Development of Fast Real-time Online Dynamic Security Assessment System

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Weakly interconnected system
- Sub-networks are loosely coupled
- A disturbance in one sub-network usually won’t cause any problem to the neighboring sub-networks
- Stability concern: Low-frequency oscillation

Strongly interconnected system
- Sub-networks are strongly coupled
- A disturbance in one sub-network is likely to cause problems to the neighboring sub-networks
- Real-time fast sub-network coordination is needed
  - Need for a “Fast” DSA system
Over the last 10 years China has built a UHV national Grid. On-line DSA has been widely used in China for the grid operation.

**Current DSA System**

- Power grid size: ~40K bus
- Round-trip DSA computation time ~10 min
  1. SCADA + State Estimation
  2. Alarming analysis
  3. Stability margin analysis
  4. Decision support analysis
- Current DSA is a NEAR REAL-TIME solution
  - Power system dynamics develop at the speed of seconds
• Challenges
  • DSA algorithms have limited optimization room
    • Transient stability simulation requires computation time of 
      ~2-time the physical process time (~40K bus)
  • National Dispatch Center: computer cluster with ~1K cores 
    for a contingency set of 700+ contingencies
  • Data collection and preparation (SCADA + State Estimation) 
    take time (~2 min)
  • End-to-end system wide optimization needed
    • IT + Power Engineering
Comparison: Auto Navigation System

AAA Map

Navigation System

Key feature: Real-time position on the map
Online DSA

- **Off-line Study**
  - Define the security region for a given power network

- **On-line DSA**
  - Determine the security position of the current operation point
  - Automatic Operator (Dy-Liacco 1997)
    - DSA scans system very 15 min
  - Challenges
    - Currently 10 min to complete the computation
    - “Near real-time position with delay of 10 min”
    - On-line DSA computation results thrown away
    - No historic computation result based Knowledge Base
Our Proposed Approach

Goal: A new fast real time online DSA system with the round-trip computation time less than 60 seconds or “real-time position with delay < 60 sec”

- **Feature-1:** Systematically store the existing online DSA simulation results
  - Categorize and index the online DSA results
  - Apply deep machine learning method
  - Create a DSA simulation case knowledge base

- **Feature-2:** Search and pattern matching based Fast DSA analysis
  - Fast DSA analysis through the knowledge base search
  - Google search – search indexed Google datastore instead of the Web itself
Current Approach:
- Secure region limit calculated by off-line study
- Current operating point is checked every 15 min
- Current operating points are analyzed in isolation
- Online DSA simulation results are not saved systematically

Proposed Approach:
- Off-line and on-line simulation results are saved systematically
- Fast DSA analysis through the search of the “Closer” historic simulation cases
- Power system operation is periodic and recurring
- Power system operation condition normally changes slowly
“The Two-second Advantage” Principle

Speed vs Accuracy: As compared with the on-line DSA computation, how accurate is the search based results?

“If you have a little bit the right information, just a little bit before hand, it is a lot more valuable than all the information in the world six months after...”
Search based Solutions

The Chinese national dispatch center:
  • Off-line simulation case: 20K/year
  • On-line DSA simulation case: 25M/year
  • We have enough computing power to achieve AlphaGo smartness!
  • The on-line DSA simulation results are not systematically saved currently

According to the Nature paper:
  • AlphaGo has not invented any new AI algorithm
  • Its strategy is based on search of 30M existing Go cases and the deep machine learning approach
Fast DSA Solution Architecture

Current DSA

SCADA → Loadflow Snapshot → Periodic DSA analysis

Proposed Fast DSA Analysis

Change Event → Real-time Analysis Model

① Simulation case store

② Situation Awareness

③ DataStore (Hahoop)

④ Alarming

⑤ Search & Pattern Match

⑥ Assessment & Decision Support

Systematically save DSA analysis results

Data-driven instead Of Model-driven

SCADA + Model Update + Situation Awareness + Search + Assessment & Decision Support < 60 sec (40K-Bus)
EMS has a real-time measurement and monitoring (M&M) model.

The M&M is a Break/Switch model.

Bus/Branch model for DSA analysis.

Build a real-time analysis model with an update delay less than one sec with regarding to the M&M model.

High-speed data bus will be used to integrate the two network models.
Key Tech(2): Search & Pattern Matching Implementation

- Lambda Architecture for Big Data processing
- Used in Twitter and many other places
Key Tech(3) Complex Event Processing (CEP)

- Current DSA : Near Real-time Batch Processing
  - Every 15 min: Create input file -> Run Programs -> Output
- Fast DSA : Real-time Event Based Application Integration
  - EDA – Event Driven Architecture
  - Complex Event Processing technology
  - PJM AC2 Intelligent Event Processing Module

- CEP Engine
  - Rule Engine
  - Distributed Data Grid
  - State Machine
A new fast real-time DSA system development project has been started.

- **Sponsor**: State Grid of China
- **Participants**
  - State Grid Electrical Power Research Institute
  - Nari Beijing KeDong Company (Leading EMS vendor)
  - EPRI China (Leading DSA vendor)
  - Tsinghua University
  - Hunan Provincial Power Company
- **Time-line**: two-phase approach
  - Key technology development (2016-18)
    - Infrastructure and application software component development
    - Prototype and demonstration
  - Full-scale development and deployment (2019 and beyond)
Thanks