Development of Fast Real-time Online Dynamic Security Assessment System

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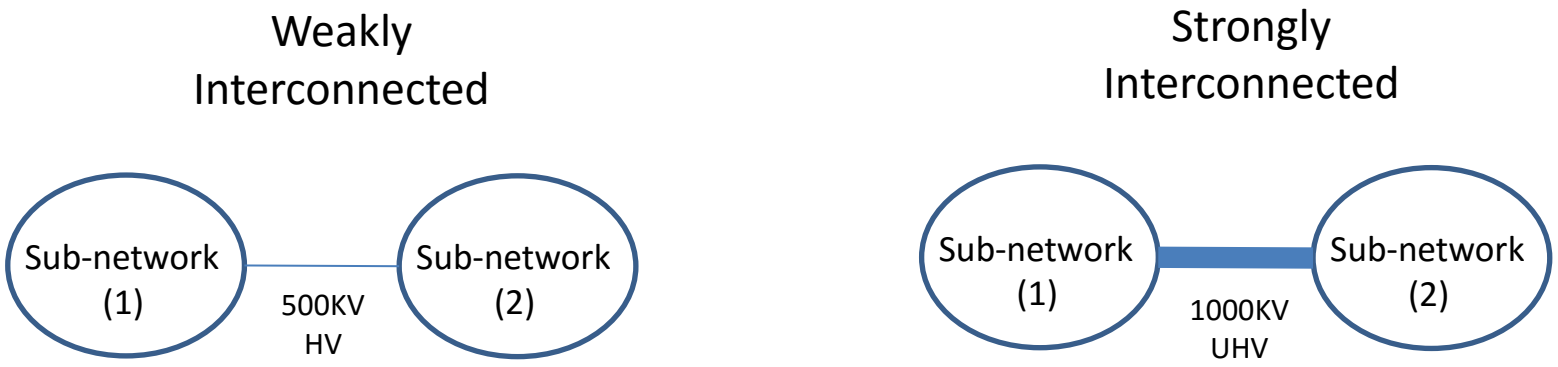
Interconnected Power System



- 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

Current DSA System in China

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

Current DSA System in China（cont）

- 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

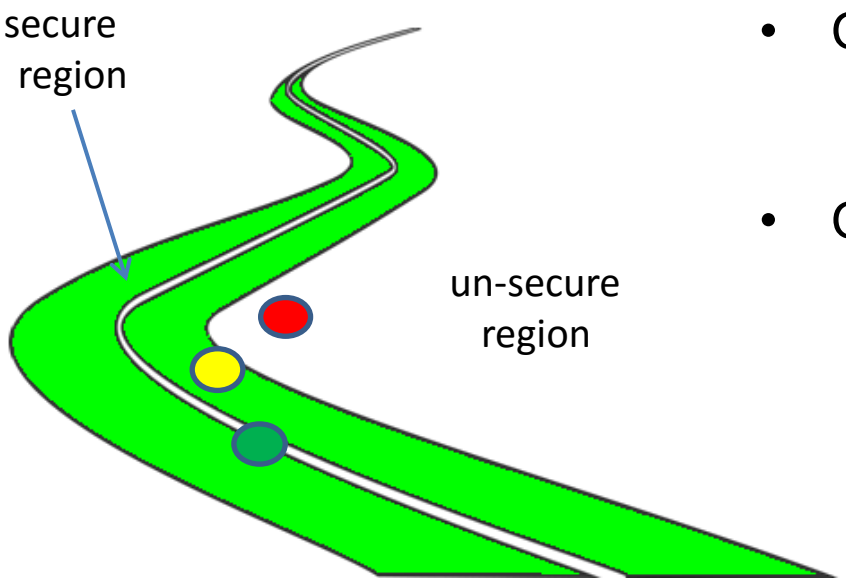
Comparison: Auto Navigation System

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

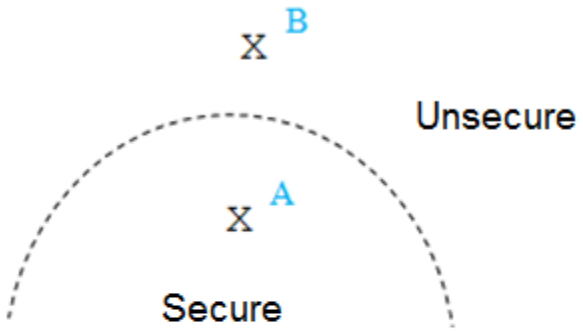
Our Proposed Approach

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”

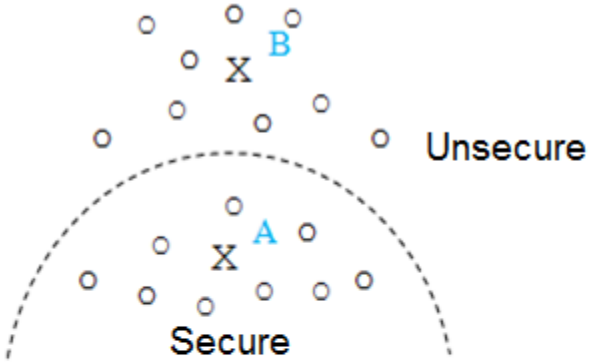
- Feature-1: Systematically store the existing online DSA simulation results
  - Categorize and index the online DSA results
  - Apply deep machine learning method
  - Create a DSA simulation case knowledge base
- Feature-2: Search and pattern matching based Fast DSA analysis
  - Fast DSA analysis through the knowledge base search
  - Google search – search indexed Google datastore instead of the Web itself

Search and Pattern Matching

Current Approach



Proposed Approach



x Current operating point

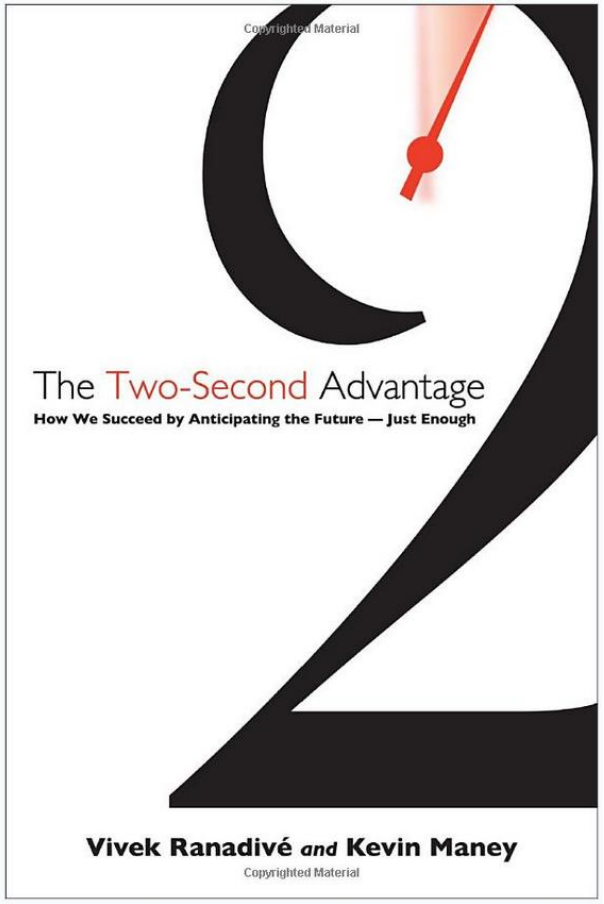
o Historic operating point with DSA results

--- Secure Region Limit

- 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

- 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

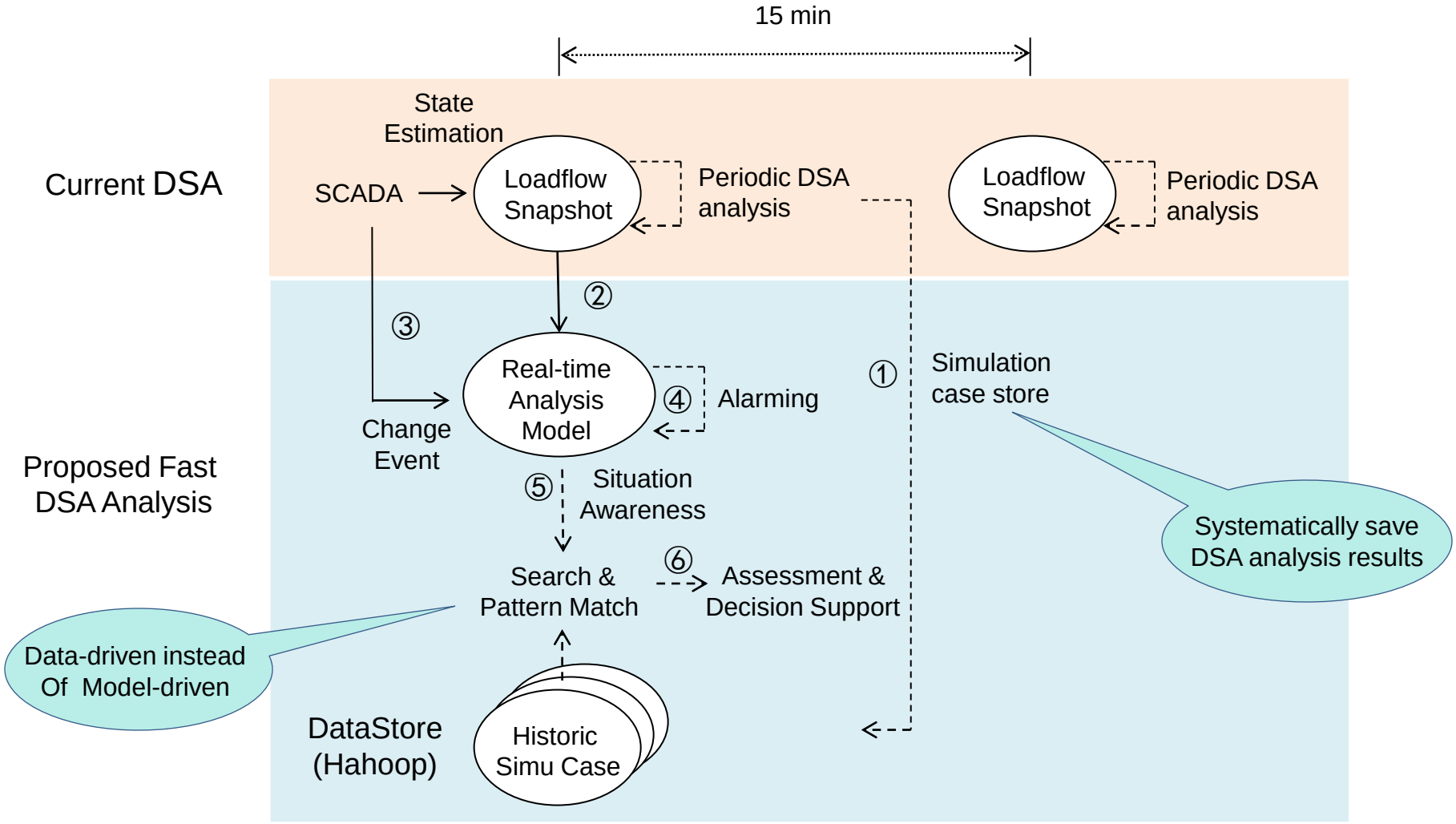
The Chinese national dispatch center:

- 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:

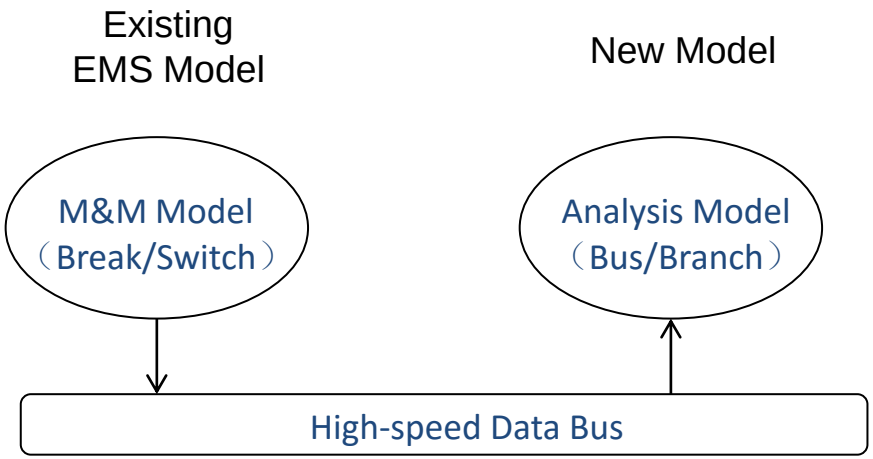
- AlphaGo has not invented any new AI algorithm
- Its strategy is based on search of 30M existing Go cases and the deep machine learning approach

Fast DSA Solution Architecture



SCADA + Model Update + Situation Awareness + Search + Assessment &Decision Support < 60 sec（40K-Bus）

Key Tech(1): Real-time Power Network Model



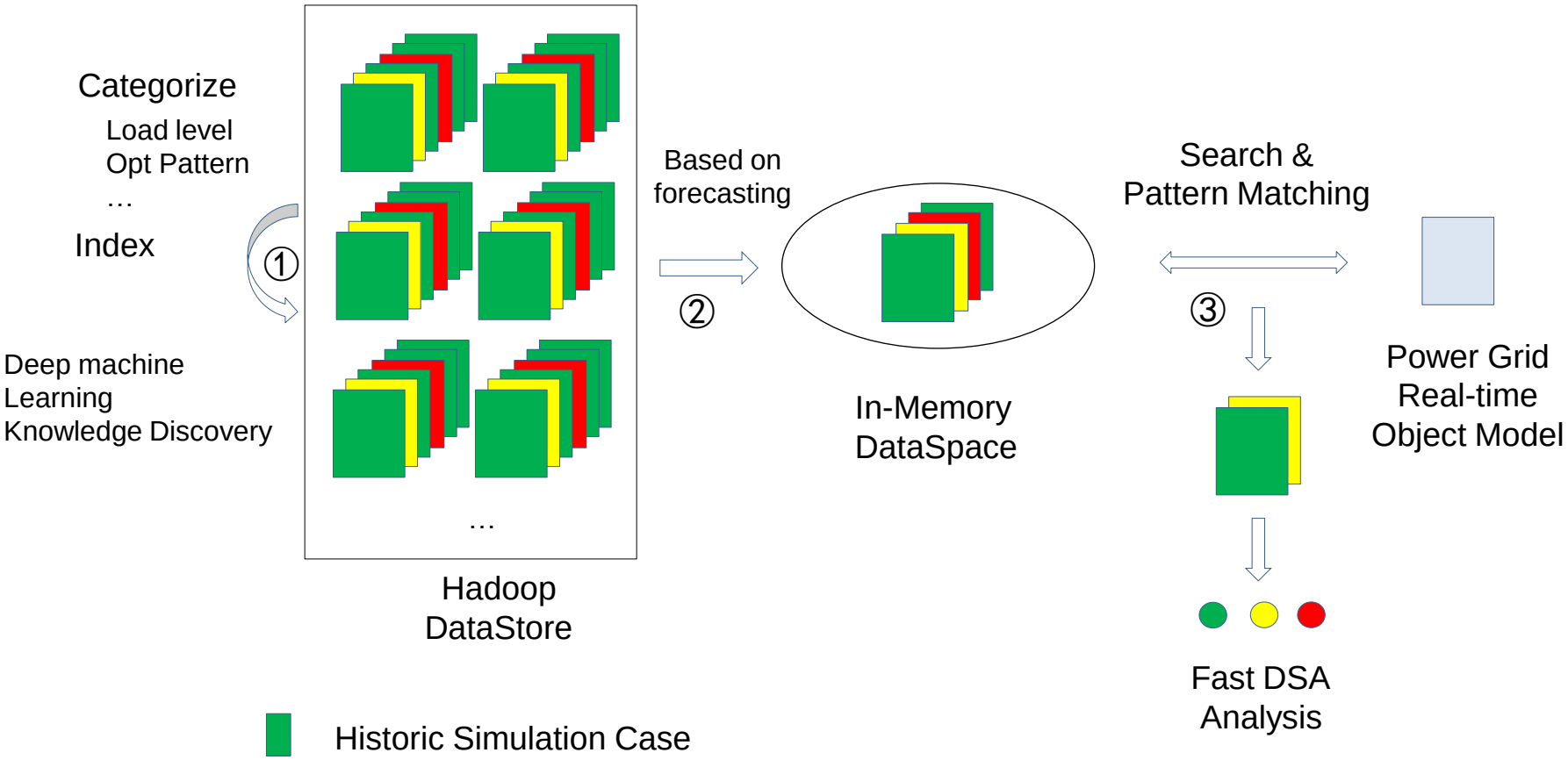
M&M Model

- EMS has a real-time measurement and monitoring (M&M) model
- The M&M is a Break/Switch model

Analysis Model

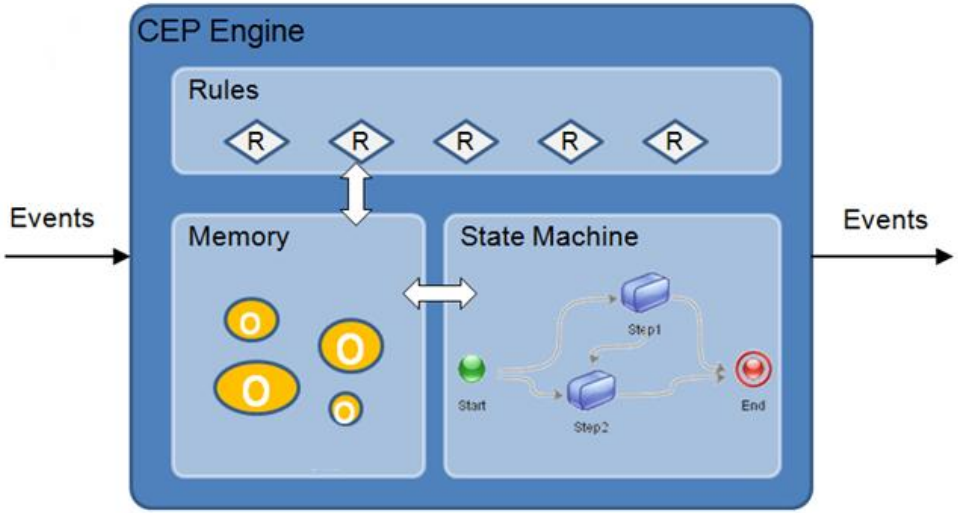
- Bus/Branch model for DSA analysis
- Build a real-time analysis model with an update delay less than one sec with regarding to the M&M model.
- High-speed data bus will be used to integrate the two network models

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

Project Status

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