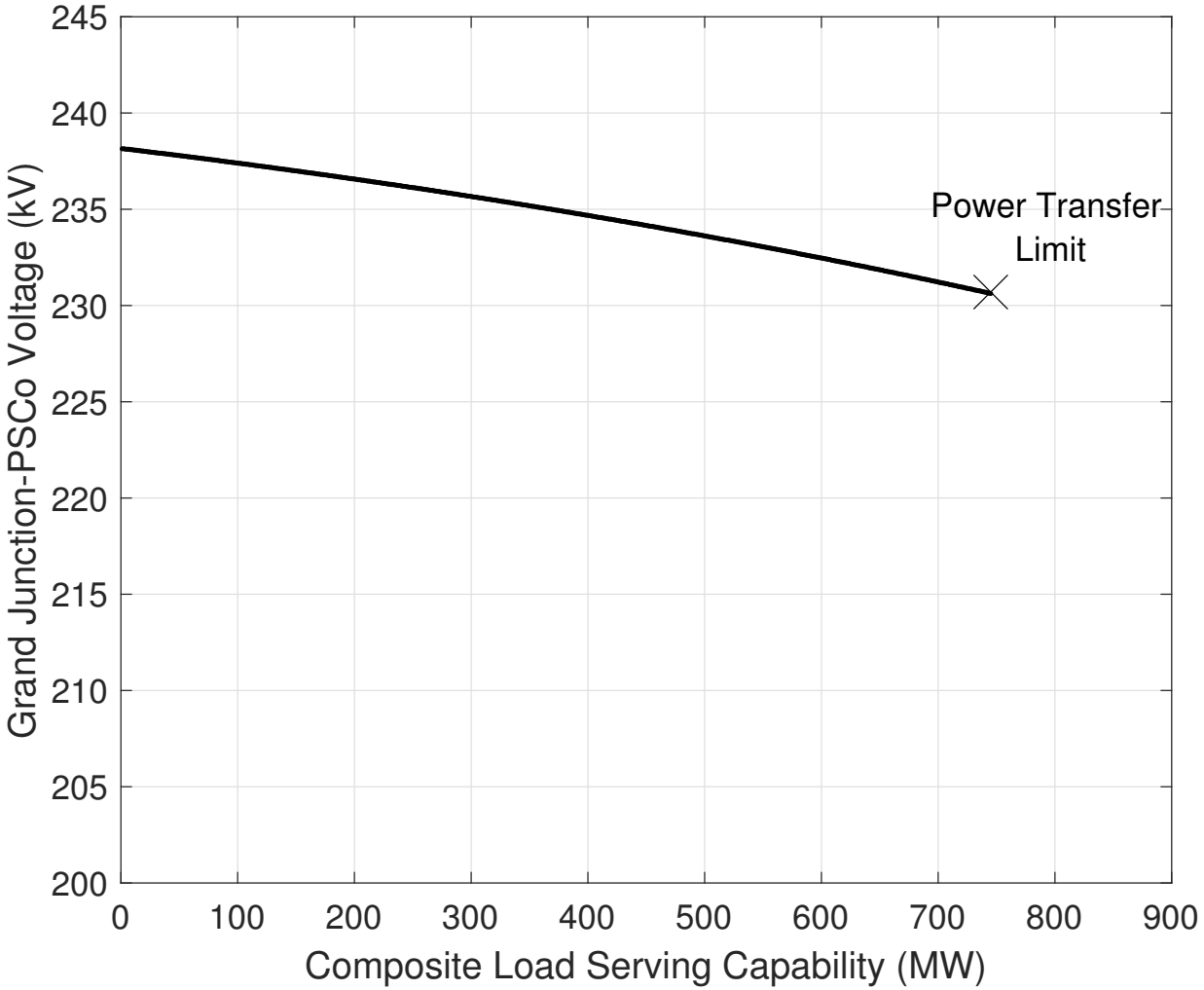
- The multi-dimensional change in load and generation captures more realistically how a normal operating condition could evolve into a reliability situation.
- Extremely complicated to model
- No industry software or systematic approach to stress the system in a multi-dimensional manner.

Composite Load Participation Factors (%)

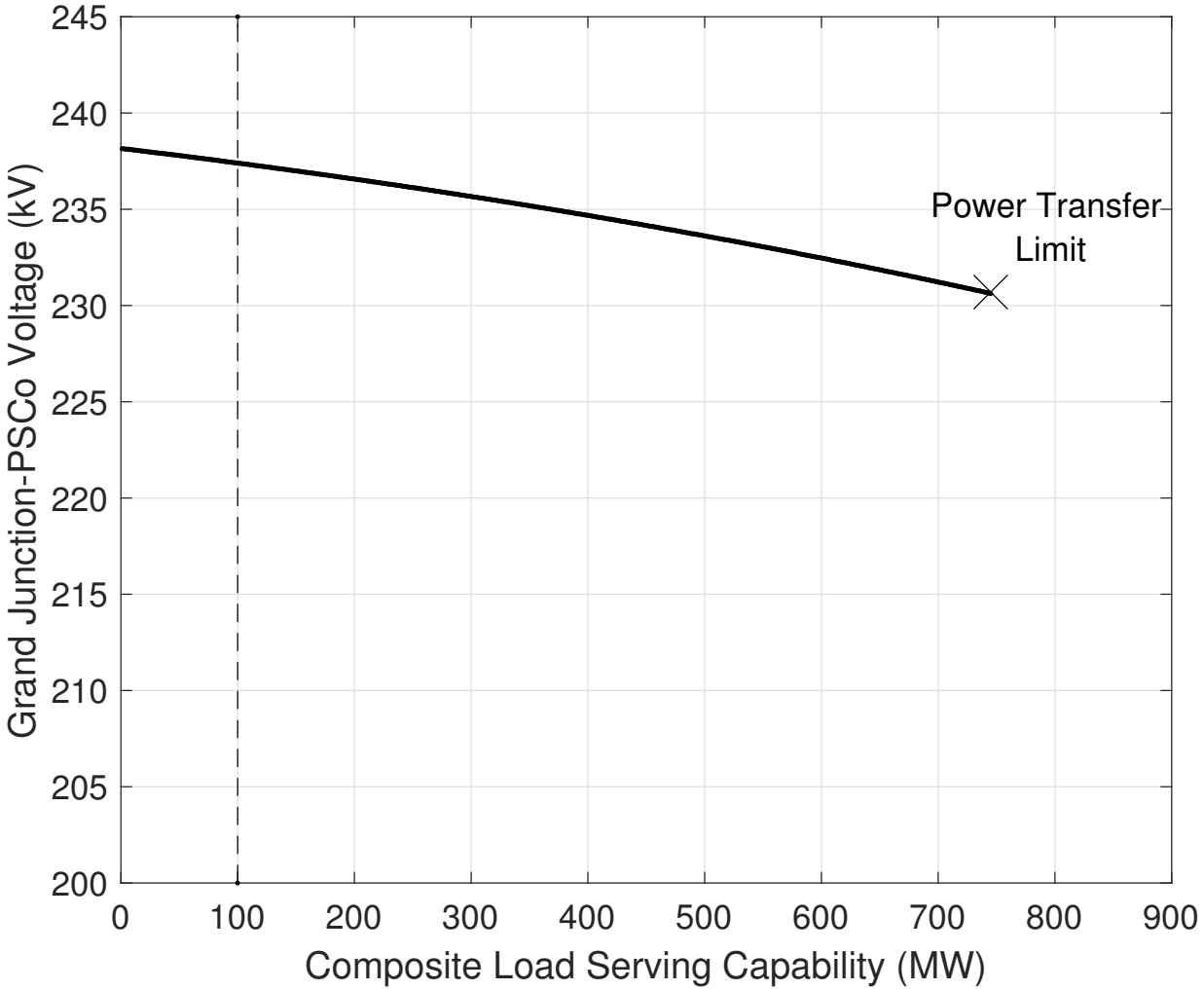
ID	Substation	Voltage	%
66278	RANGLEY	138	4
70009	CRAIG_YV	230	1
70055	BNVST	115	1
70089	CARBNDAL	115	1
70109	UNA_ORCH	69	2
70113	CLIFTON	230	3
70114	CLIMAX	115	3
70206	GRANDJPS	230	7
70214	GRANDJCT	69	3
70218	HENDERPS	115	1
70233	HORIZON	230	3
70268	ADOBE	230	1
70281	MAYFLOWR	115	2
70287	MILL	115	3
70299	STKGULCH	230	5
70304	OTEROTP	115	1
70309	PARACHUT	230	2
70357	BENCH	230	5
70438	UINTAH	230	3
70541	ASPEN_PS	115	3
70542	SNOWMASS	115	1
70560	BASLTDST	115	1
72137	TELLURID	115	1
72780	GOODMNPT	115	1
72781	DOECANYN	115	1
72784	AIR_PROD	115	1
72786	BASKTMKR	115	1

ID	Substation	Voltage	%
72800	EMONTROS	115	1
73061	FRASER	138	1
73220	WINDYGAP	138	1
79006	BEAVERCU	115	2
79018	CRYSTLPS	115	1
79037	GUNNISON	115	1
79042	HOTCHKIS	115	1
79056	RIFLE_CU	138	1
79065	STEAMBT	230	2
79066	VAIL	115	2
79067	VERNAL	138	1
79069	WOLCOTT	230	1
79075	EMPIRETS	115	1
79076	AM EAST	115	1
79077	BAYFIELD	115	2
79078	BODO	115	4
79079	BULLOCK	115	2
79081	CRSTBUTT	115	1
79082	HAPPYCAN	115	1
79086	PAGOSA	115	1
79092	AVON	115	1
79099	FLOR.RIV	115	2
79103	GARNET M	115	3
79108	HOVENWEP	115	2
79118	Y.JACK W	115	1
79127	SYLVSTGU	115	1
79400	DES.MINE	138	1

Composite Load Serving Capability

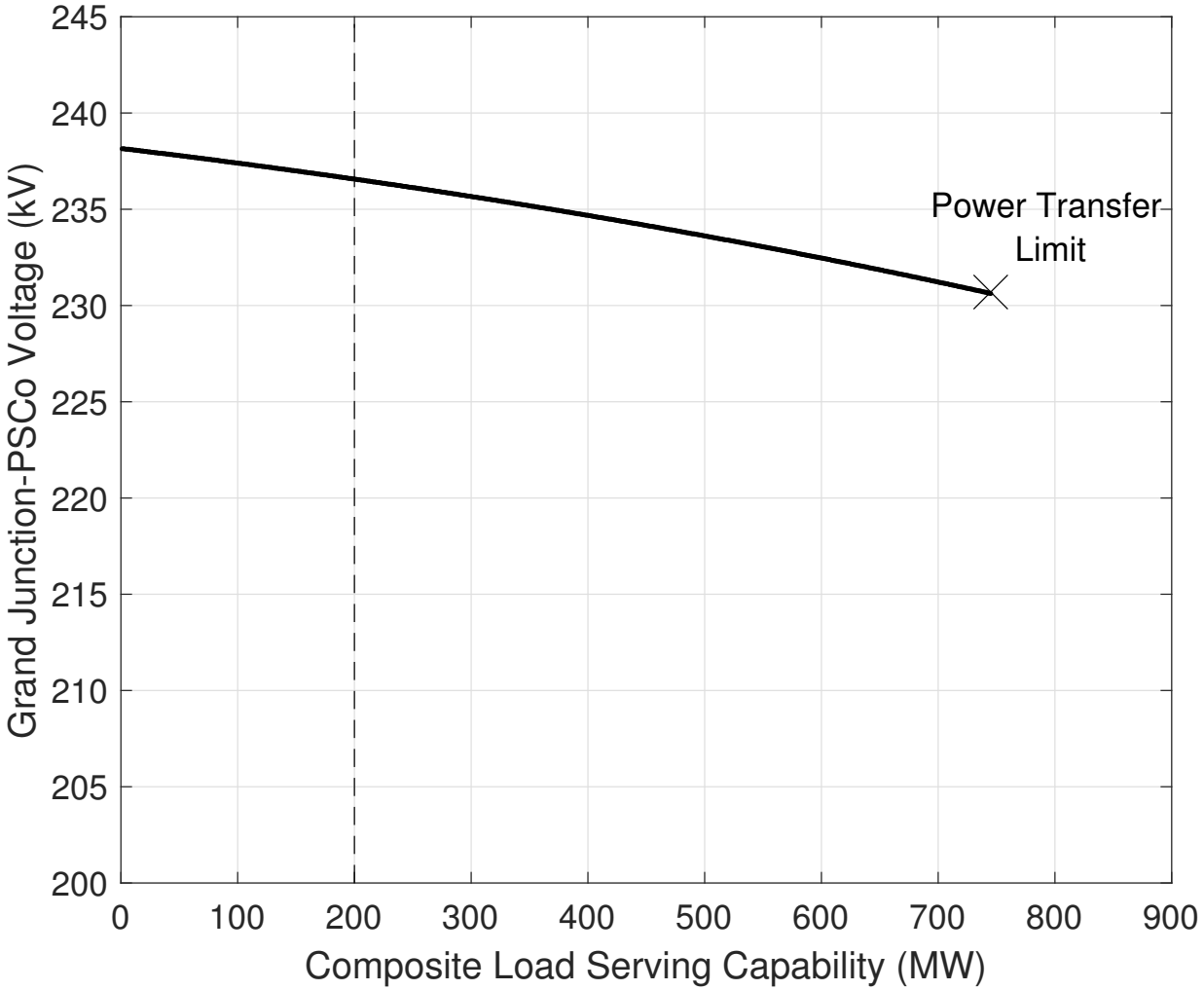


Composite Load Serving Capability



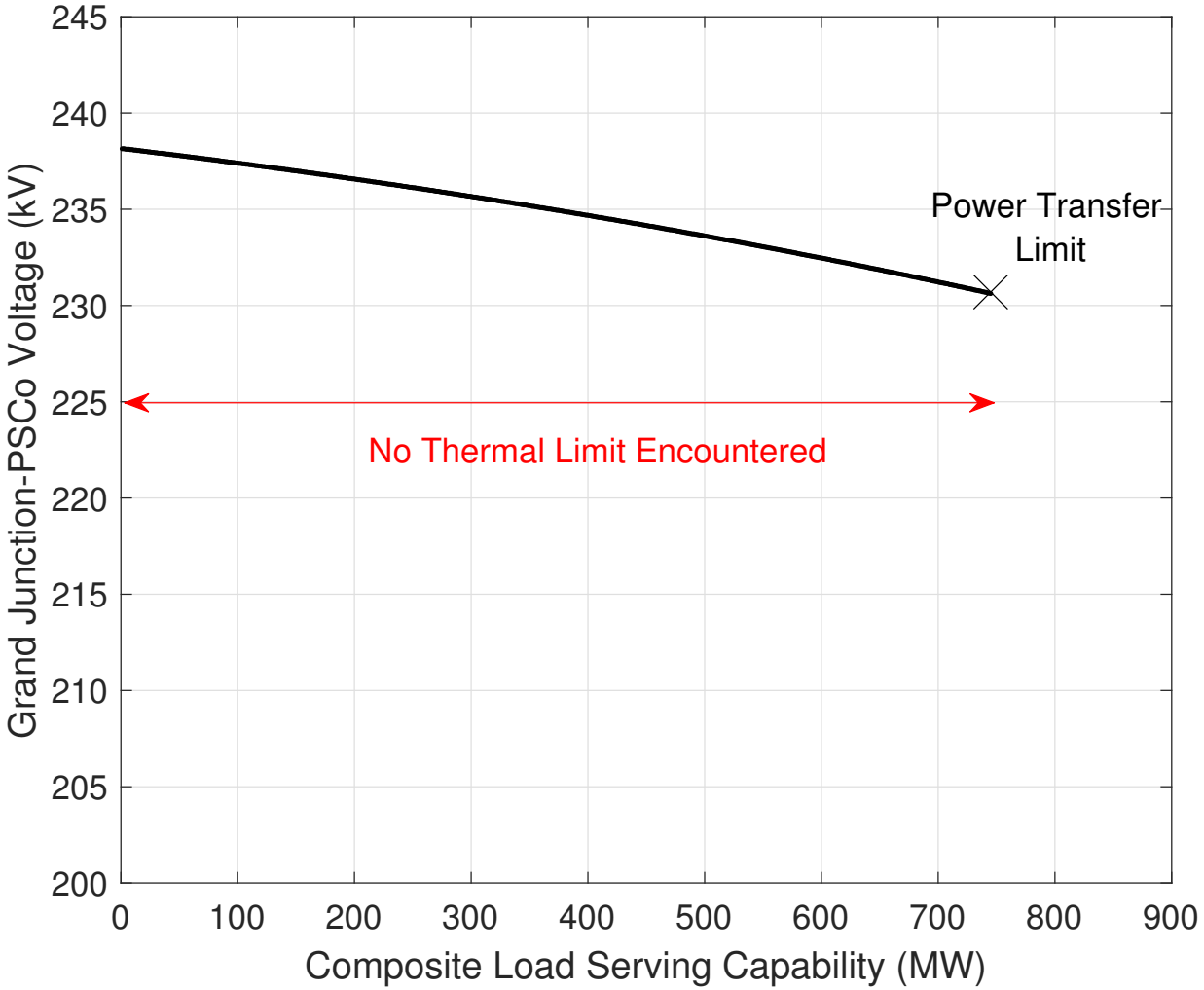
Composite Load		Grand Junction		Aspen		Steamboat		etc
100MW	=	7MW	+	3MW	+	2MW	+	...

Composite Load Serving Capability



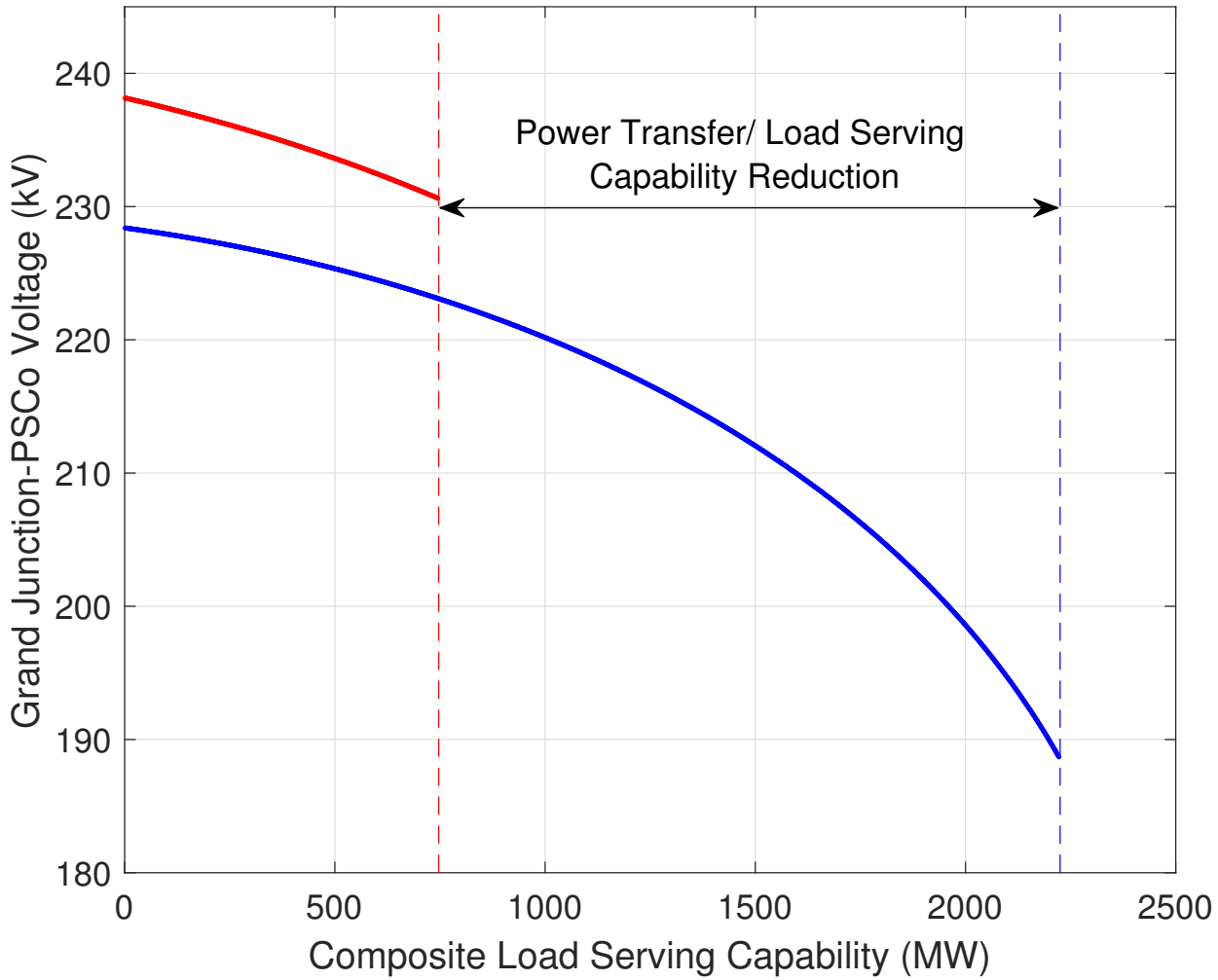
Composite Load		Grand Junction		Aspen		Steamboat		etc
2×100MW	$=$	2×7MW	$+$	2×3MW	$+$	2×2MW	$+$	...

Composite Load Serving Capability



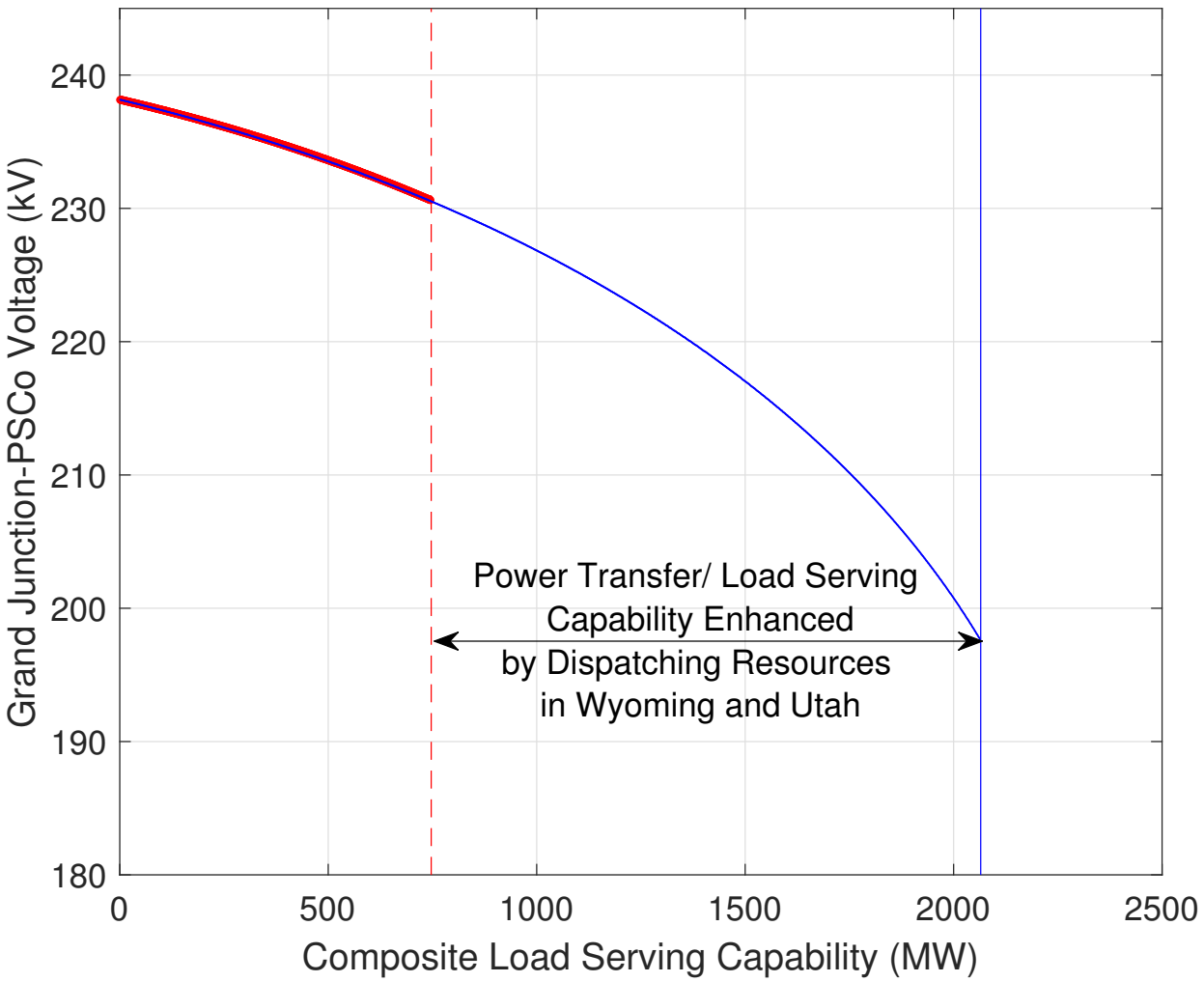
750MW increase in load can push the system to its power transfer limit without causing a single thermal overload!

Dispatch Resources in NW (Washington/Oregon)



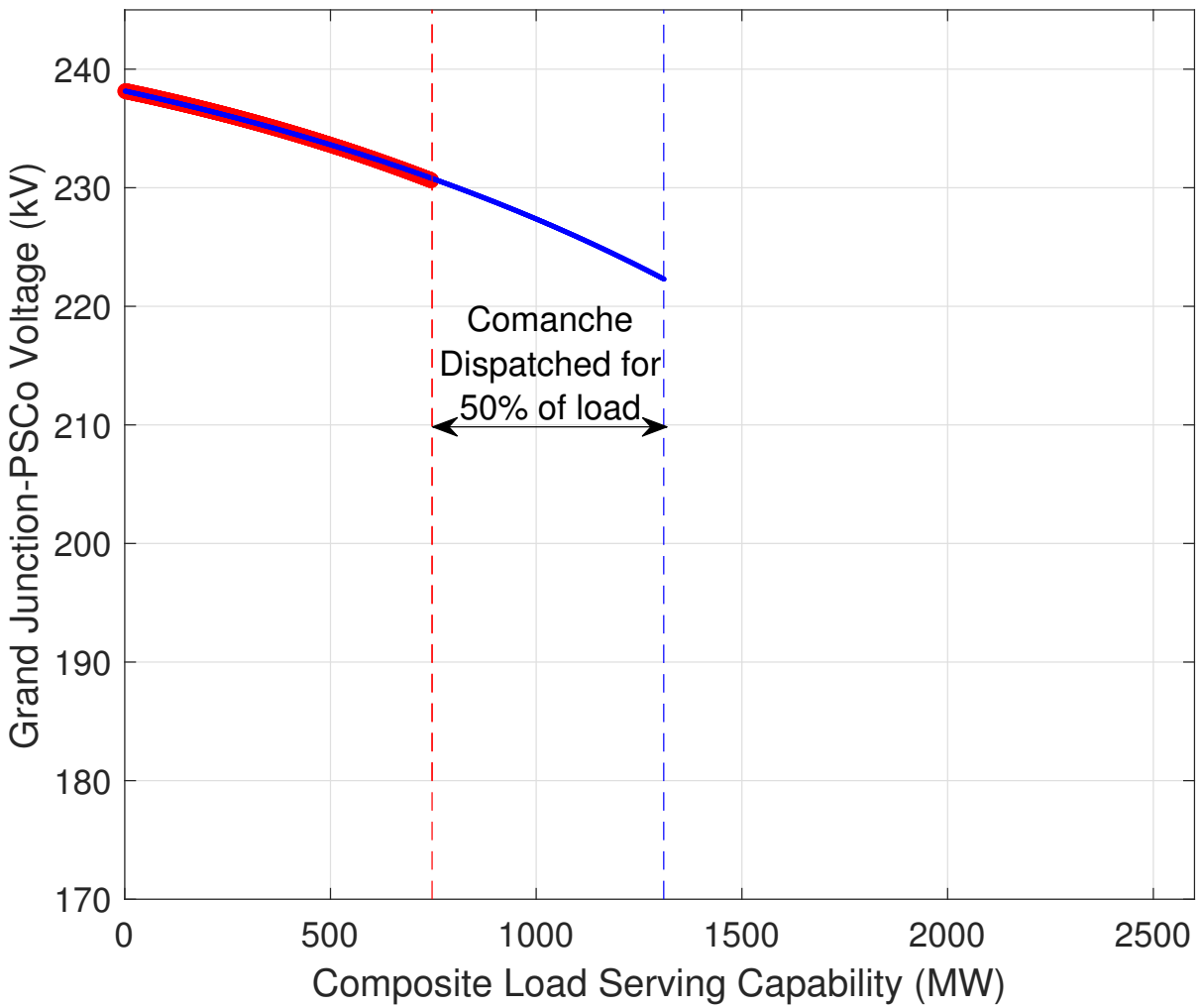
Distributed Slack: Grand Coulee 50%, John Day 25%, Klamath Falls 25%

Dispatch Resources in the Rocky Mountain Region



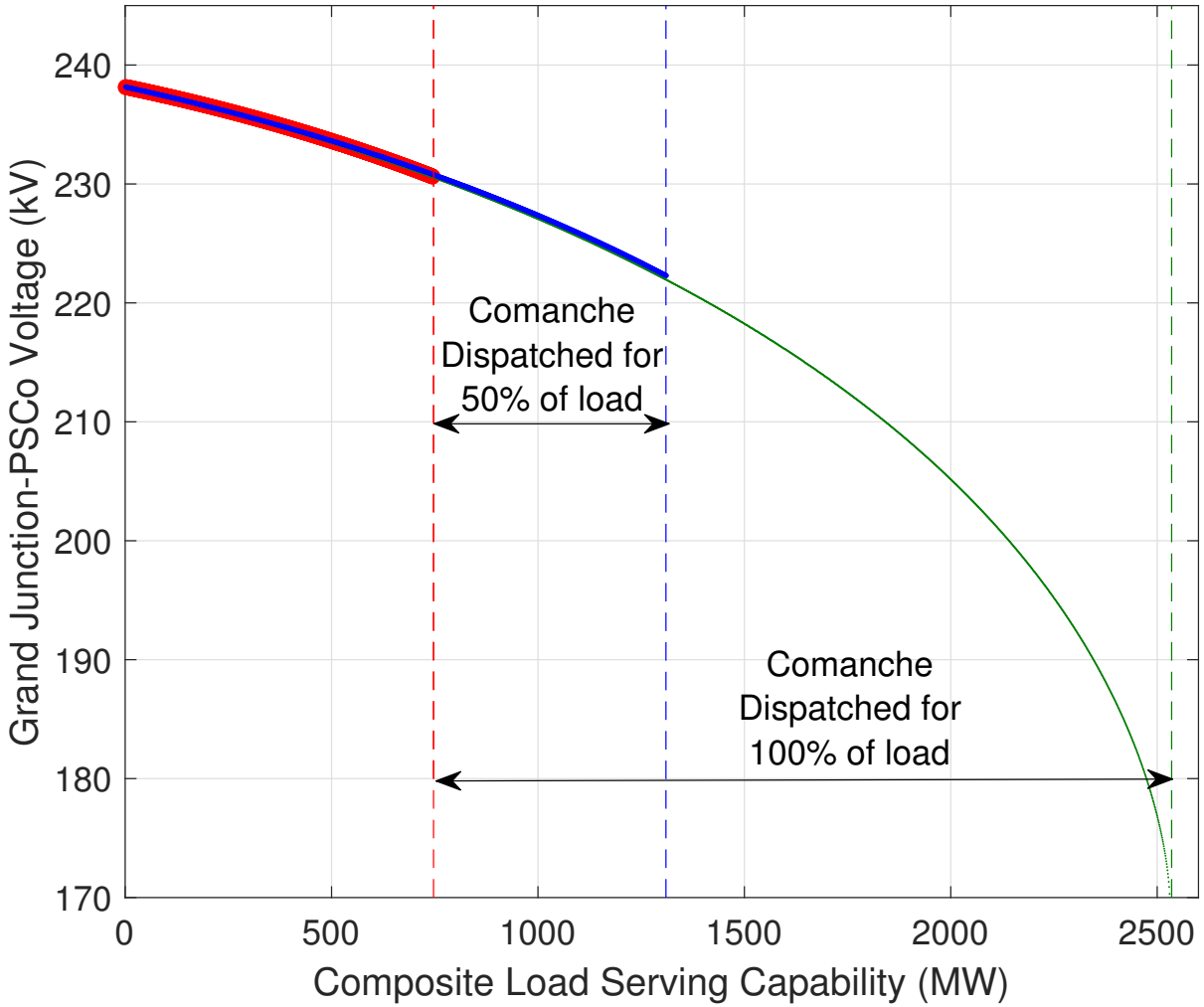
Distributed Slack: Intermountain (UT) 50%, Jim Bridger (WY) 50%

Partial Dispatch of Resources in Colorado



Distributed Slack: Comanche 50%, Grand Coulee 25%, John Day 25%

Dispatch Resources in Colorado (if available!)



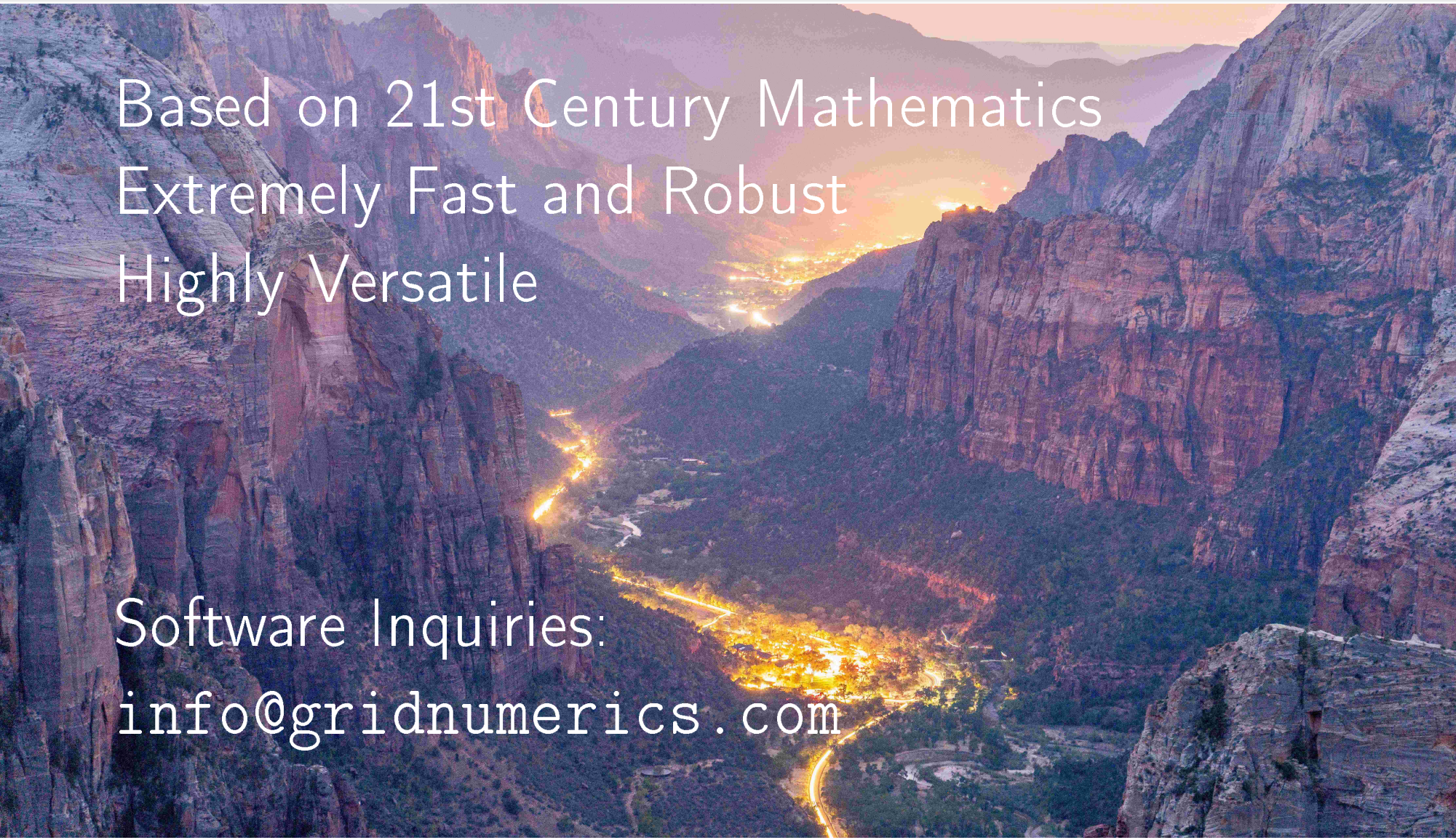
Conclusion

The power transfer capability between Colorado and the rest of the Western Interconnection is limited. How to mitigate this issue?

- Better integrate Colorado's grid into the Western Interconnection through new transmission lines.
- Better integrate Colorado's grid into the Eastern Interconnection by building new DC ties.
- Reduce the variability of renewable generation through spatial distribution and diversifying the resource mix between solar, wind and storage.

Unless this inter-regional power transfer capability is addressed with a combination of measures that *better integrates* the Colorado grid into the Western and Eastern Interconnections and *reduces the variability* of renewable generation resources, removal of large-scale centralized generation *may* cause load serving issues or partial blackouts.

Grid Numerics:
A New Platform for Analyzing Power Transfer



Based on 21st Century Mathematics
Extremely Fast and Robust
Highly Versatile

Software Inquiries:
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