Dr. Vladimir Brandwajn and Dr. Show Chang - ABB Network Management, June 23, 2010

OPF in Energy Markets:
Current Practices and Future Directions

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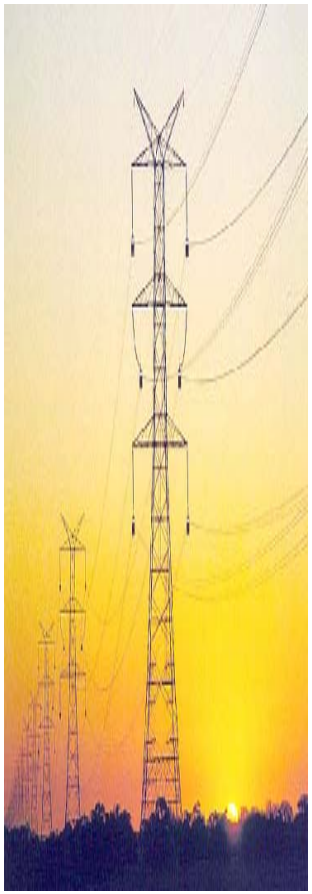
Outline

- **Historical Perspective**
- **OPF Model**
- **Solution Process**
- **Security Monitor Implementation**
- **Performance and Features**
- **Going Forward**

Historical Perspective

- **Security Constrained UC (SCUC) developed in ’90s for NYISO**
- **Network analysis (Security Monitor) initially based on well established EMS software**
- **Extensive development over several ISO markets**
  - **Different features for different markets**
- **Continuing enhancements to support ever changing market requirements**



OPF Applications
Energy Markets

- **Applicable to both Real-Time and Day-Ahead Markets**
- **Optimization Objective**
  - **Security Constrained Economic Dispatch**
    - Linear Programming
  - **Security Constrained Unit Commitment**
    - Mixed Integer Programming
    - LR

OPF Applications
Optimized Controls

- **Control types:**
  - **Generators**
  - **Loads (buses, zones, hubs)**
  - **Virtual Offers/Bids (buses, zones, hubs)**
  - **Phase Shifters**
  - **DC Links**
  - **Congestion Revenue Rights (options and obligations)**
- **The first three controls participate in the system power balance**
- **Other controls are modeled as balanced injections**
- **The phase shifter MW flows (not angles) are modeled as controls**

OPF Applications
Power Flow Controls

- **Control types:**
  - **Distributed Slack**
  - **Area Interchange**
  - **Phase Shifter MW Flow**
  - **Generator MVAR Limit Enforcement**
  - **Transformer Tap Voltage/MVAR Flow**
  - **Generator Voltage (Local/Remote)**
  - **Reactive Shunt Switching / SVC**
- **Power flow controls may alter the optimized controls and this has to be considered in the optimization**
- **Power flow controls are difficult to model as explicit constraints in the OPF**

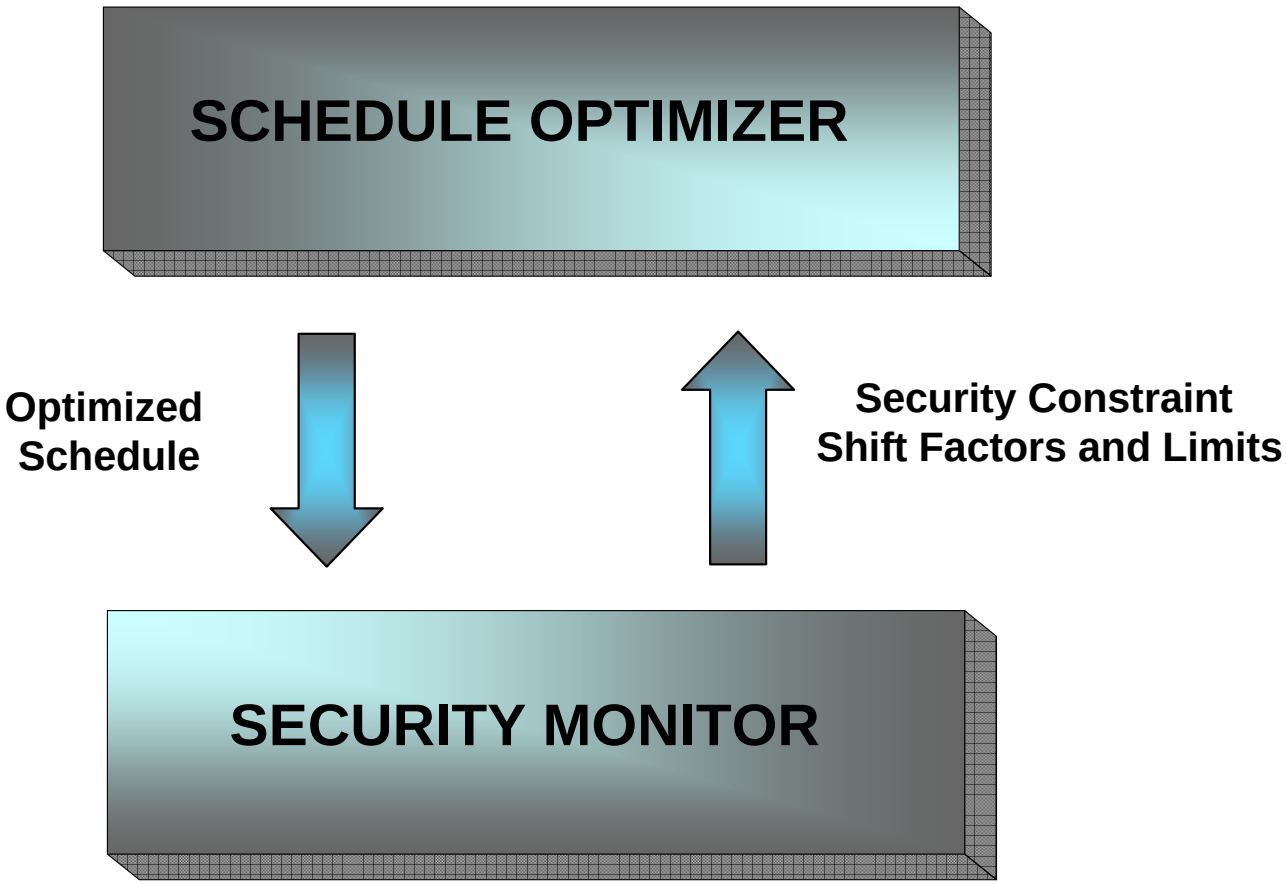
OPF Model
Network Constraints

- **Branch flows**
- **Branch group (interface) flows**
  - **Represent stability and/or voltage collapse limits**
  - **May vary with system configuration changes**
- **Generic constraints (operating security limits)**
  - **Linear combinations of generators, loads, branch flows and branch group flows**
  - **May vary with system configuration changes**
- **Branch angular differences**
  - **Essential to model the MW steady state limits**

OPF in Markets
Practical Considerations

- **Reliable and robust solution process**
  - **Solutions must be obtained regardless of the data quality**
    ➔ multiple solution schemes needed (AC, Non-linear DC, DC)
- **High performance**
  - **Large number of optimized controls**
  - **Large number of contingencies (> 2500)**
  - **Multi-interval optimization**
  - **Temporal Constraints**
  - **Transmission loss modeling**
  - **Suppression of ineffective control scheduling**

Solution Process
Tailored to Efficiently Model Market Requirements



Solution Process
Components

- **Schedule Optimizer**
  - **Calculates the minimum cost dispatch or commitment schedule of the controls, while simultaneously satisfying both control variable and system constraints as well as network security constraints**

- **Security Monitor**
  - **Evaluates the feasibility of the operating schedule calculated by Schedule Optimizer**

Solution Process
Security Monitor

- **Perform base case power flow**
- **Compute loss delivery factors**
- **Perform contingency analysis**
- **Select critical network security constraints**
  - **Base case and post-contingency**
- **Compute shift factors of the selected security constraints**
- **Determine overall solution convergence**
- **Calculate Location Marginal Prices (LMP)**

Solution Process
Solution Features

- **Solution convergence independent of system size and number of contingencies**
- **Intelligent selection of critical security constraints to achieve rapid convergence and enhance the Schedule Optimizer performance**
- **All standard power flow controls modeled in the Security Monitor**
- **Efficient sparse matrix and contingency analysis techniques**
- **Modeling of SPS**
- **Dependence of flow limits on loading and weather**
- **Voltage-dependent load modeling**

Performance

- **Consistent performance across different ISO markets**
- **Modeling of 2500 contingencies on a 6000-bus system is routinely executed in both Real-Time and Day-Ahead markets (35 million security constraints)**
  - **The Security Monitor takes less than 15% of the overall solution time**
- **The ever increasing number of CRR options may present a performance challenge**
  - **Special techniques have been developed**

Security Monitor
Going Forward

- **Modeling of voltage constraints and reactive power controls**
- **Integration of post-contingency corrective rescheduling into the preventive optimization**
- **Integration with voltage and transient stability**
- **Parallel processing**
- **Transmission switching**

OPF in the Market Environment
Future

- **Integration of variable energy resources and demand resources (DR, DG, and storage)**
- **Role of OPF in Reactive Power pricing**
- **Benchmarking**
- **Performance**

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