

Smart RAS (Remedial Action Scheme)

IEEE PES Conference on
Innovative Smart Grid Technologies

January 19-21, 2010

NIST Conference Center, Gaithersburg, MD

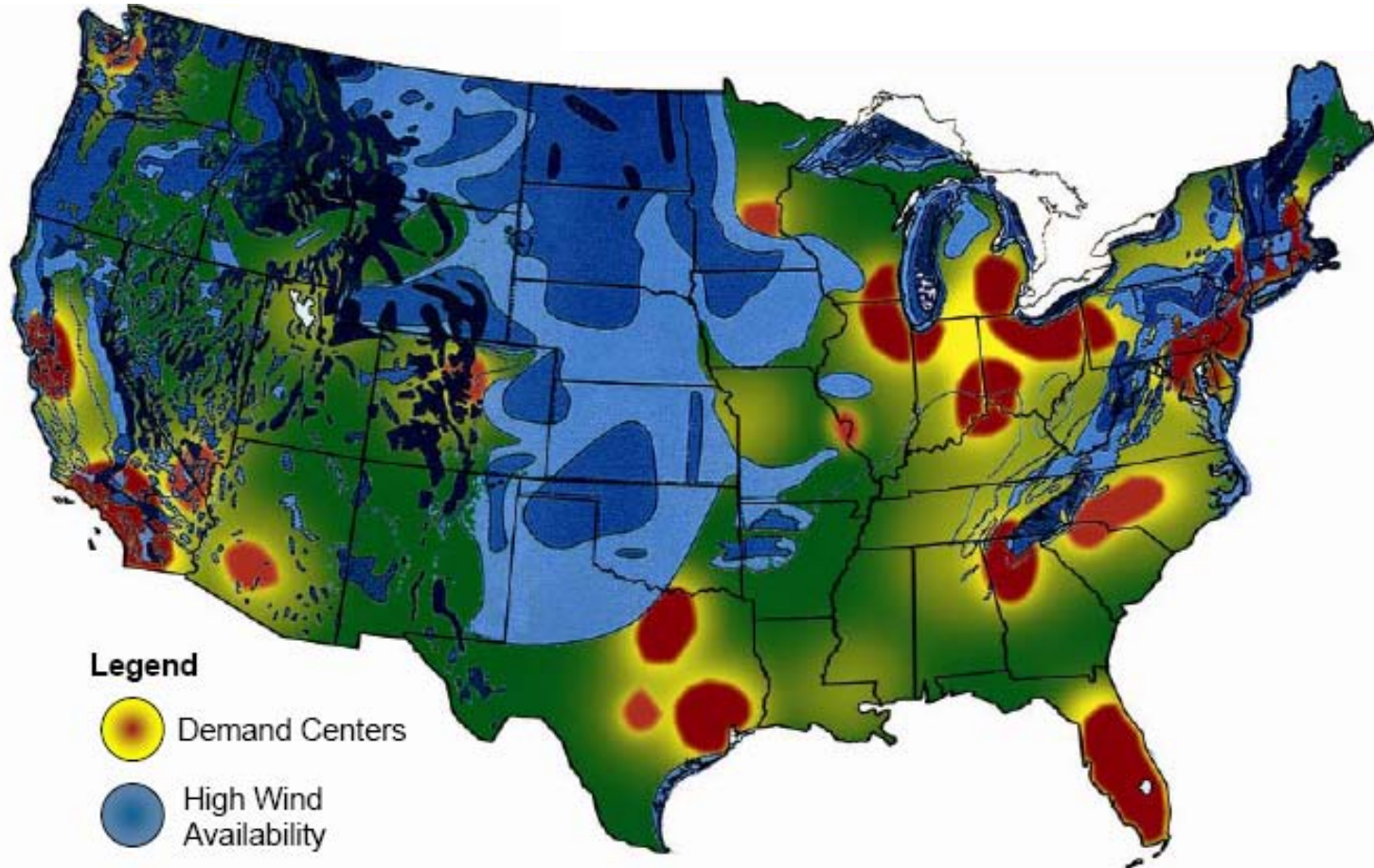
Shimo Wang, Senior Member, IEEE

George Rodriguez, Member, IEEE

Existing RAS and Limitations

- ❑ Important solution to handle post-fault stability issues.
- ❑ Armed by pre-fault path flow, triggered by grid topology change.
- ❑ Pre-set according to off-line studies.
- ❑ Setting is quite conservative in order to cover all possible operational conditions.
- ❑ Hard to deal with the volatile operational conditions caused by high penetration of intermittent renewable generation.

National Wind Availability and Demand Centers

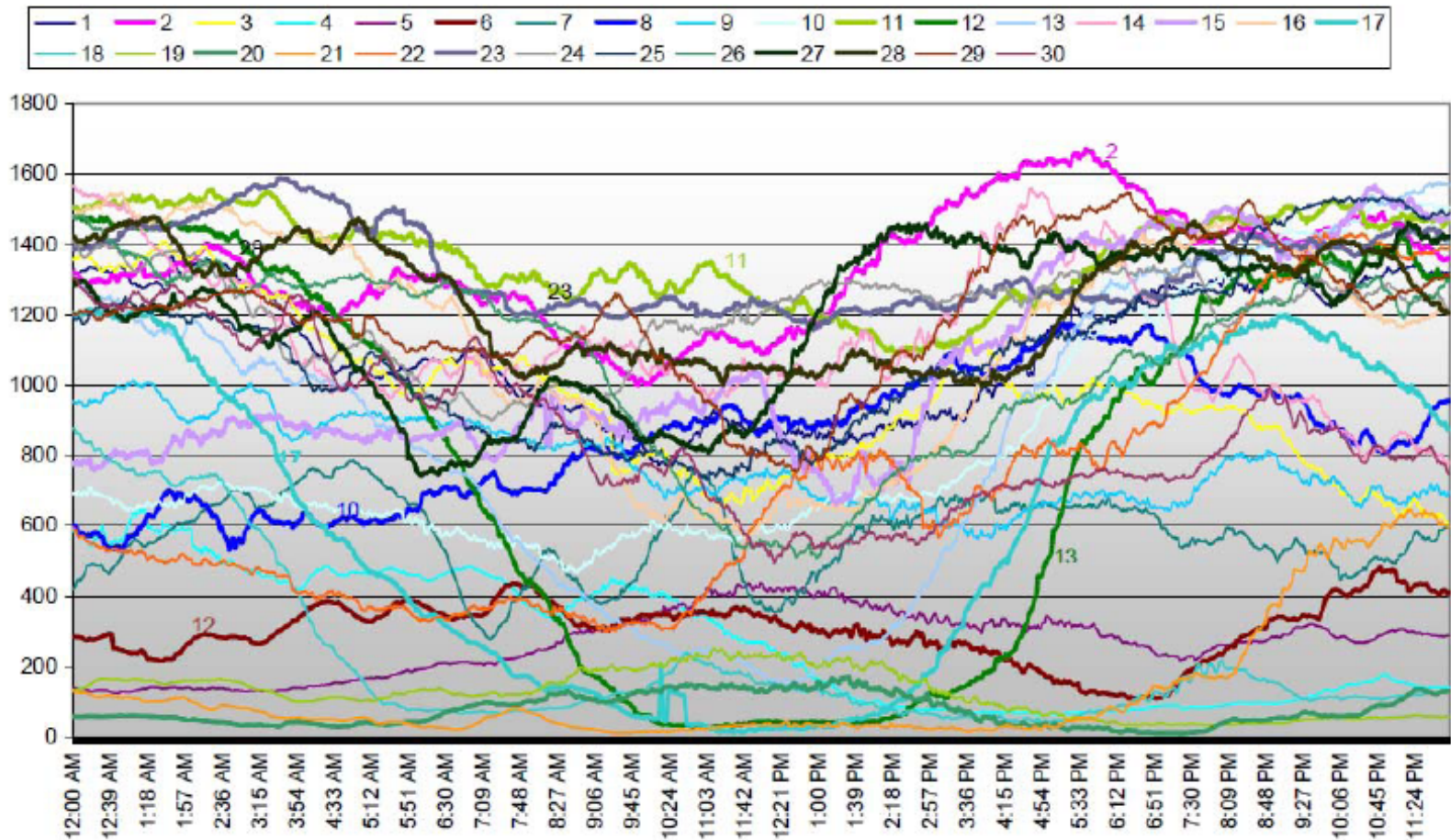


Southern California Potential Renewable Energy Sites

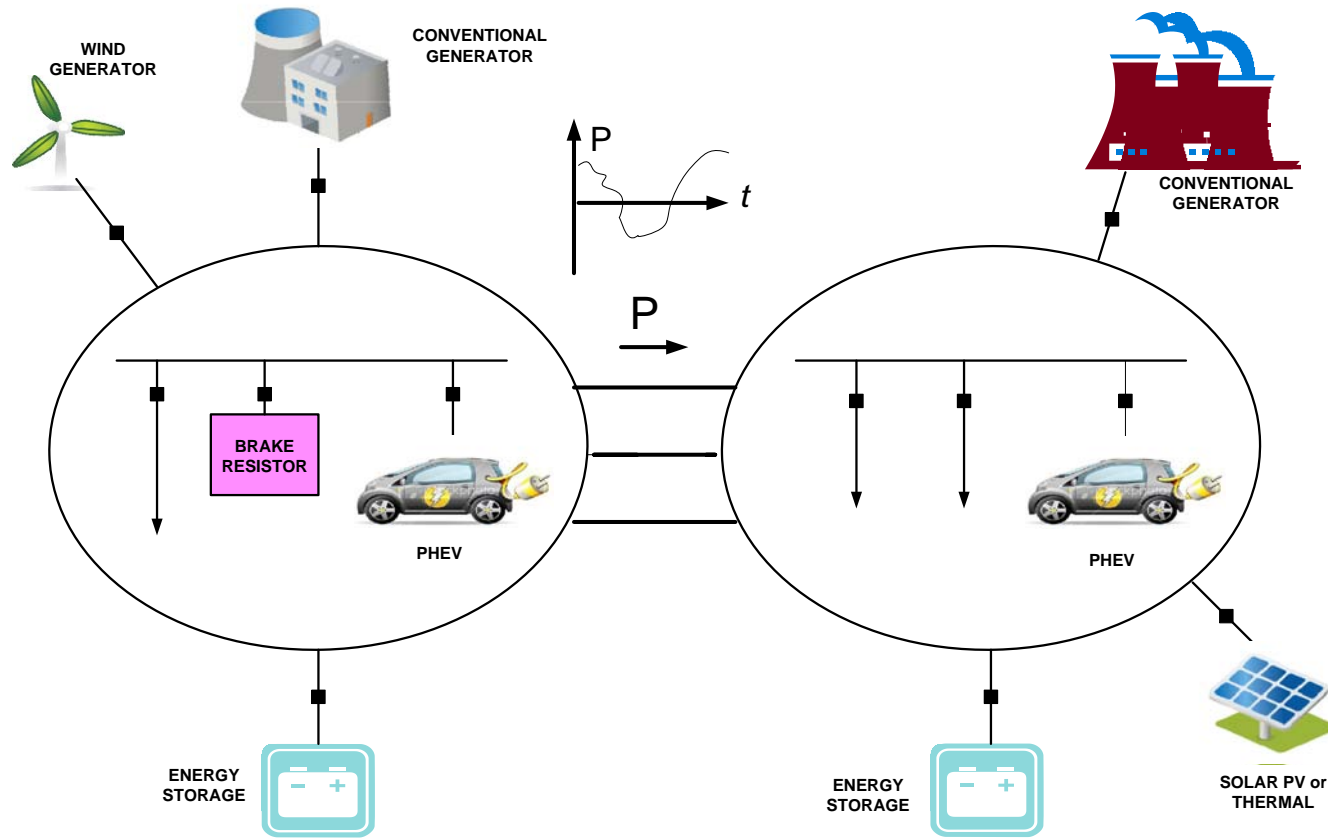


Wind Generation in April 2009

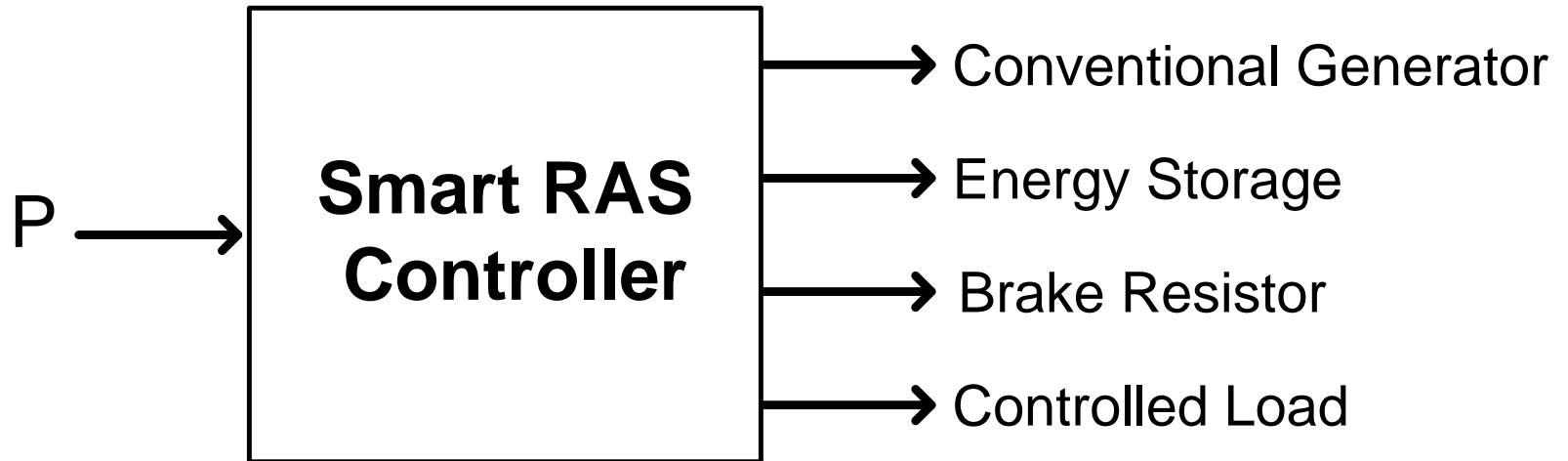
April 2009 Wind Generation



Inter-Area Power System

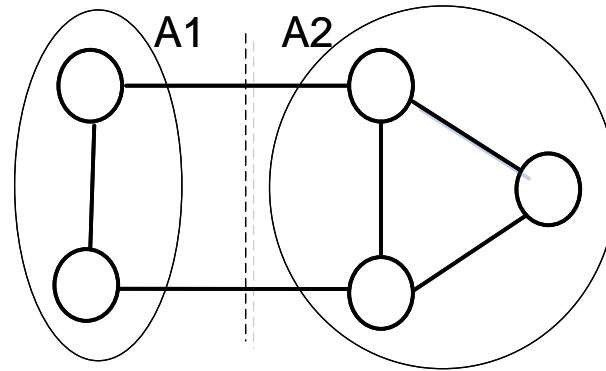


Smart RAS Inputs and Outputs

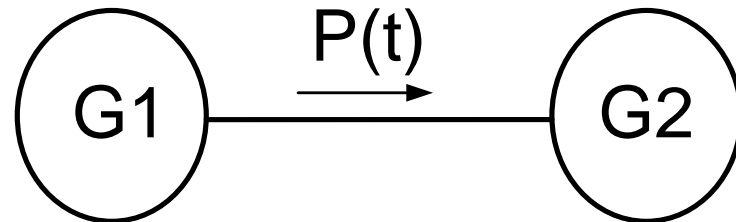


Inter-Area Model Without Parameters

- the concerned area **A1**
- the remaining area **A2**



Each area can be represented as an equivalent generator. $P(t)$ is the active power from G1 to G2.





$$P(t) = P(\delta(t)) = \frac{E_1 E_2}{X} \sin \delta(t) \quad (1)$$

where $\delta(t) = \delta_1(t) - \delta_2(t)$

$\delta_1(t)$ and $\delta_2(t)$ are subject to:

$$\frac{d\delta_1}{dt} = \omega_1 - \omega_0 \quad (2)$$

$$\frac{d\delta_2}{dt} = \omega_2 - \omega_0 \quad (3)$$

$$M_1 \frac{d\omega_1}{dt} = P_{M1} - P(t) = \Delta P_1(t) \quad (4)$$

$$M_2 \frac{d\omega_2}{dt} = P(t) - P_{M2} = \Delta P_2(t) \quad (5)$$

Assume $P_{M1} = P_{M2} = P(t_0)$, subtract (3) from (2) and (5) from (4) separately

$$\frac{d\delta_1}{dt} - \frac{d\delta_2}{dt} = \omega_1 - \omega_2 = \Delta\omega \quad (6)$$

$$\frac{(M_1 \frac{d\omega_1}{dt} - M_2 \frac{d\omega_2}{dt})}{2} = P(t_0) - P(t) = \Delta P(t) \quad (7)$$

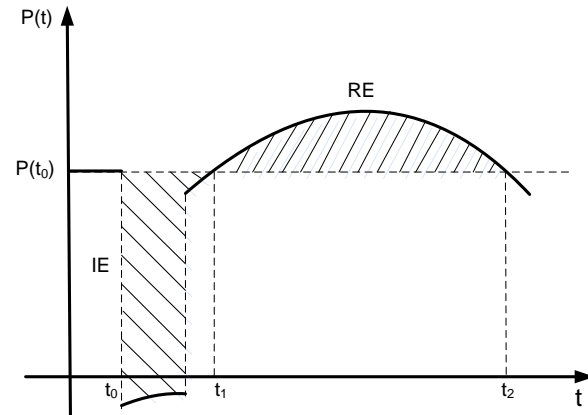
Impact Energy and Instability Criterion

Impact Energy is defined as

$$IE = \int_{t_0}^{t_1} \Delta P(t) dt$$

Where

- t_0 is the time when the impact starts
- t_1 is the time when changes sign



Reverse energy is defined as:

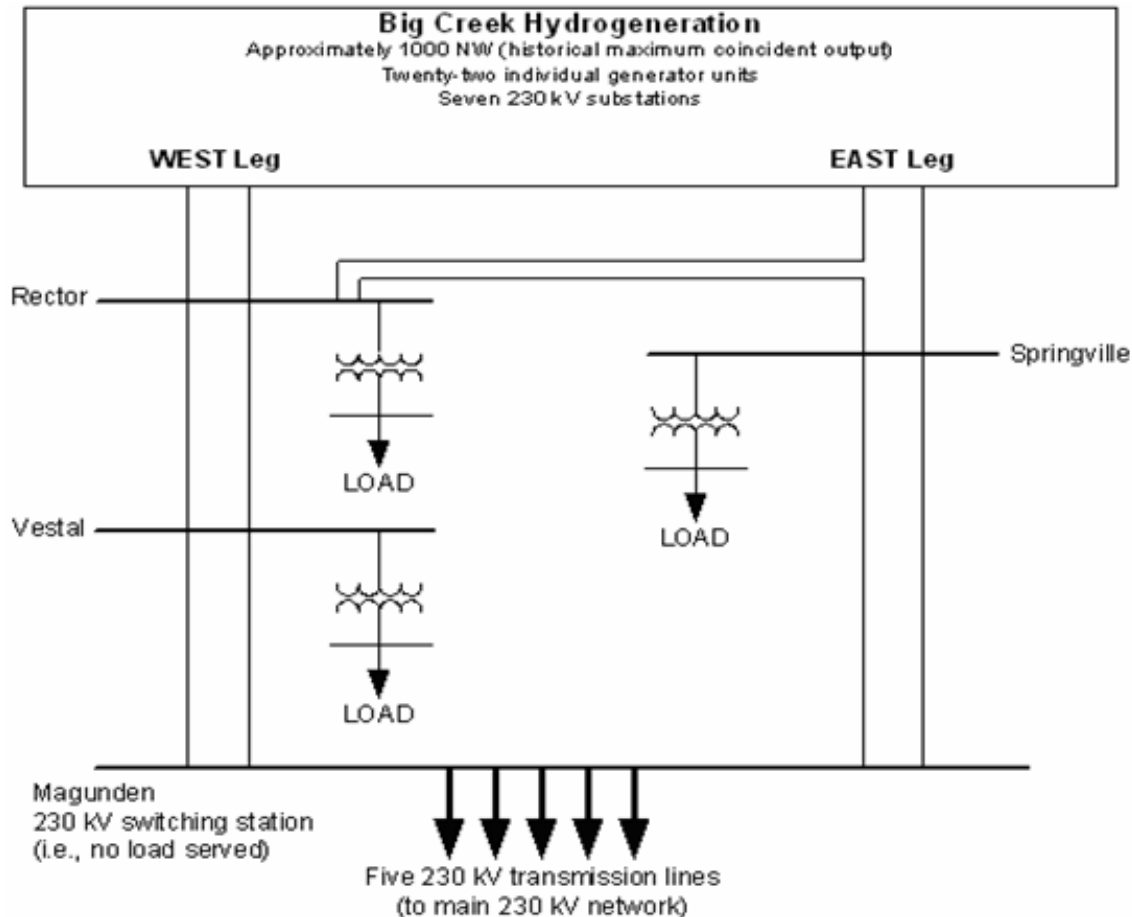
$$RE = \int_{t_1}^{t_2} \Delta P(t) dt$$

Where t_2 is the time when $\Delta P(t)$ changes sign again.

$$\Delta E = |IE| - |RE|$$

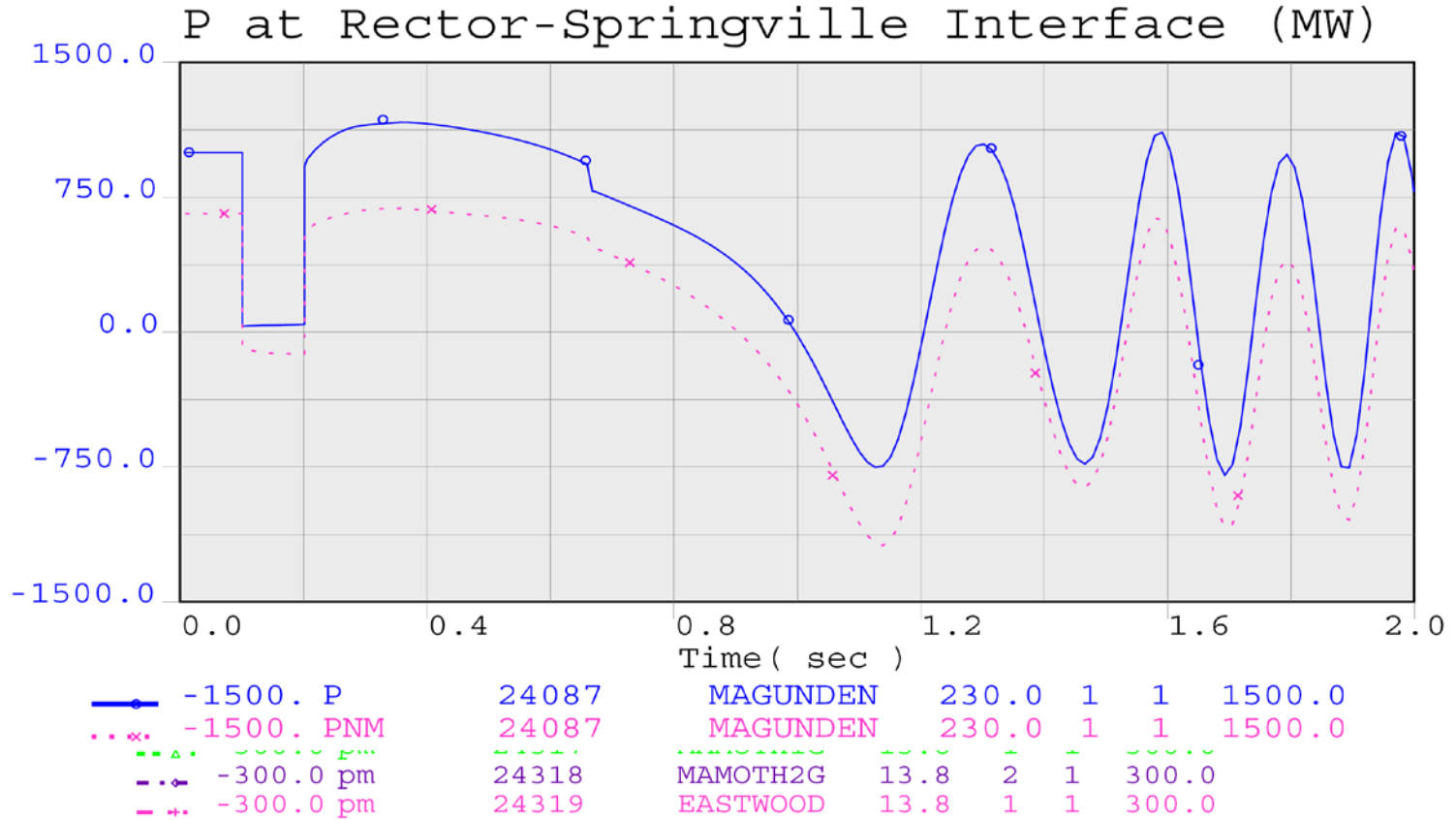
If $\Delta E < 0$ it will be stable, otherwise unstable.

Big Creek Hydro generation Area



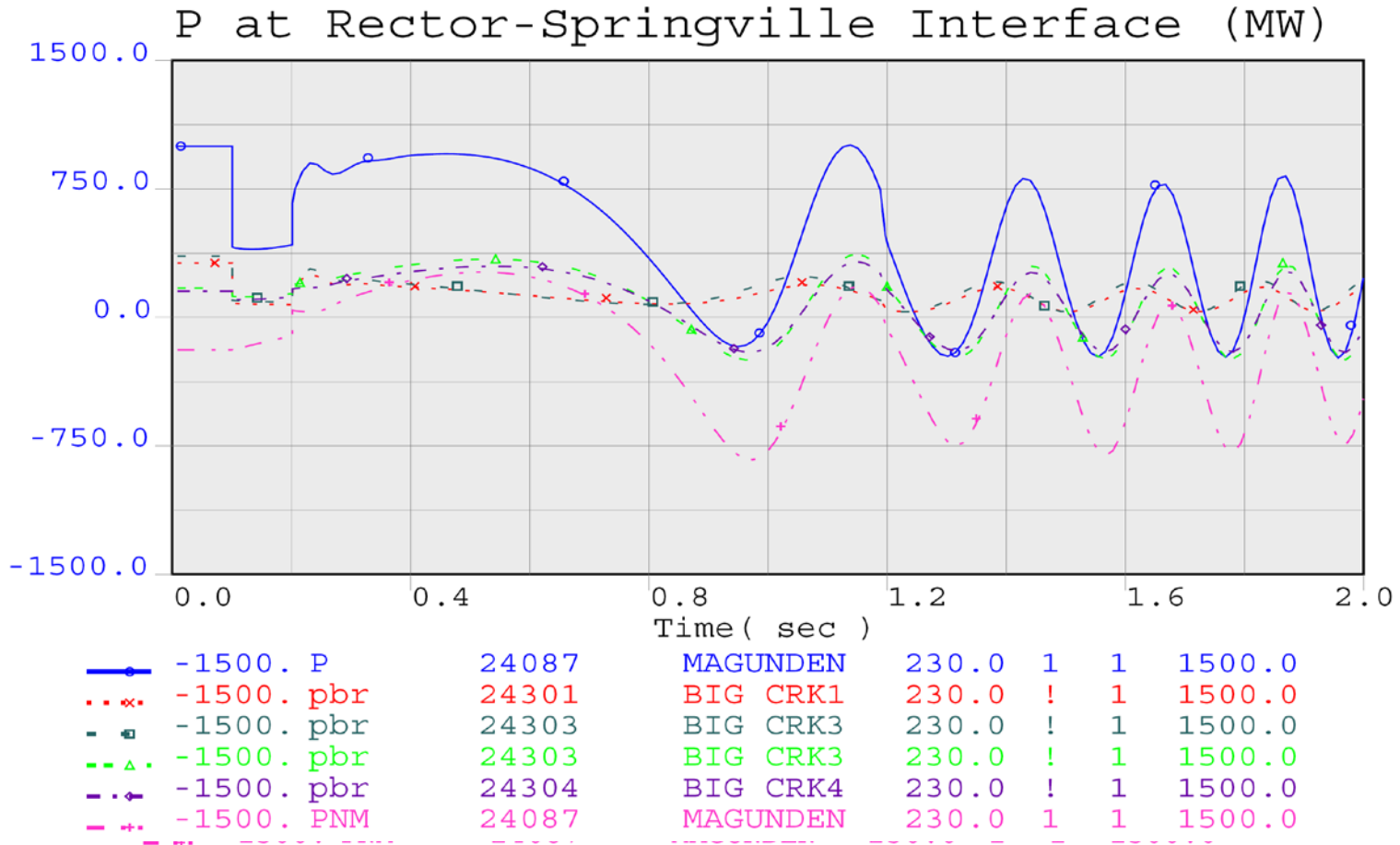


Example 1 Simulation



~~Generator tripped~~
P(t) without remedy

Example 2 Simulation



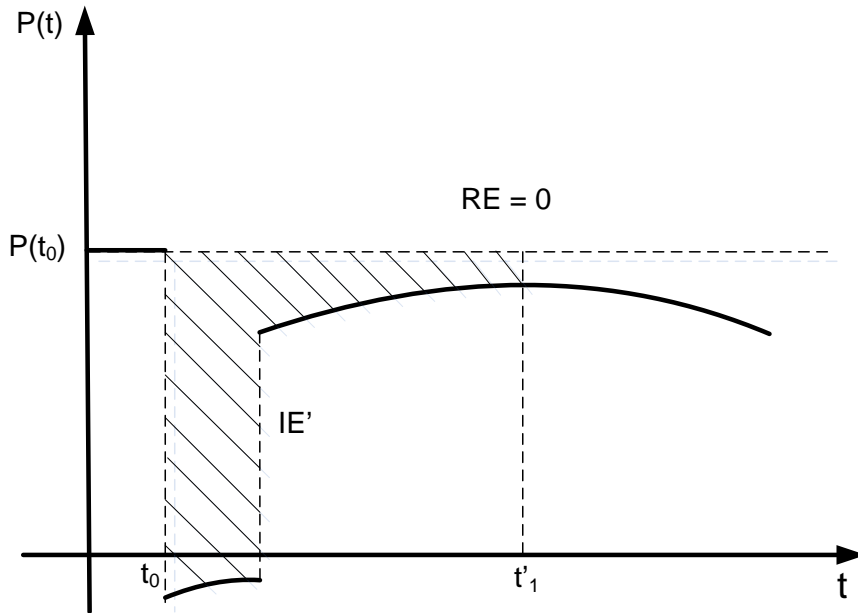
PG with reports triggered
P(t) with remedy



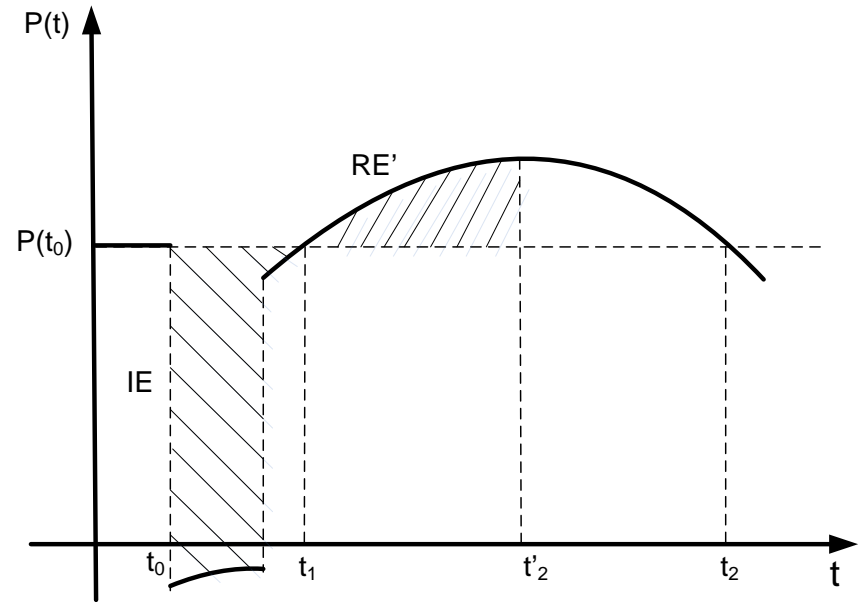
Simulation Results for Examples 1 and 2

Example	Stability w/out remedy	IE (mw-sec)	RE (mw-sec)	Prediction	Remedy	Result
1	unstable	96.86	45.49	unstable	trip generators at 0.67 sec.	unstable
2	unstable	421.11	0.11	unstable	trip generators at 1.19 sec	unstable

Algorithm Improvement

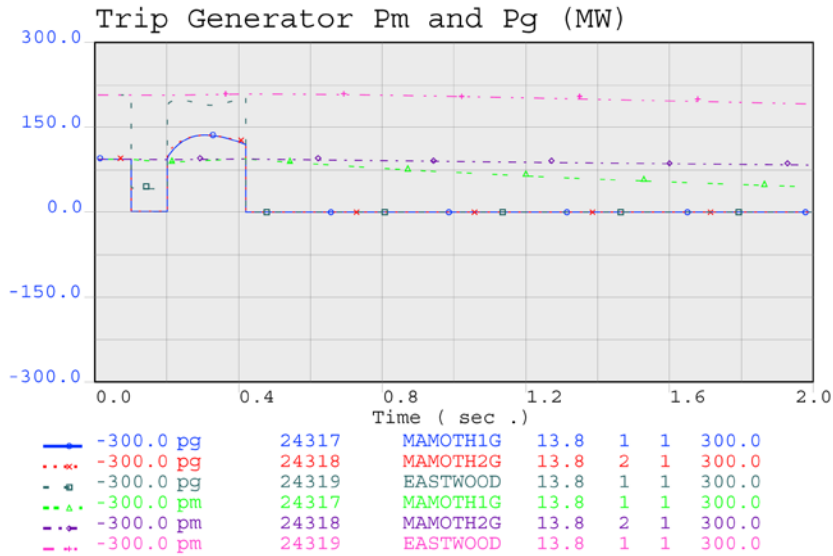


Early Determined $RE=0$

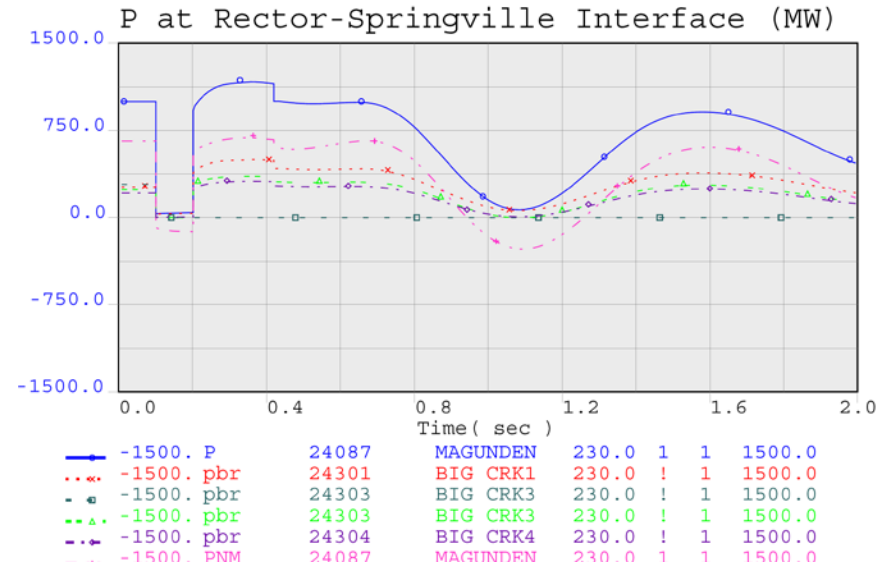


Early Determined $RE = 2RE'$

Example 1 Simulation

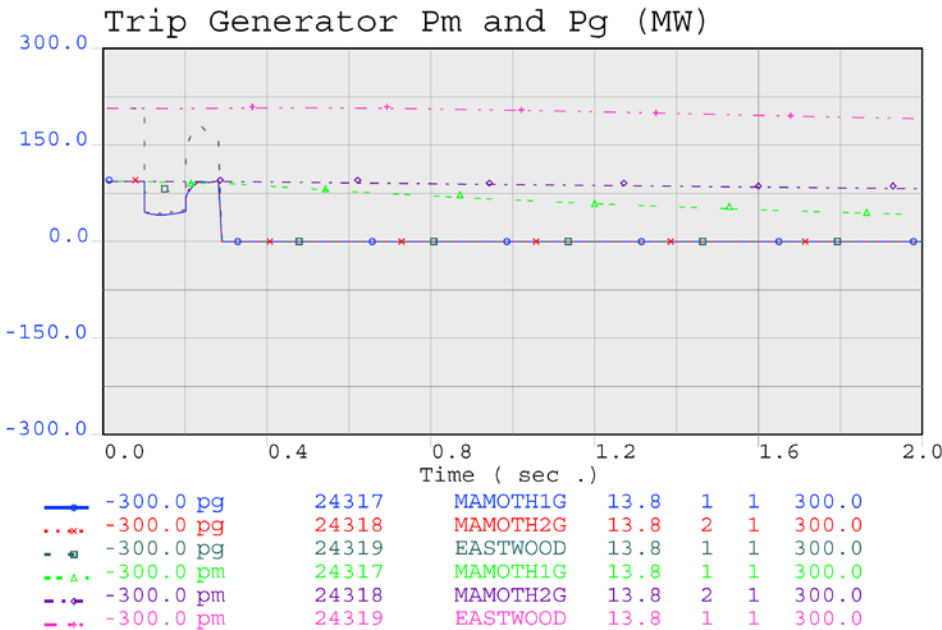


Generators Tripped

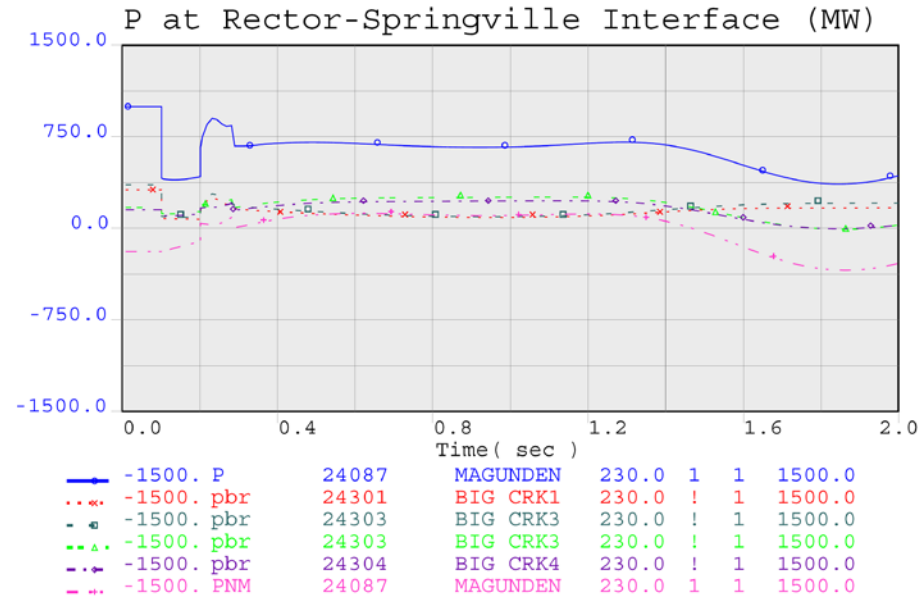


P(t) with Remedy

Example 2 Simulation



Generators Tripped



P(t) with Remedy



Simulation Results for Examples $\bar{1}$ and $\bar{2}$

Example	Stability w/out Remedy	IE (mw-sec)	RE (mw-sec)	Prediction	Remedy	Result
$\bar{1}$	unstable	96.86	38.97	unstable	trip generators at 0.42 sec.	stable
$\bar{2}$	unstable	64.79	0	unstable	trip generators at 0.29 sec	stable

Conclusions

- ❑ To deal with the RAS issues caused by high penetration of intermittent renewable generation and plug-in vehicles, a Smart RAS is proposed.
- ❑ Based on real time synchrophasor measured inter-area active power, an innovative Adaptive Impact Energy Method is used to predict instability and trigger RAS. No model parameters and RAS setting are needed.
- ❑ Simulations demonstrate the Smart RAS operation's correctness and efficiency.
- ❑ Further PMU data verification, different software simulations and various remedial action studies will be performed.

Questions?

Contact Information:

Email: shimo.wang@sce.com

Phone: (626) 302-8745