Adaptive Impact Energy Method for Synchrophasor Measurements Based Inter-Area Instability Prediction and Remedy

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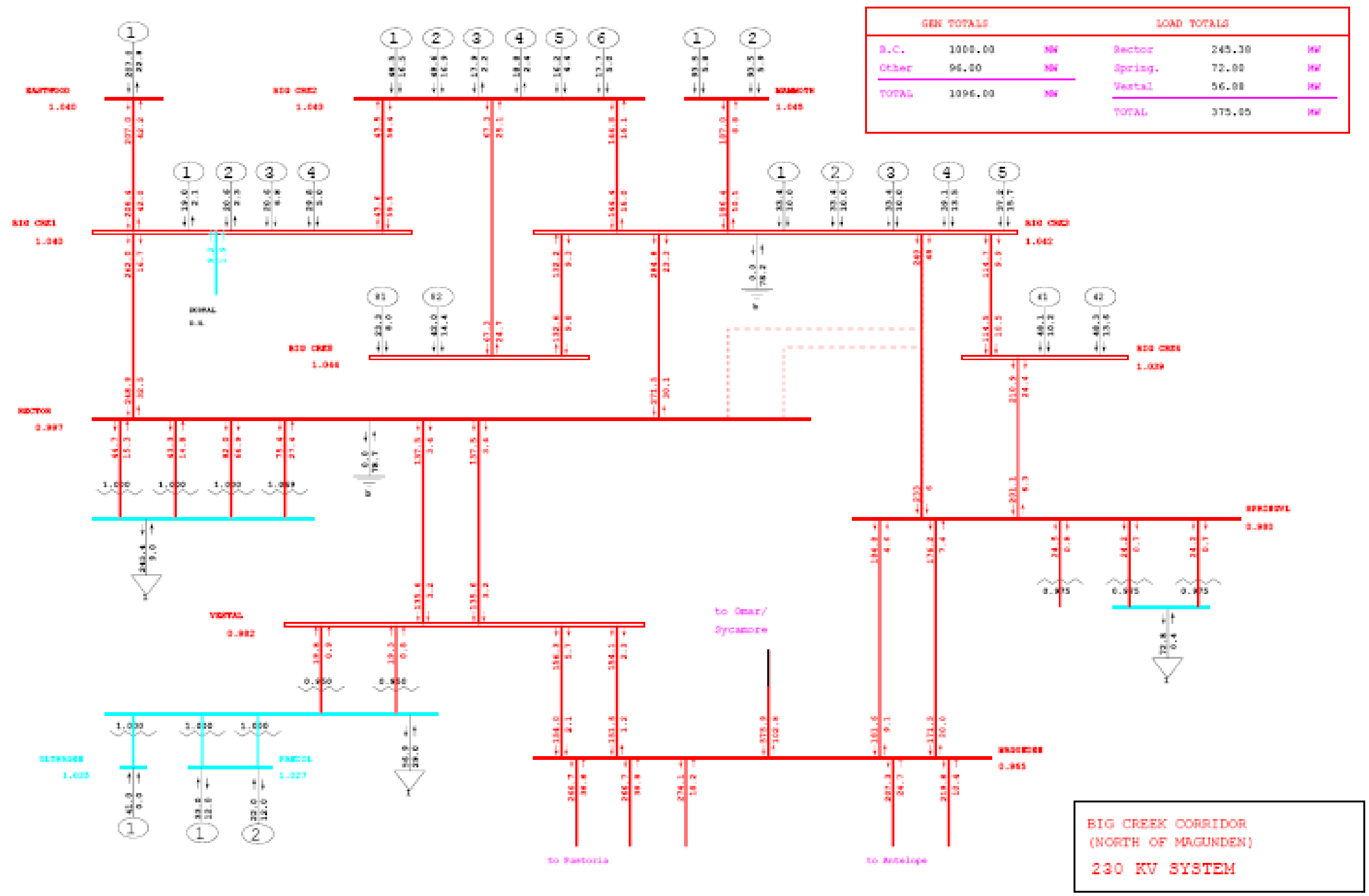
SCE Big Creek Project



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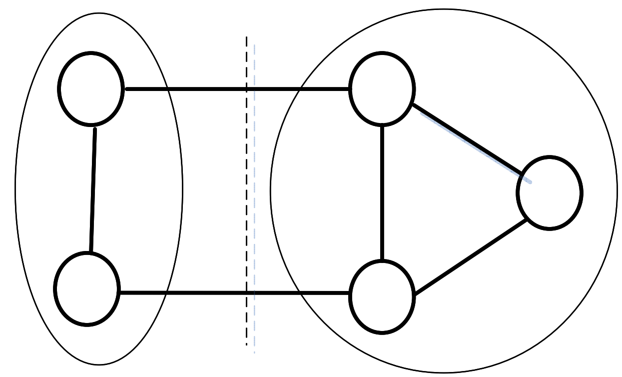
Existing Other Methods and Problems

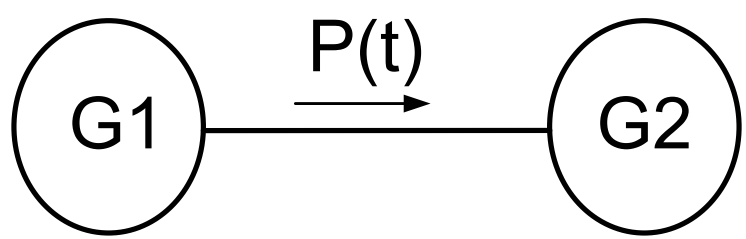
- Equivalent generator rotor angle method
- Transient energy function method
- Problems
  - Huge amount of calculations on real time model equivalent parameter estimates for fault and post-fault periods
  - Not enough time to determine the disturbance mode and the trigger criterion from off-line or on-line pre-fault contingency study results.

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.



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

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

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

$$\frac{d\delta_1}{dt} = \omega_1 - \omega_0 \qquad (2) \qquad\qquad \frac{d\delta_2}{dt} = \omega_2 - \omega_0 \qquad (3)$$

$$M_1 \frac{d\omega_1}{dt} = P_{M1} - P(t) = \Delta P_1(t) \qquad (4) \qquad\qquad M_2 \frac{d\omega_2}{dt} = P(t) - P_{M2} = \Delta P_2(t) \qquad (5)$$

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

$$\frac{d\delta_1}{dt} - \frac{d\delta_2}{dt} = \omega_1 - \omega_2 = \Delta\omega \qquad (6) \qquad\qquad \frac{(M_1 \frac{d\omega_1}{dt} - M_2 \frac{d\omega_2}{dt})}{2} = P(t_0) - P(t) = \Delta P(t) \qquad (7)$$

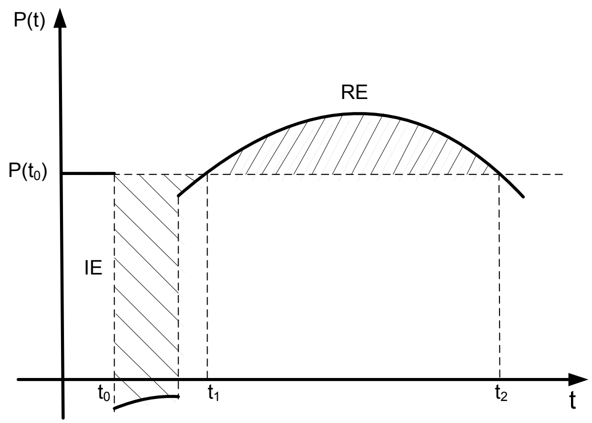
Impact Energy and Instability Criterion

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:

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

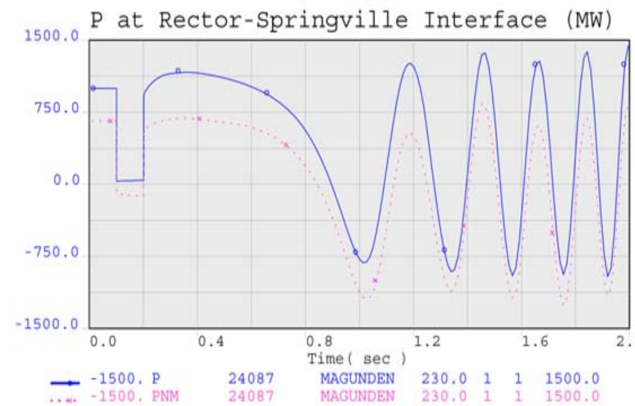
Where t_2 is the time when ΔP(t) changes sign again.

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

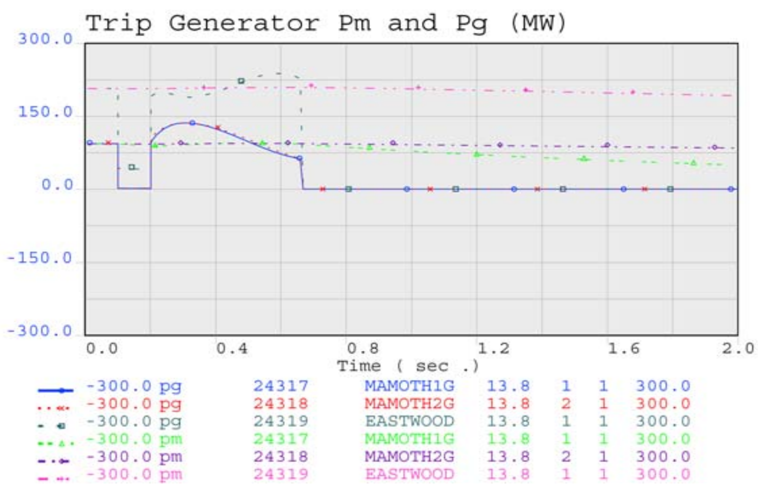
If ΔE < 0 it will be stable, otherwise unstable.

Example 1 Simulation

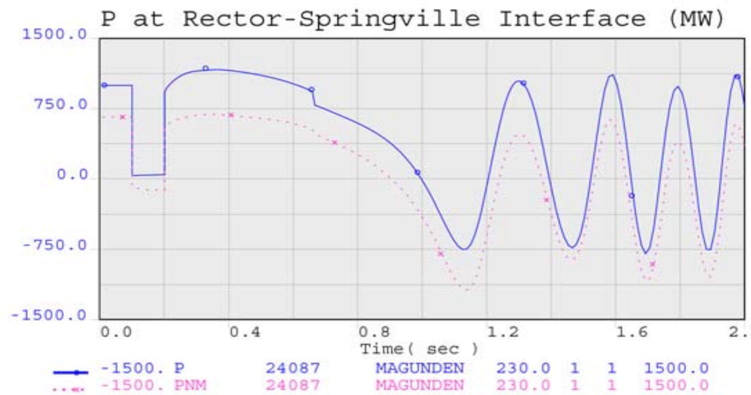
- North to south active power flow direction
- 3-phase short circuit fault on Big Creek 3 to Rector 230 kV transmission line near Big Creek 3 end
- Fault is cleared 6 cycles later by tripping the line



P(t) without remedy



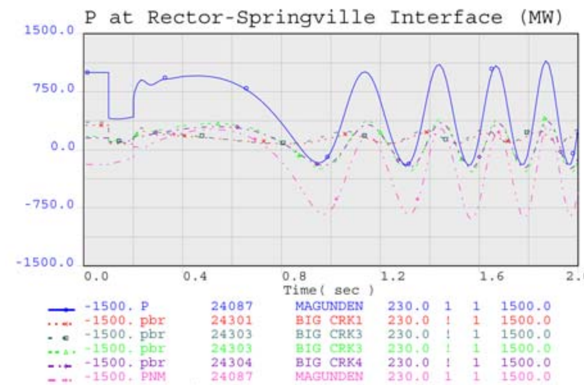
Generators tripped



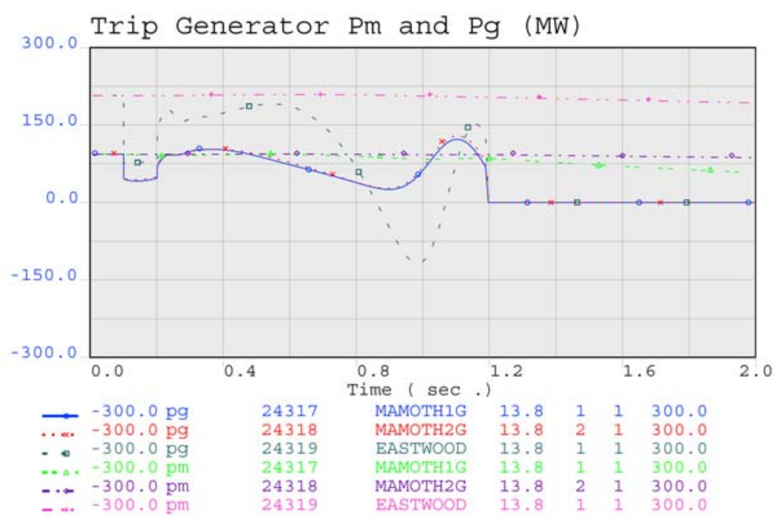
P(t) with remedy

Example 2 Simulation

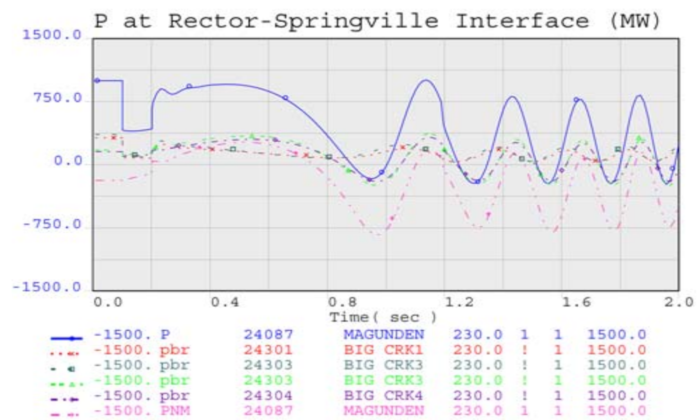
- South to North active power flow direction
- 3-phase short circuit fault on Rector to Vestal 230 kV transmission line near Rector end
- Fault is cleared 6 cycles later by tripping the lines



P(t) without remedy



Generators tripped



P(t) with remedy

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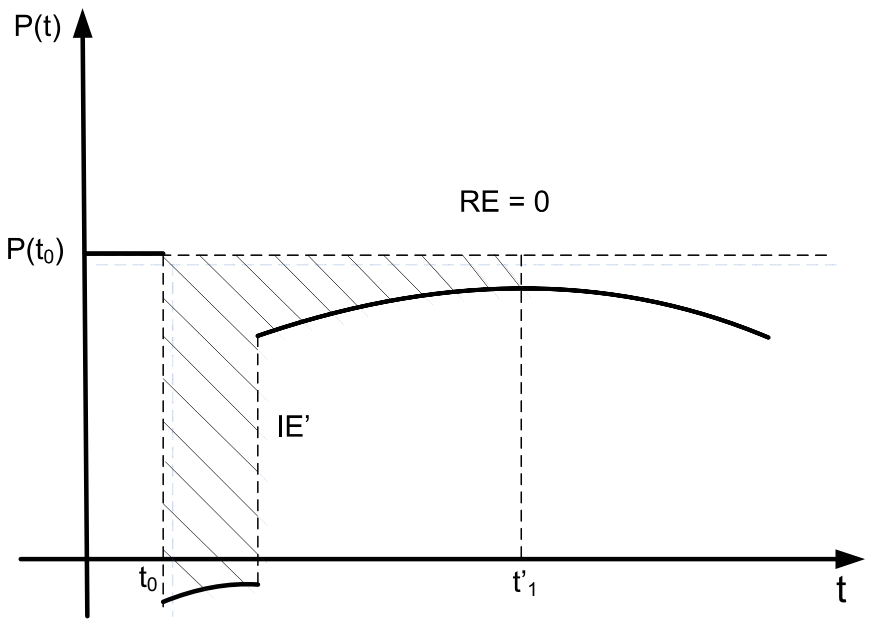
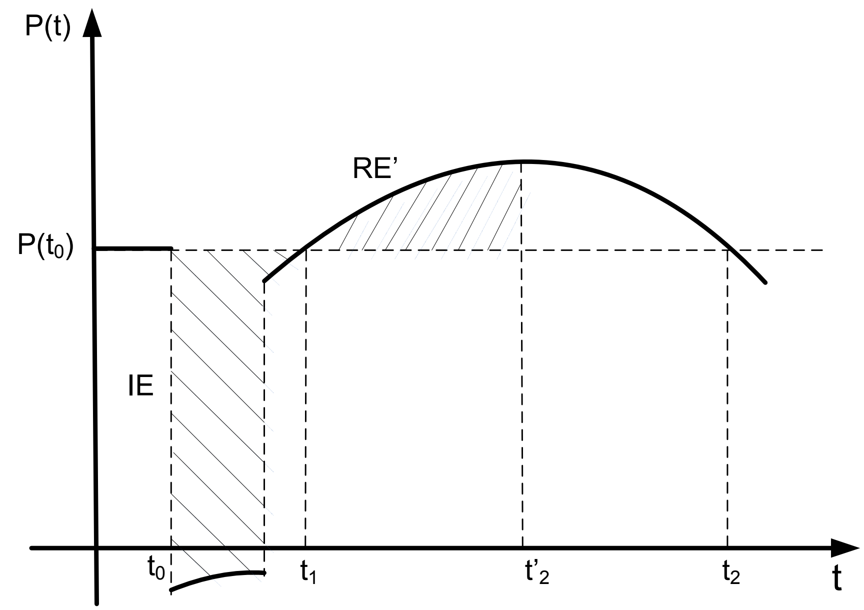
Simulation Results for Examples 1 and 2

Example	Stability wiout 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'

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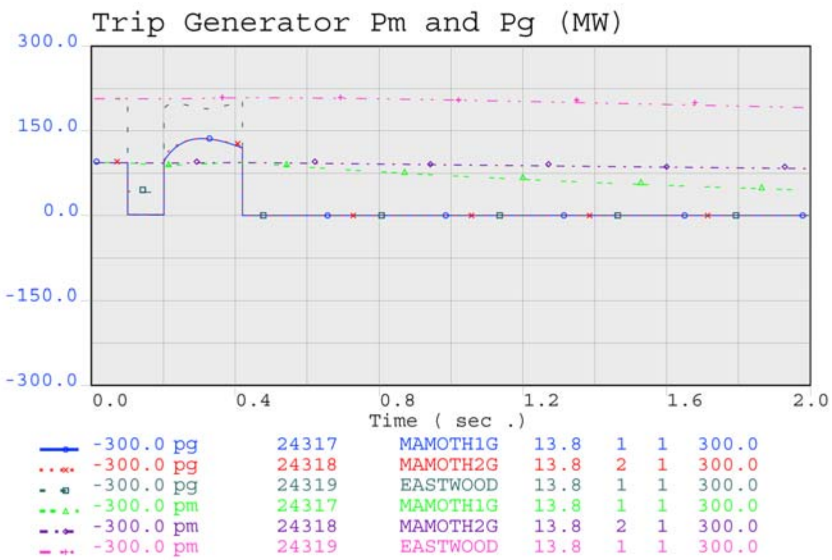
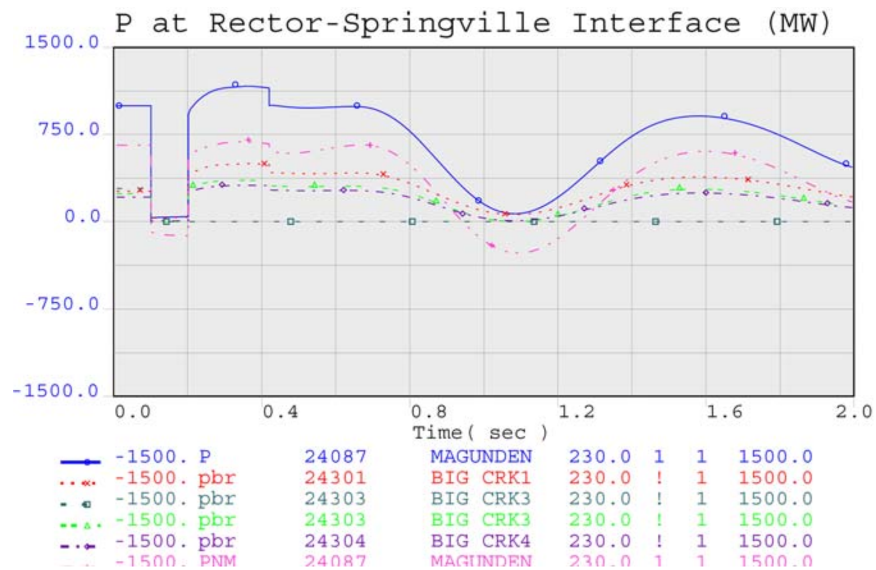
Example 1 Simulation

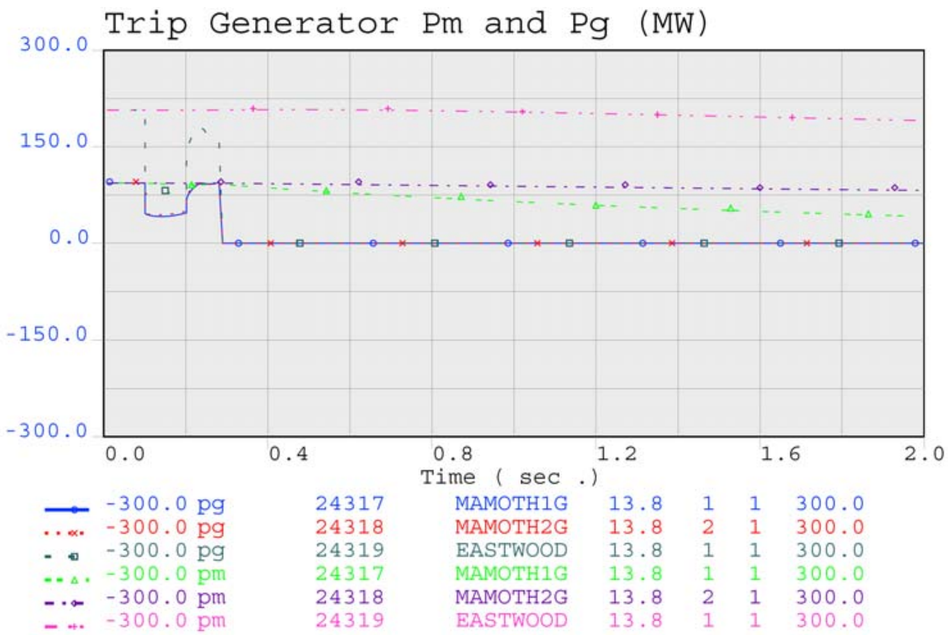




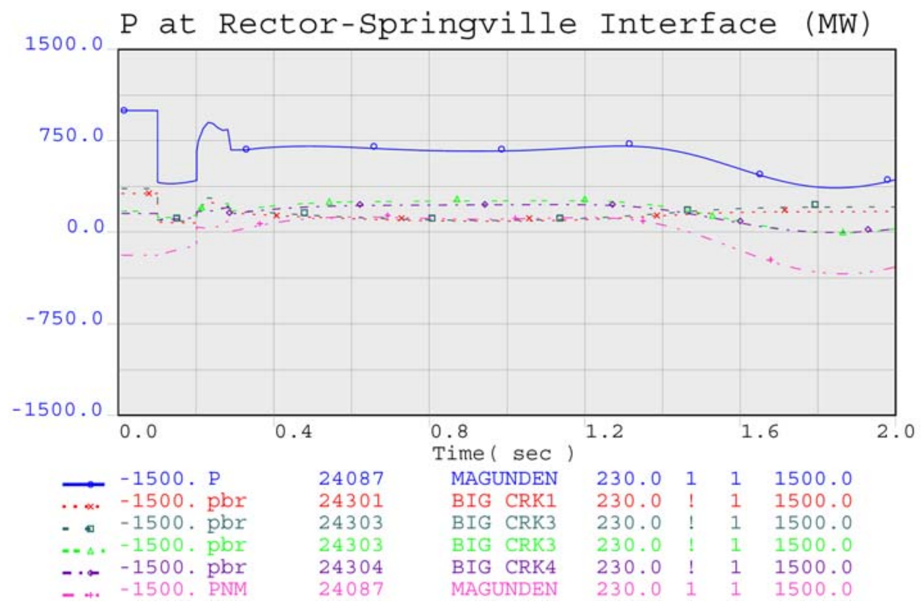
Generators Tripped

P(t) with Remedy

Example 2 Simulation



Generators Tripped



P(t) with Remedy

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

Example	Stability wiout Remedy	|IE| (mw·sec)	|RE| (mw·sec)	Prediction	Remedy	Result
$\overline{1}$	unstable	96.86	38.97	unstable	trip generators at 0.42 sec.	stable
$\overline{2}$	unstable	64.79	0	unstable	trip generators at 0.29 sec	stable

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Conclusions

- An innovative inter-area model without parameters and adaptive instability prediction criteria without settings are presented for synchrophasor measurement based. power system transient instability prediction and remedy
- Examples validate the correctness of the model and the criteria.
- As the improved algorithm speeds up the prediction, remedy earlier, the system is more possible survived.
- The presented model, criteria and algorithm will take field test at Big Creek corridor.