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

Legend
- Demand Centers
- High Wind Availability
Southern California Potential Renewable Energy Sites
Wind Generation in April 2009

April 2009 Wind Generation

[Graph showing wind generation patterns for April 2009]

[Legend for the graph showing various wind generation lines]
Inter-Area Power System

- Wind Generator
- Conventional Generator
- Solar PV or Thermal Energy Storage
- Energy Storage
- PHEV
- Brake Resistor
Smart RAS Inputs and Outputs

Smart RAS Controller

- Conventional Generator
- Energy Storage
- Brake Resistor
- Controlled Load
Inter-Area Model Without Parameters

- the concerned area $A_1$
- the remaining area $A_2$

Each area can be represented as an equivalent generator. $P(t)$ is the active power from $G_1$ to $G_2$. 
\[ P(t) = P(\delta(t)) = \frac{E_1 E_2}{X} \sin \delta(t) \quad (1) \]

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

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

\[
\frac{d\delta_1}{dt} = \omega_1 - \omega_0 \quad (2) \quad \frac{d\delta_2}{dt} = \omega_2 - \omega_0 \quad (3)
\]

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

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

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

P at Rector-Springville Interface (MW)

P(t) without remedy

P(t) without remedy
Example 2 Simulation

-1500. P 24087 MAGUNDEN 230.0 1 1 1500.0
-1500. pbr 24301 BIG CRK1 230.0 ! 1 1500.0
-1500. pbr 24303 BIG CRK3 230.0 ! 1 1500.0
-1500. pbr 24303 BIG CRK3 230.0 ! 1 1500.0
-1500. pbr 24304 BIG CRK4 230.0 ! 1 1500.0
-1500. PNM 24087 MAGUNDEN 230.0 1 1 1500.0
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

Trip Generator Pm and Pg (MW)

Generators Tripped

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         | 38.97         | unstable    | trip generators at 0.42 sec. | stable |
| 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