APPLICATION OF WIDE AREA MEASUREMENTS FOR IMPROVED PROTECTION

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NASPI Meeting, February 29, 2012, Orlando, Florida

Lecture outline:

- Synchronized Phasor Measurements
- Modern WAMS
- Driving Force: Prevention of Blackouts
- WAMS based improvements to protection systems
- Future prospects

Synchronized Phasor Measurements

Wide Area Measurement System

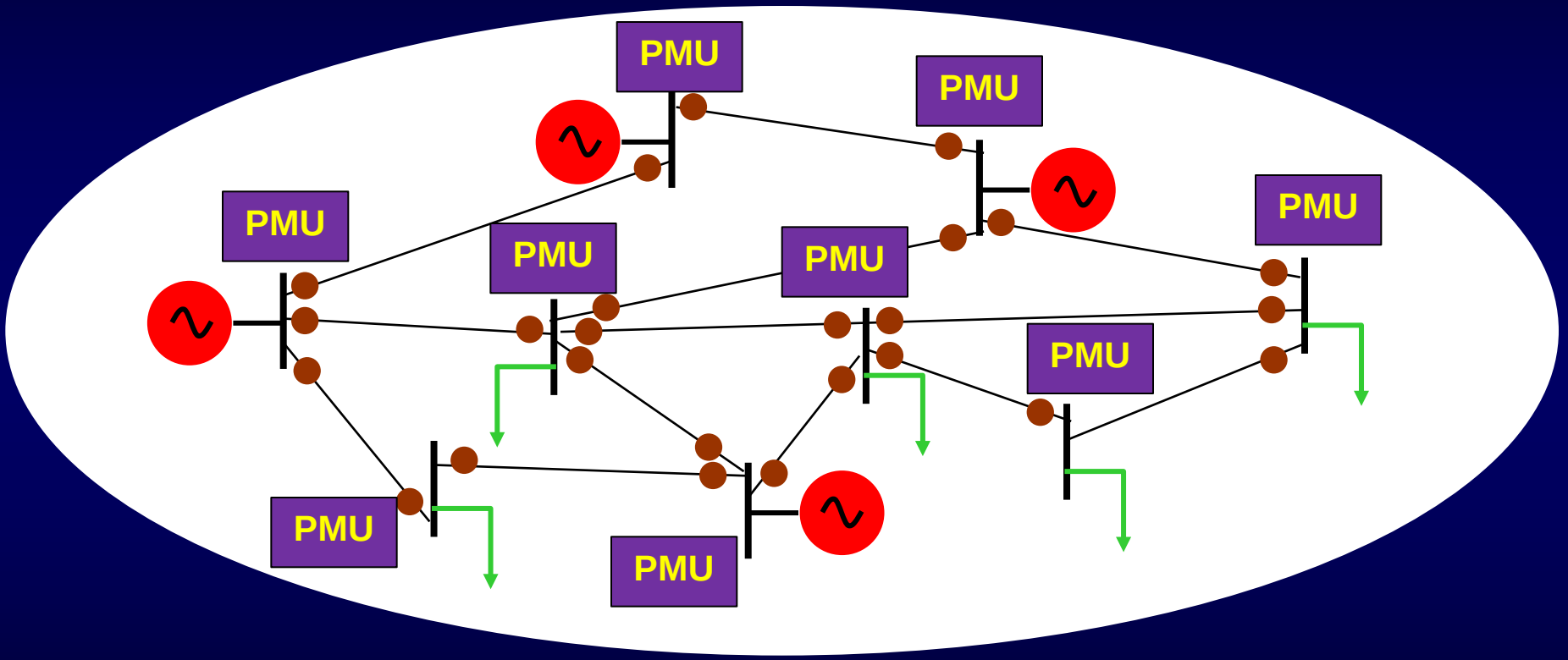
PMUs measure (synchronously):

- Positive sequence voltages and currents
- Phase voltages and currents
- Local frequency
- Local rate of change of frequency
- Circuit breaker and switch status

PMU data reporting rates:

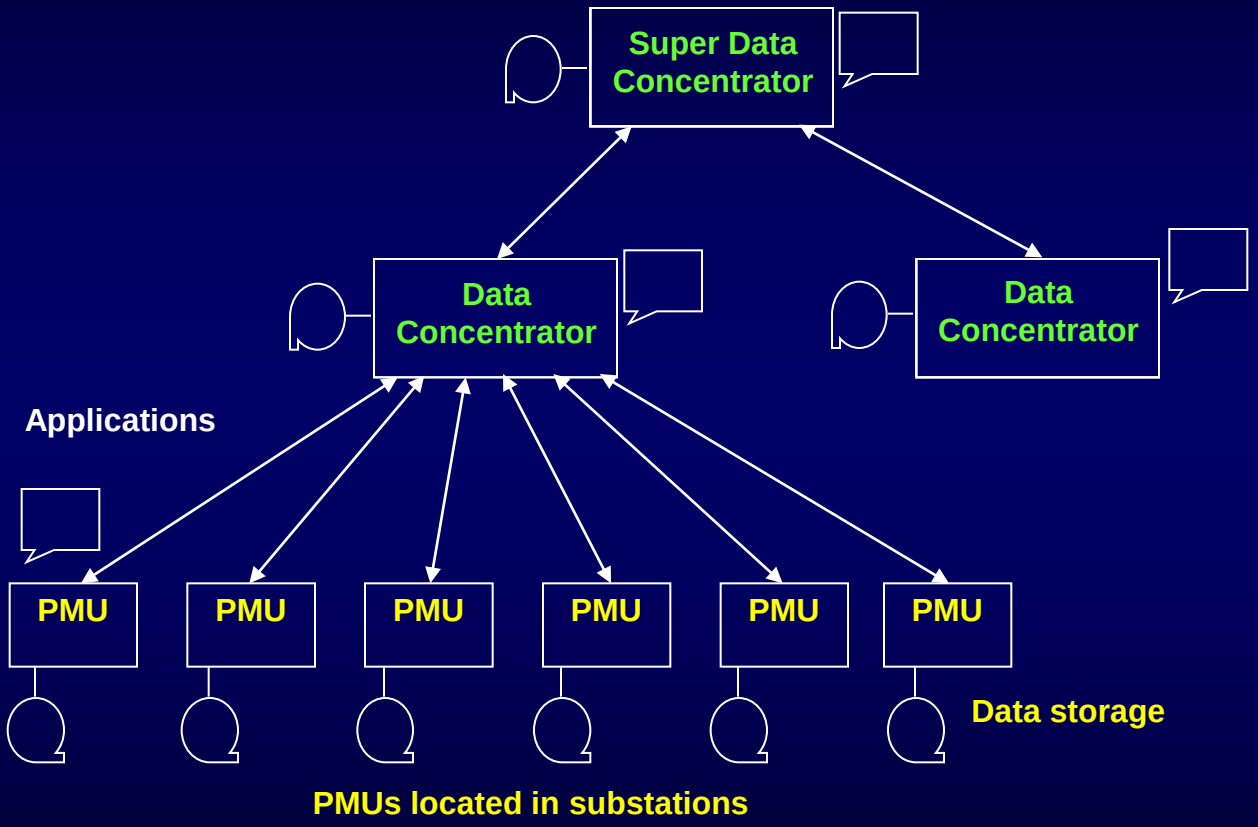
- Data reported at up to once per cycle

Wide Area Measurement System



Wide Area Measurement System

System Architecture



- **Moving towards fewer and less intense blackouts**

Protection system performance issues

(1) Inappropriate settings for prevailing conditions

(2) Hidden failures in protection systems

(3) Security-Dependability balance

Overview of protection systems and practices

1. Equipment Protection (Primary)

   Example: Lines, Transformers, Generators, Buses

   Fairly straight forward: Protect against faults to avoid damage to the equipment, to get the fault off the system as quickly as possible to avoid cascading failures of the network.

   Modern relays are autonomous, fast acting, and often duplicated or even triplicated to avoid failure to clear a fault.

   Relay times may be as short as a cycle, and circuit breaker times may be 2-3 cycles.

   These are primary protection systems.

Overview of protection systems and practices

1. Equipment Protection (Primary)

   Contest between security and dependability

   Biases

2. Equipment Protection (Back-up)

   Back-up operation is more damaging

   Of necessity it is slower

   It trips larger part of the system

   It is more difficult to set, depends too much on conditions of the network.

Overview of protection systems and practices

3. System Protection

The aim is to protect the power system from hurtful faults

- Load shedding and restoration
- Loss of field
- Out-of-step
- Islanding

It has the same performance characteristics as the Back-up systems:

- Of necessity it is slower
- It trips larger part of the system
- It is more difficult to set, depends too much on conditions of the network.

4. Remedial Action Schemes

More complex, a start on wide area measurement based protections

Preliminary Remarks

- **Wide area measurements: PMU data**
- **High-speed protections not affected**
- **Slow speed protections – Back-up, Stability, Loss-of-field, RAS**
- **Adequate communication facilities implied: within substation, with neighboring substations, with remote substations, system-wide**

Topics for WAMS based protection

(1) Adjusting balance of security-dependability

Balance to be shifted when the power system is in emergency state as determined from wide area measurements.

(2) Alarming for relay characteristic penetration

Wide area measurements to determine trajectories and trends of relaying parameters.

(3) Adaptive out-of-step relaying

Wide area measurements to determine trajectories and predict outcome of stability swings in real-time.

Topics for WAMS based protection

Other possibilities:

(4) Supervision of back-up zones

(5) Intelligent load shedding using load-generation imbalance estimate in real time

(6) Adaptive loss-of-field relay

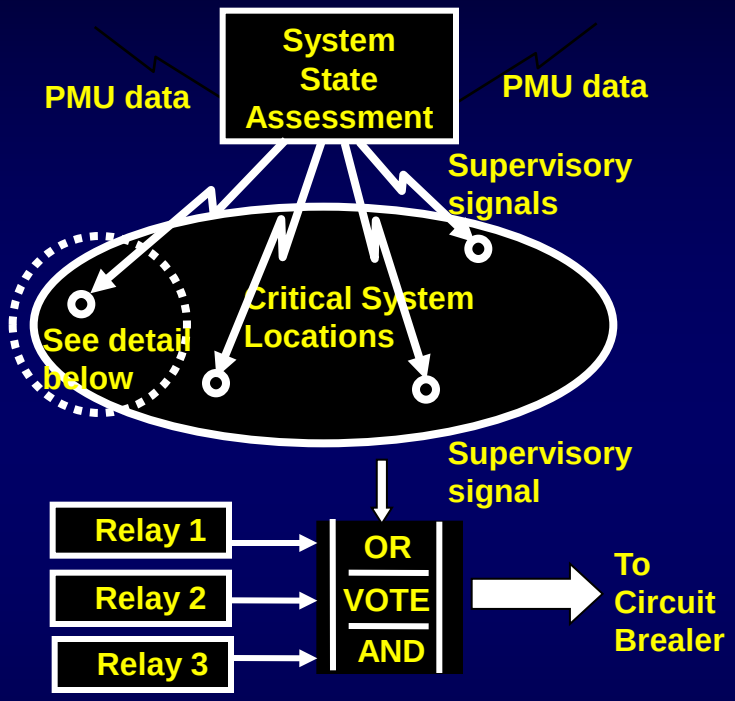
(7) System-wide integration of Remedial Action Schemes (RAS or SIPS)

(1) Adjusting balance of security-dependability

(Dealing with Hidden Failures)

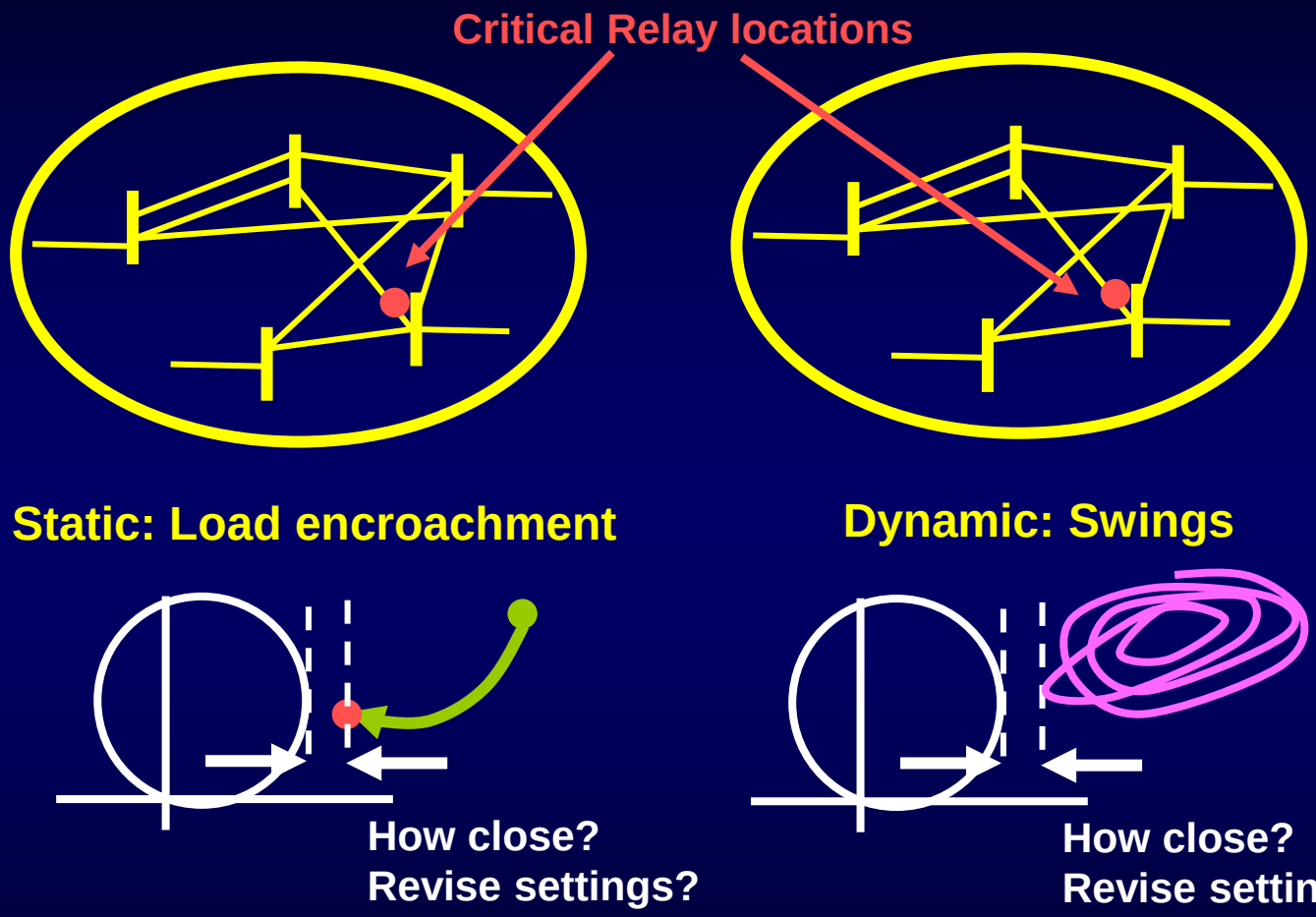
Protection system bias:

- High dependability
- Corresponding
  - best possible security



Adjustment of Dependability-Security balance under stressed system conditions.

(2) Alarming for relay characteristic penetration



Out-of-step relaying for complex networks

(1) Identify critical PMU placement sites

(2) Real-time coherency determination

(3-a) Two machine equivalent

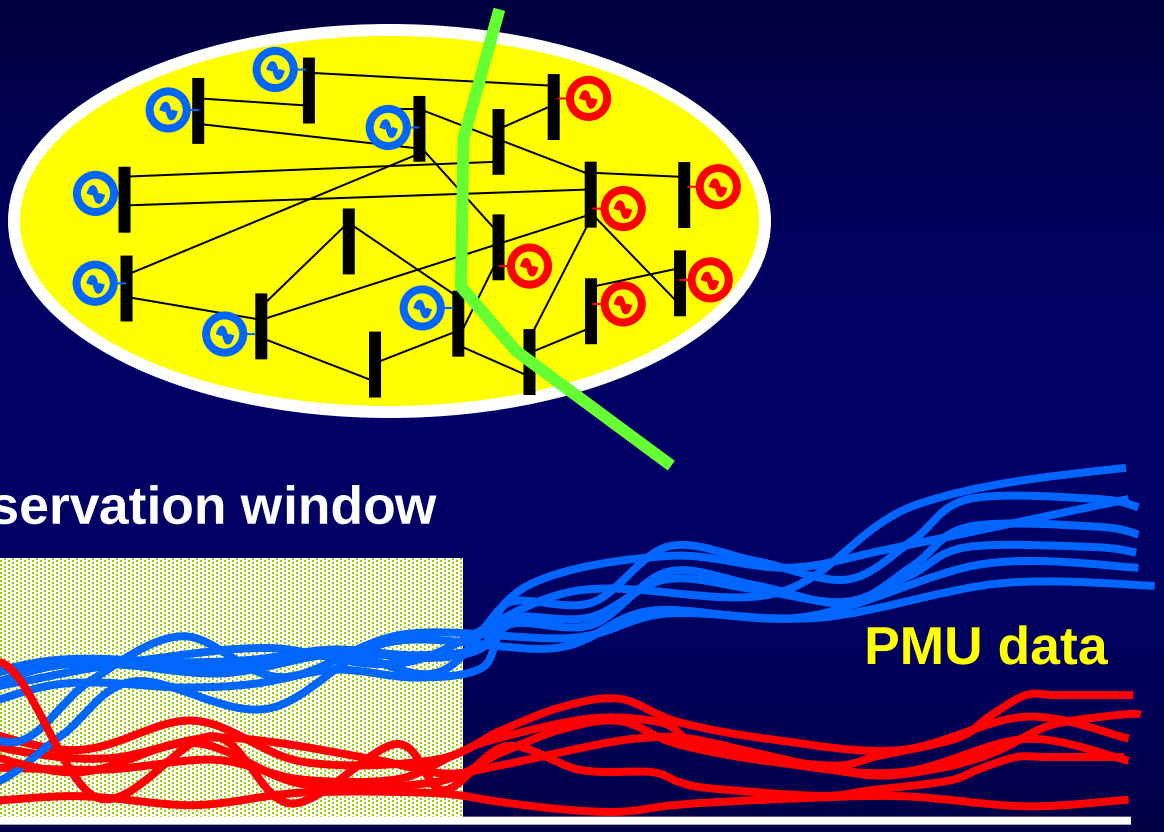
(4-a) Extended Equal Area Criterion application

(3-b) Two machine equivalent

(4-b) Time-series of swing curves and prediction

Out-of-step relaying for complex networks

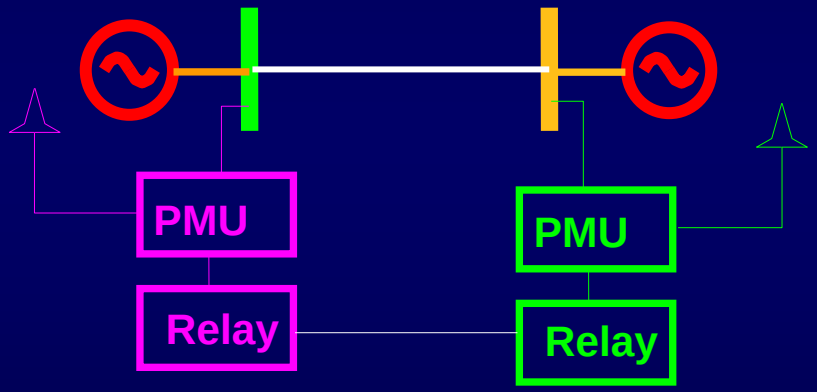
(2) Real-time coherency determination

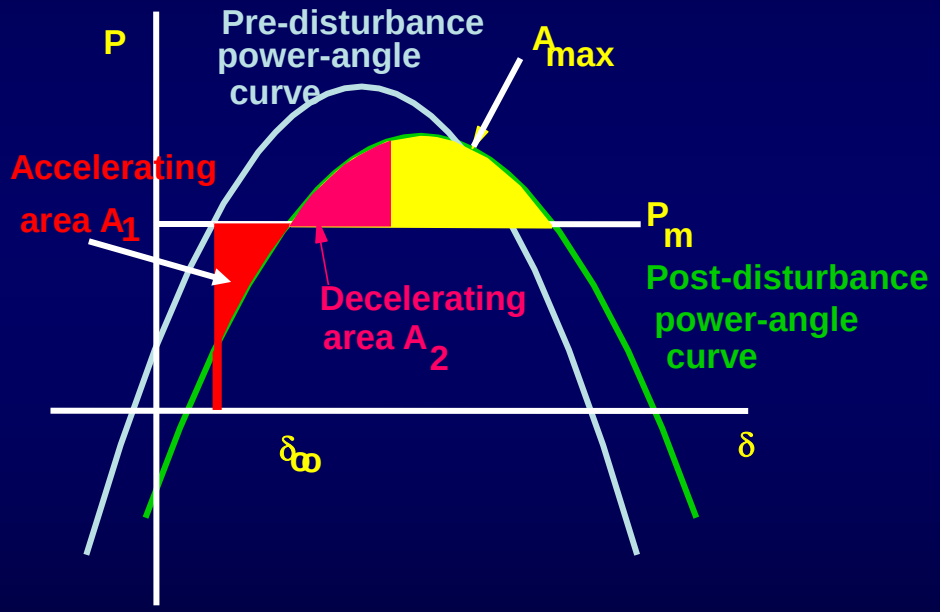


Out-of-step relaying for complex networks

(3-a) Two machine equivalent

(4-a) Extended Equal Area Criterion application

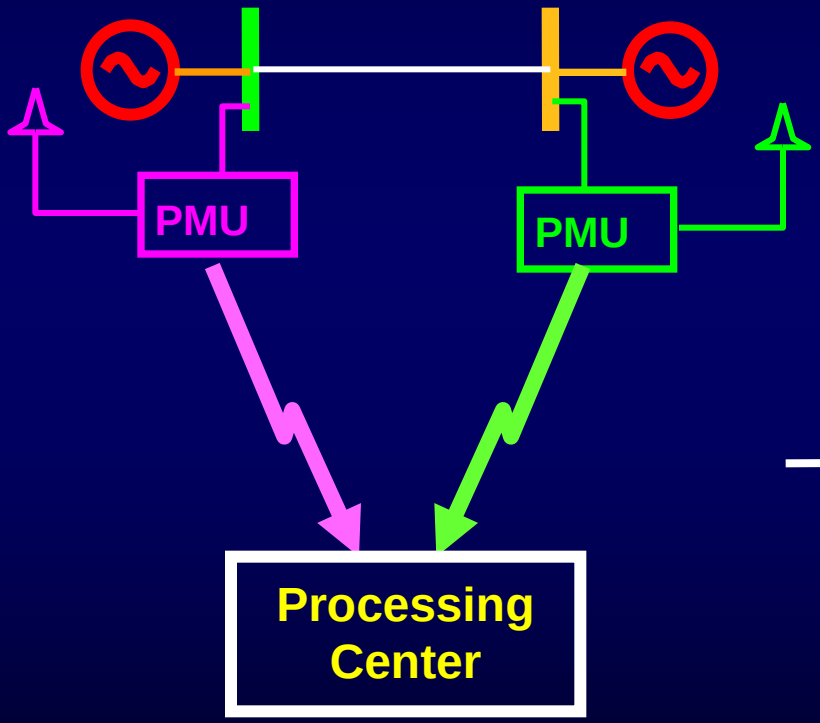


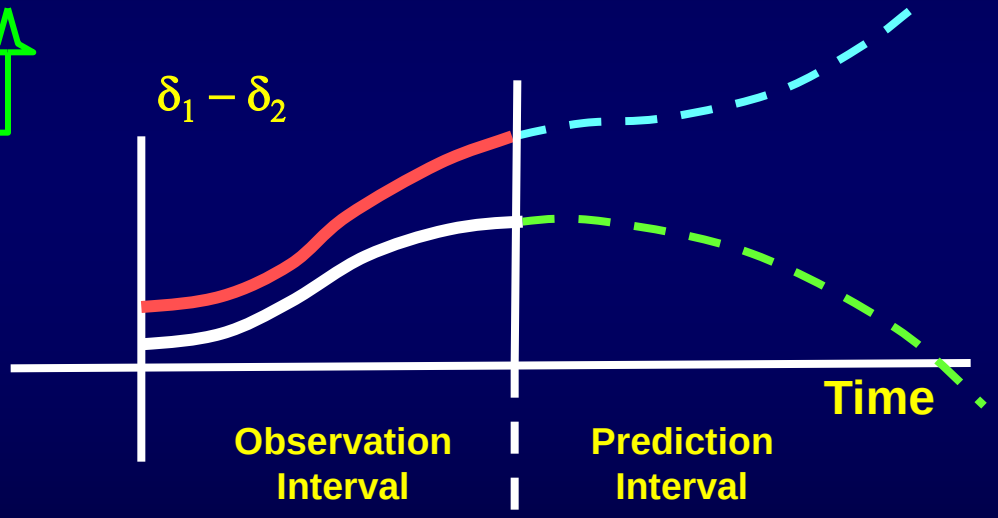


Out-of-step relaying for complex networks

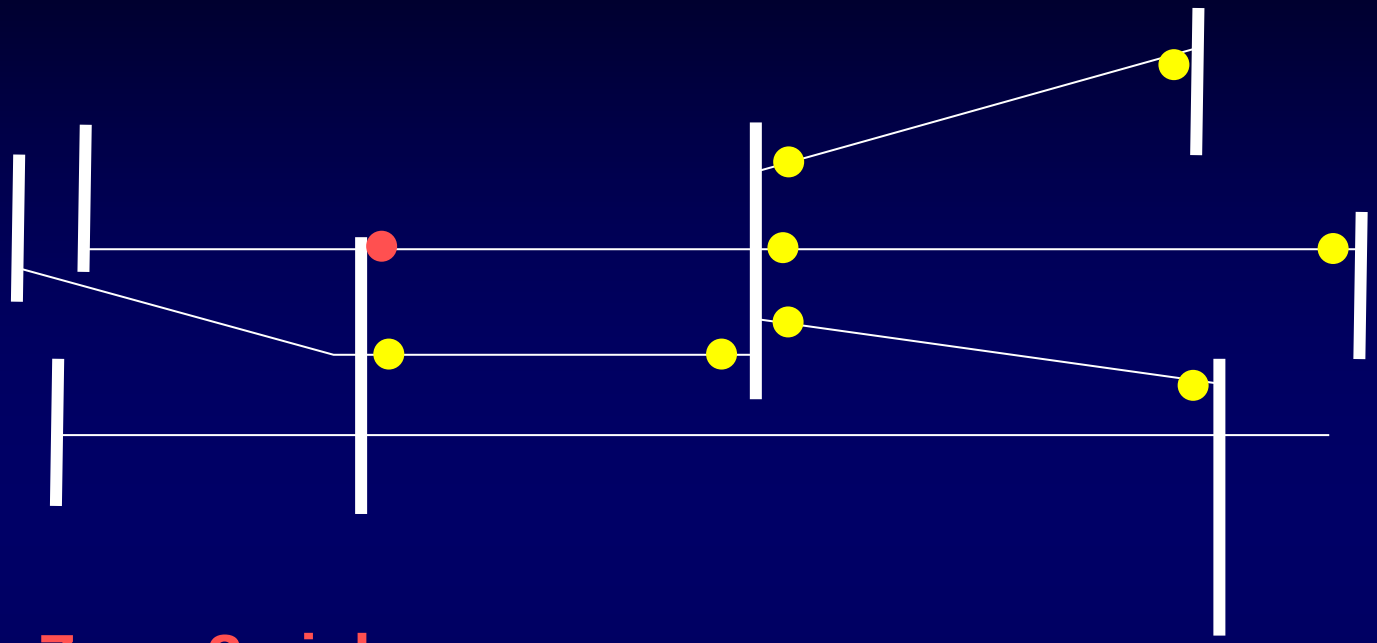
(3-b) Two machine equivalent

(4-b) Time-series of swing curves and prediction





(4) Supervision of back-up zones

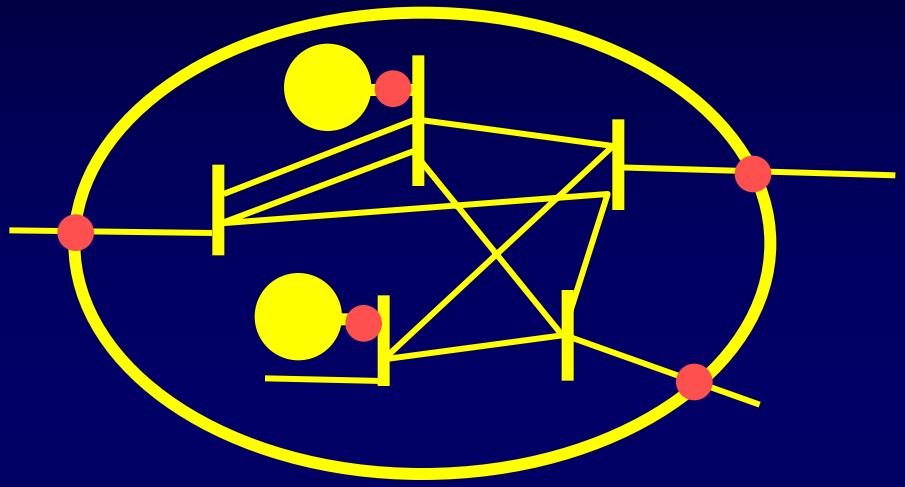


Zone 3 picks-up

Balanced Conditions?
Any Zone-1 picked up?

} **Yes.**
If not Block Zone-3

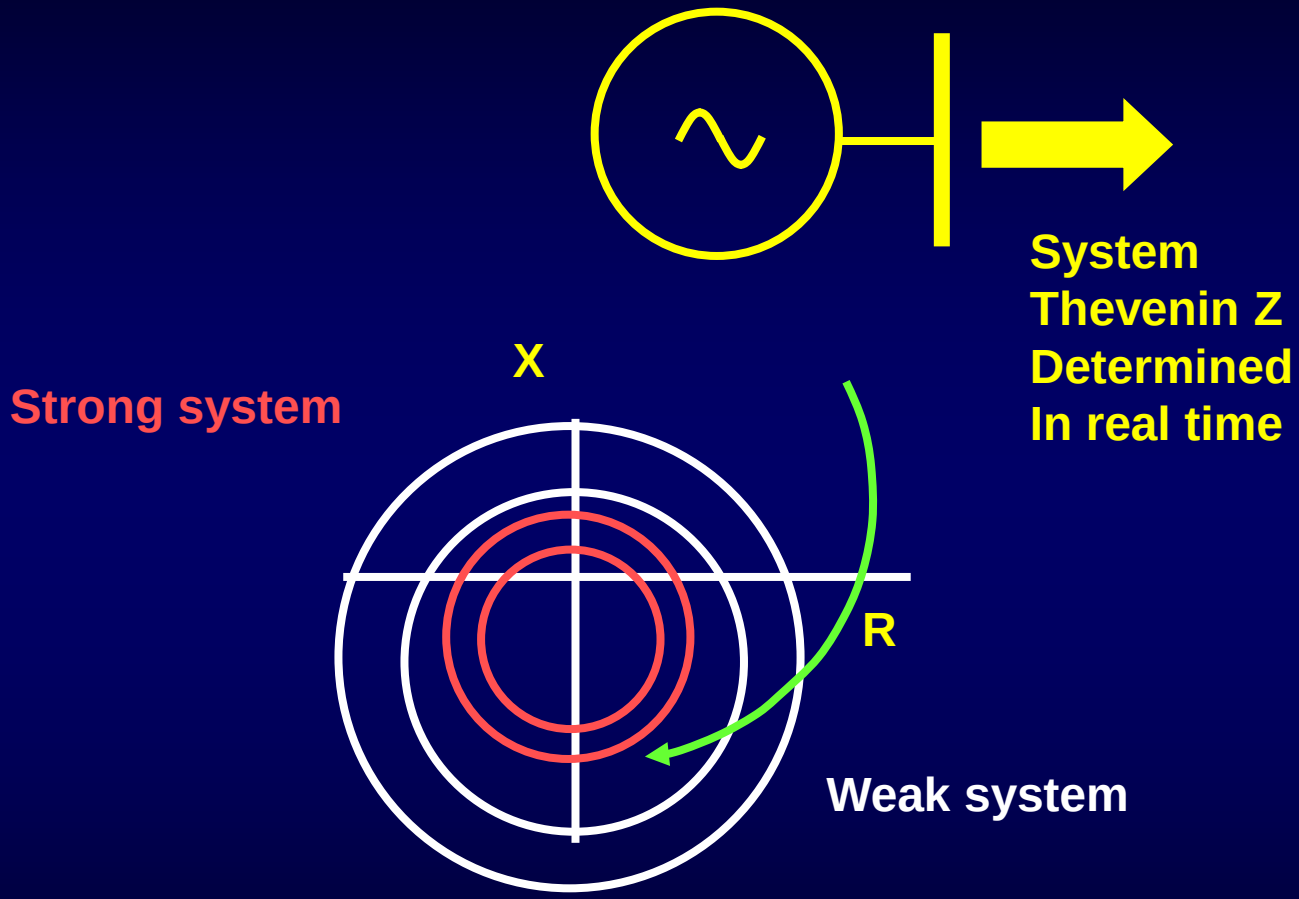
(5) Intelligent load shedding using load-generation imbalance estimate in real time



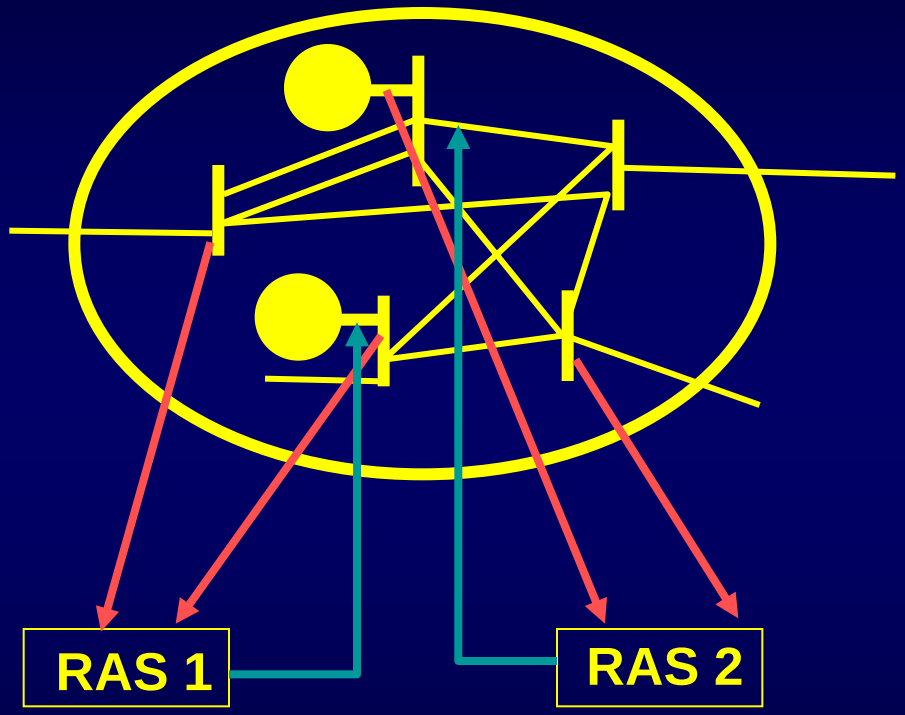
$$ACE = \Delta T - B\Delta F$$

Dynamic ACE measures
Load needed to be shed
To return to pre-disturbance state

(6) Adaptive loss-of-field relay



(7) System-wide integration of Remedial Action Schemes (RAS or SIPS)



Are RAS 1 and RAS 2 In conflict with each other?

Make one RAS which Will combine the Objectives of the two RAS schemes and Create a unified response.

Concluding remarks

- Protection systems can be improved with the help of wide-area measurements
- Only slow-responding protections are appropriate candidates for such improvements
- Many improvements occur as steps to improve response to next contingencies, and are not intended to operate when a fault has occurred.

With careful implementation, frequency and intensity of blackouts can be reduced, and service restoration can be more rapid.

In memorium

Rui Menezes de Moraes