A New Architecture for Online Power System Analysis

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***Abstract*— The current DSA system used in the dispatching control centers in China is a near real-time analysis system with response speed in the order of minutes. Based on a review of the state-of-the-art in online analysis and discussion of distributed data processing and computation architecture patterns, a new online analysis architecture is proposed. The primary goal of the new architecture is to increase the online analysis response speed to the order of seconds. A reference implementation of the proposed online analysis architecture to validate the feasibility of implementing the architecture is presented.**

***Index Terms*— Complex Event Processing, CEP, DSA, EMS, In-memory Computing, Power Grid Modeling, Power System Online Analysis.**

I. Introduction

AFTER a decade of development, online dynamic security assessment (DSA) has been widely used in the power dispatching control centers in China [1]. In an online DSA system, power grid redundant telemetry (RTU) measurement data is processed first by Supervisory Control And Data Acquisition (SCADA) and then by State Estimation (SE) to estimate the state of the grid and establish a power flow study case before starting the DSA analysis. The state grid of China currently is modeled using a 40000-bus power network model in DSA analysis. A round DSA trip, including SCADA, SE and DSA analysis, currently takes about 10 minutes. Therefore, the current online DSA system, when used to handle the large-scale power network model, is a near real-time analysis system with response speed in the order of minutes. Online DSA analysis is currently performed in the dispatching control centers periodically at an interval of 15 minutes.

Real-time may have different meanings depending on the context. In this paper, in the context of power system online analysis, real-time refers to the response speed of data processing and computation in the order of seconds. With the increasing installation of power electronic devices, such as HVDC and FACTS, and the increasing penetration of distributed generation and power electronic based loads, portions of a power grid are expected to become much more dynamic with much less inertia to maintain the synchronization. To enhance the real-time system control to maintain and improve system security and stability, the computation speed of an online analysis system is crucial [2]. With the development of the ultra-high voltage AC/DC national grid in China, it has been foreseen the need for a fast real-time online DSA system with response speed in the order of seconds. A fast real-time online DSA system could help the operator to perform real-time analysis and support their decision-making process, while the system dynamic process is developing, rather than after-the-fact analysis.

A new fast real-time online DSA development project, sponsored by the State Grid of China, has been started [3]. The primary goal is to reduce the online DSA system overall round trip time, from data acquisition to complete the analysis, from the current proximate 10 minutes to less than 60 seconds. While the focus of most online analysis R&D efforts up-to-date are at the individual subsystem level, trying to optimize a particular part of an online analysis system, the focus of the project is to investigate the online analysis response speed issue from the overall end-to-end system perspective, from remote RTU measurement data collection, in-memory database storing the measurement information, establishing power grid model to represent the current operation condition, all way to feeding the data to online DSA applications. As an import step of the effort, online analysis system architecture has been investigated. The investigation results are reported in this paper.

A review of the state-of-the-art in the online analysis is first presented in Section-II, and then followed by a discussion in Section-III of four architecture patterns relevant to the distributed data processing and computation approaches commonly used in online analysis systems in the dispatching control centers in China. Based on a review of the current online analysis architecture, a new online analysis architecture is proposed and described in Section-IV. A reference implementation of the proposed online analysis architecture is presented in Section-V.

II. State-of-the-Art in Online Analysis

Power system security refers to the degree of risk in a power system's ability to survive potential disturbances without interruption to the service. It relates to the robustness of the system to potential disturbances and, hence, depends on the current system operating condition as well as the contingent probability of disturbances [4]. To ensure that a power system is sufficiently reliable, the system must be: 1) properly designed with security as a primary consideration; 2) monitored

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and controlled during operation to ensure sufficient security margin. The system condition is determined by the system operating point, plus system controls and protections which will operate should severe disturbances occur [5], [6].

Secure system operation has become more challenging with the evolution of the electric power industry toward open markets around the world. In China, the development of the ultra-high voltage AC/DC national grid has introduced a number of factors that have increased coupling between interconnected systems and possible sources for system-wide disturbances, reduced robustness of systems and less predictability of the system operation condition[7], [8]. This section reviews the state-of-the-art in the online analysis.

A. *Dynamic Security Assessment*

The control center is the central nerve system of the power system. It senses the pulse of the power system, adjusts its condition, coordinates its adjustment, and provides defense against disturbances [9]. Traditionally, security has been achieved solely through off-line analyses using forecasted information. This approach has proven inadequate and often impractical for ensuring the secure system operation. Increasingly online DSA is used in which a snapshot of the current system operating condition is obtained and is used to conduct the security assessment. This approach reduces the need for prediction of system conditions and therefore has demonstrated to provide more accurate assessments [10].

DSA system in China has been in use in the dispatch centers for more than a decade [1]. The DSA system is running on top of the D5000 EMS system [7], which is currently deployed in all national, regional and provincial power dispatch centers in China. The D5000 system provides comprehensive data service, supporting the horizontal integration of four categories of applications deployed in three security zones (I/II/III zone) in a dispatch center, and vertical data access across the national, regional and provincial dispatch centers [11].

B. *Online Analysis*

Online analysis of the current system operation snapshot is the most importance part of a DSA system. There are many challenges in enhancing the performance of an online analysis system. Currently, acceptable performance is achieved through a combination of grid model reduction, distributed/parallel computing, and sometimes simplified computation methods. The completion of an entire analysis cycle within 5–60 minutes, from the time the snapshot is taken to the time the results are made available to the grid operator, is considered a reasonable target [5], [10], [12]. The applicability of various computation methods used in the online analysis in China was reviewed in Ref.[2].

C. *Complex Event Processing(CEP)*

Event processing is a method of tracking and analyzing streams of information about things that happen in a physical system, which are represented digitally as events, and deriving conclusions from them. Complex event processing (CEP) [13] is an event processing approach that combines data from multiple distributed sources, possibly over a period of time, to infer events or patterns that suggest more complicated circumstances. The goal of complex event processing is to identify meaningful events to recognize possible opportunities or threats, and response to them in real-time.

The events may be happening across various time points, locations and/or layers of a complex system. CEP gives us a new way to analyze patterns in real-time. Event correlation is most interesting since it might identify certain event pattern, which, based on historical data or human experience, might lead to disaster, for example, large-scale power grid blackout. If such pattern could be identified in real-time, early warning can be sent out and immediate action taken to prevent the disaster happening or limit the impact caused by the disaster.

D. *Intelligent Event Processing*

PJM Interconnection in the US operates one of the largest wholesale power markets. For PJM, real-time operational visibility of regional conditions and reliability issues is essential. Based on the CEP technology, PJM has built an Intelligent Event Processing (IPE) system that enables operators and engineers to have better visibility of events occurring in the grid to see trends and potential problems within the grid before they become real issues. The data aggregation of events in the grid and recognizing patterns from the data is automated and presented to the operator in real-time, who can focus more on problem-solving and decision making [14].

A typical CEP based monitoring system includes two key parts: 1) a real-time physical system model to be monitored; 2) a rule engine. Ideally, in the online analysis, a power grid model should provide support for the real-time update to track the current grid operating condition so that monitoring rules could be applied, as well as support for fast security assessment (online analysis). In the case of PJM IEP, the real-time power grid model was created based on IEC CIM specification, which is a power grid Node/Breaker physical device model. IPE grid model provides support for real-time monitoring, however, it falls short to provide support for fast online analysis.

A significant amount research and development have been done in the field of online analysis over the last 30 years. Most R&D efforts are aimed at extending the features and capabilities of the existing system. Areas of work include handling of new technologies, such as wind farms, improving speed and scope of assessments, improving visualization of results to operators, using optimization in the determination of remedial measures, and use of intelligent systems, such as the PJM IPE system [5]. It is our opinion that the focus of most online analysis R&D efforts up-to-date are at the individual subsystem level, trying to optimize a particular part of an online analysis system. There is a need to look the online analysis response speed issue from the overall end-to-end system perspective, especially investigate the online analysis system architecture.

III. Architecture Patterns

Software system architecture describes the logical organization and physical realization of a software system. An architecture pattern is a general, reusable architecture solution to a set of commonly occurring problems in software architecture within a given context. The architecture patterns address various issues in software engineering. In this paper, we are particularly interested in the performance issues associated with data processing and computation.

A. Power Grid Model

Power grid modeling technique is the foundation of power system analysis. By modeling, we mean establishing data/object structure in database or computer memory (RAM) to store power system information for the analysis purpose. In general, there are two types of power grid models: 1) Node/Breaker physical device model; 2) Bus/Branch logical analysis model. Information stored in the EMS in-memory database are of the Node/Breaker model type, while input data to power system online analysis programs are of Bus/Branch model type. It is important to note that both types of power grid models are necessary for the online analysis, which allow us to analyze and monitor power system operation from different perspectives. The primary goal of the proposed new online architecture presented in this paper is to make the Bus/Branch logical analysis model real-time or with response speed in the order of seconds.

B. In-Memory Database (IMDB)

In-Memory Database (IMDB) is a database management system that primarily relies on RAM for data storage, instead of using a disk as the storage mechanism. IMDB is faster than disk-optimized databases because disk access is slower than memory access, and the internal optimization algorithms are simpler. Applications where response time is critical often use IMDB, especially in the Big Data analytics area, due to mainly multi-core processor technology that can address large memory and much less expensive RAM price.

C. In-Memory Data Grid (IMDG)

In-memory data grid (IMDG) is a data structure that resides entirely in RAM and is distributed among multiple computer nodes. RAM, roughly, is 5K-times faster than traditional hard disk. Recent technology advances in multi-core processors have made it practical to store a large amount of data completely in memory, replacing the electromechanical mass storage media such as hard disks. IMDG can support hundreds of thousands of in-memory data updates per second and can be clustered and scaled in ways that support processing a large volume of data. IMDG is the foundation for in-memory computing.

D. In-Memory Computing (IMC)

In-memory computing (IMC) means using IMDG that allows one to store data in RAM, across a cluster of computer nodes, and process the data directly in memory and often in parallel. IMC software, in general, is designed to store data in a distributed fashion, where the entire dataset is divided into individual computer nodes' RAM, each storing only a portion of the overall dataset. Once data is partitioned, highly efficient parallel distributed processing becomes possible.

An IMC technology based power system analysis architecture was proposed in Ref.[15]. In the paper, using a large-scale power grid model (40K+ buses), which was exported from the online DSA system currently used in the national power dispatching center in China, as an example, IMC based power system simulations were performed to study the feasibility to apply IMC to online power system analysis.

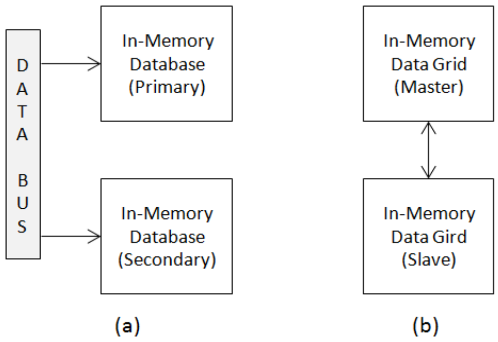

Fig. 1. Distributed Data Processing Patterns.

E. Pattern-1: Distributed Active/Passive Data Storage

The distributed active/passive data storage architecture pattern is shown in Fig.1(a). The primary database (active) and the secondary database (passive) are hosted at different computer nodes and running independently. The data stored in the primary and secondary databases are kept synchronized by subscribing to data change events from the same Data Bus. It has been known that this kind active/passive data storage architecture cannot guarantee the consistency of the data stored on the primary and secondary nodes. Currently, this kind of data storage pattern is used in the D5000 EMS system [7] in China to store power grid online Node/Breaker physical device model information.

F. Pattern-2: Distributed Master/Slave Data Storage

The distributed master/slave data storage architecture pattern is shown in Fig.1(b). IMDG software system, in general, provides automatic data synchronization mechanism to keep data stored on the master/slave nodes in synchronization, through the internal communication between the master/slave nodes. In other words, IMDG based master/slave data storage architecture can guarantee consistency (Eventual Consistency) of the data stored. Eventual consistency is a consistency model used in distributed computing to achieve high availability that informally guarantees that, if no new updates are made to a given data item, eventually all accesses to that item will return the last updated value. This kind of data storage pattern is commonly used in real-time Big Data processing.

G. Pattern-3: Relational Structure Based Data Processing

The relational data structure based data processing architecture pattern is shown in Fig.2. The power grid measurement information from RTU is stored in an EMS in-memory relational database. The data storage system and the computation system are hosted on different computer nodes. When the computation is triggered to be started, simulation program hosted on the computation node retrieves data from the in-memory database hosted on the data node. The data retrieved is with a relational data structure, which needs to be mapped to an object relationship to create or update the object model (OR Mapping in Fig.2). After the mapping and model creating/updating, simulation algorithm could be applied to the grid Bus/Branch logical analysis model to perform simulation tasks (Simulation in Fig.2).

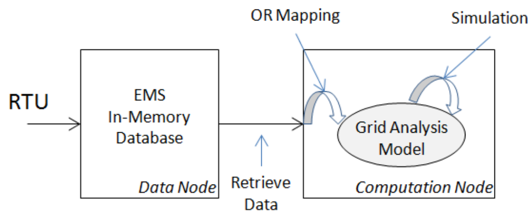

Fig. 2. Relational Data Structure Based Data Processing Pattern.

H. Pattern-4: Data Grid Based In-memory Computing

Data grid based in-memory computing architecture pattern is shown in Fig.3. The power grid measurement information from RTU is subscribed by the grid Bus/Branch logical analysis model to update the model in real-time (Model Update in Fig.3). Power grid simulation data are stored in the data grid in an object form. Computer nodes in the data grid provide both data storage service and computation service functionality. When the computation is triggered to be started, simulation algorithm could be applied to the grid Bus/Branch logical analysis model through in-memory access without the need to re-create the object model.

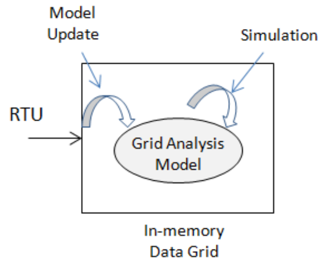

Fig. 3. Data Grid Based In-memory Computing.

Four architecture patterns are discussed in this section, which will be used in the next section to examine data processing and computation performance issues associated with the current online analysis architecture and define a new online analysis architecture. The relational data structure based data processing architecture pattern has been widely and successfully used in enterprise application integration (EAI) over the last 30 years. It is only when this type architecture pattern is used in Big Data processing in recent years that its limitation has been observed.

IV. A New Online Analysis Architecture

The current online analysis system architecture used in the D5000 EMS systems [7] in China, as shown in Fig.4, is based on the distributed active/passive data storage pattern and the relational data structure based data processing pattern, as shown in Figs.1(a),2. Behind the SCADA and SE in Fig.4, there is an in-memory database supporting the two applications. The RTU measurement information is fed into the database through high-speed D5000 Data Bus [7]. The periodical online analysis in Fig.4 refers to the current DSA analysis applications, which runs periodically with an interval of 15 min. The data flow from the grid Node/Breaker physical device model, stored in the in-memory database, to the grid Bus/Branch logical analysis model, used in the periodical online analysis subsystem, is in sequence and with response speed in the order of minutes. The relational data structure based grid Node/Breaker physical device model is an important part of an EMS system. Information describing power grid physical device operation state are stored in the in-memory database to support SCADA, SE, and other monitoring/alerting applications.

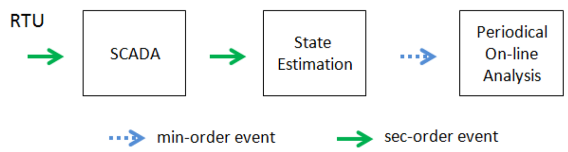

Fig. 4. The Current Online Analysis System Architecture, where *min-order*: response time in the order of minutes, *sec-order*: response time in the order of seconds.

A new online analysis architecture is proposed in this paper, as shown in Fig.5, to speed up the online analysis to achieve response speed in the order of seconds. In parallel with the current online analysis data processing and computation path (min-order path in Fig.5), a new real-time, event driven data processing and computation path (sec-order path in Fig.5) is introduced in the new architecture. The new path is based on the distributed master/slave data storage pattern and the in-memory computing pattern.

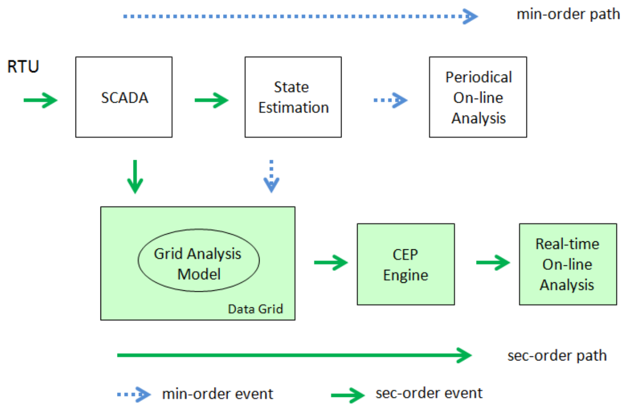

Fig. 5. The Proposed Online Analysis System Architecture.

At the center of the new architecture is the grid Bus/Branch logical analysis model, which is hosted in an IMDG and supports in-memory computing [15]. The grid Bus/Branch logical analysis model is periodical, for example, every 15 min, synchronized with the SE outcome. It also subscribes the power grid change events published by the SCADA system and updates itself based on the real-time event-driven data processing approach. In the realization of the new architecture, the grid Bus/Branch logical analysis model is implemented based on the object-oriented power grid simulation model proposed in Ref.[16]. The InterPSS project [17] provides an open implementation of the simulation model using the Java programming language. The simulation model has been extended to Hazelcast [18] distributed in-memory data grid and supports in-memory computing.

The grid Bus/Branch logical analysis model running in the data grid provides an event-driven API. Changes (update) to the model are published in real-time as model change events. A

CEP engine subscribes to the event, perform situation awareness analysis and drive the downstream real-time online analysis applications. The goal of the new online analysis architecture is to speed up the online analysis from the current min-order response to sec-order response in the future. This also requires substantial computation performance enhance -ment of the current DSA system. A project to develop a fast real-time online DSA system is currently under the way, where the time-consuming online analysis, such as transient stability simulation, will be performed by searching for existing historical simulation study cases in a knowledge base, rather than using the step-by-step time-domain simulation method [3].

The use of CEP engine in the new architecture is particularly interesting. In the current online analysis architecture, the near real-time batch data processing approach is used. The data processing and computation process flow is linear, periodic and predictable. In the new online analysis architecture, an event-driven real-time data processing path (sec-order path in Fig.5) is introduced. The event-driven approach makes the data processing and computation process flow non-linear and dynamic since power grid operation condition change events are random in nature. The CEP engine is responsible to coordinate multiple applications to response to and process the power grid change events in real-time.

The current online analysis architecture is based on the distributed active/passive data storage pattern and the relational data structure based data processing pattern. The grid Node/Breaker physical device model and the grid Bus/Branch logical analysis model are running in sequence. The grid Node/Breaker physical device model updates the grid analysis mode periodically by feeding the power grid analysis data. The data processing and computation response speed is in the order of minutes. The proposed new online analysis architecture is based on the distributed master/slave data storage pattern and the in-memory computing pattern. The grid Node/Breaker physical device model and the grid Bus/Branch logical analysis model are running in parallel. The grid Bus/Branch logical analysis mode gets updated in real-time by subscribing the power grid change events published by the SCADA system. The data processing and computation response speed is designed to be in the order of seconds.

V. Reference Implementation

A reference architecture is an architecture template where the structures, respective elements, and relations provide templates for concrete software system architecture designs. Implementation of the reference architecture is usually done at an early stage of a large-scale complex software development project to study the feasibility and the complexity of implementing the project solution architecture. A reference implementation has been done in a laboratory environment to evaluate the proposed new online analysis architecture. The implementation details are presented in this section.

A. *Hardware Configuration*

Two high-performance physical machine (PM) servers were used for hosting the implementation, as shown in Fig.6. The server had the hardware configuration: Huawei RH5885 server with Intel Xeon E7 CPU, 2.0 GHz, total 80 cores, 128GB RAM, 600GB*2 hard disk.

Six virtual machines (VM) were created on the two physical server machines. The VMs had the configuration: 16 cores, 6G RAM, 100G hard disk. A Monitor Console running on a Laptop connects to one of the VMs for the application running status monitoring purpose.

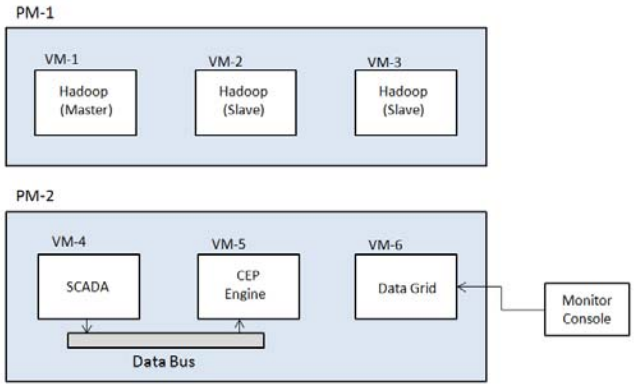

Fig. 6. Hardware and Software Configuration for the Reference Implementation.

B. *Software Configuration*

Hadoop was installed on three VMs (1~3) on PM-1, as shown in Fig.6, for storing historical simulation cases. An SCADA emulator was installed on VM(4) on PM-2, which published simulated RTU measurement information on to the Data Bus periodically as events, at a speed of several thousand per sec.

D5000 Data Bus was installed on VMs(4~5) on PM-2 so that applications running on these two VMs could be connected through the Data Bus. A D5000 Data Bus Adapter was developed for the implementation, which allows the SCADA emulator to publish events onto the Data Bus, and the CEP Engine to subscribe the events from the Data Bus.

CEP Engine was installed on VM(5) on PM-2. The engine was responsible to create and update the grid Bus/Branch logical analysis model. Also, it was responsible to coordinate the search and pattern matching activity.

Hazelcast Data Grid software system [18] was installed on VM(6) on PM-2. The grid Bus/Branch logical analysis model was hosted in the data grid. The Monitor Console was connected to the data grid to monitor the status of the objects stored in the data grid.

C. *Usecase Scenario*

Usecase scenario describing the implementation is shown in Fig.7. A set of historical simulation cases (100 to be exact), which were captured from an online DSA system running in one of the provincial dispatching centers in China, were stored in the Hadoop datastore. The simulation cases had a grid model size of 41219 buses，34028 branches and 12 HVDC lines. Using Hadoop MapReduce method, the search index of all historical simulation cases was computed and stored in the Data Grid for fast search and pattern matching.

A power flow snapshot, representing the current system operation condition, was loaded by the CEP engine to create a grid Bus/Branch logical analysis model to represent the current operation condition in the Data Grid. In this reference implementation, a case was randomly selected from the historical simulation case set to emulate the current system operation condition.

RTU signals, representing generation and load changes were generated by the SCADA emulator. The change events were subscribed by the CEP Engine, which in turn updated the grid Bus/Branch logical analysis model stored in the Data Grid.

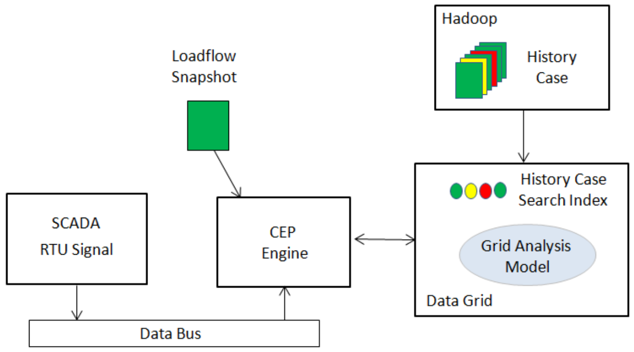

Fig.7. Usecase Scenario for the Reference Implementation.

Periodically (every 1 min) search was triggered by a CEP Engine timer. The CEP engine sent a search request to the Data Grid. Using the in-memory computing approach [15], the search index of the current model was computed and used to perform search and pattern matching to find the closest match from the historical simulation cases.

The reference implementation was completed successfully and running in a laboratory environment. The software systems and modules behaved as designed. Since this was a reference implementation to evaluate the feasibility of the proposed new online analysis architecture, due to the space limitation of the paper, we intentionally omitted discussion of the details of the software components used in the implementation.

VI. Performance Testing

The primary goal of the new architecture is to hence the online analysis system data processing and computation performance (response speed). Some preliminary testing was performed using the 40K-Bus network model, based on the reference implementation environment, to evaluate the performance. The testing results are presented in this section.

A. *Parallel Computing*

The grid analysis model, as shown in Fig.5, supports parallel computation implementation at three levels: a) Multi-process level; b) Multi-case level; or c) Algorithm level. The parallel implementation at these three levels can be run in the data grid, which hosts the grid analysis model [19].

1) *Multi-case level Parallel Computation*: The grid analysis model is multi-thread safe. Multiple objects, each representing a simulation case, could reside in one Java Virtual Machine process, and these objects could be processed in parallel. Multi-case level parallel computation implementation testing results are shown in Table-I. In the testing process, multiple Loadflow calculation jobs (Par. Jobs), from 1 to 32, were created and run in parallel. The total simulation time and acceleration ratios (Acc. Ratio) are shown. The testing hardware had 4 cores with 8 hyper-threads with a theoretical acceleration ratio of 4 times. As can be seen, when the number of parallel jobs were larger than 8, the acceleration ratios were in the range of 3.75~3.79, which were very close to the maximum possible value of 4. This indicates that the case level parallel computation implementation has linear scalability.

TABLE I
Case-level parallel computing

Par. Jobs	1	2	4	8	16	32
Time(sec)	0.342	0.367	0.458	0.722	1.459	2.890
Acc. Ratio	—	1.88	2.99	3.79	3.75	3.78

2) *Algorithm level Parallel Computation*: Certain types of simulation algorithms could be designed and implemented such that the grid analysis model is in read-only mode during the execution of the algorithm. These types of algorithms are multi-thread safe and can apply to the grid analysis model in parallel. Algorithm level parallel computation implementation testing results are shown in Table-II. The testing hardware was a high-performance server with 4 CPU and total 40 cores.

TABLE II
Algorithm-level Parallel Computing

	Sen. Cal.	*N-1 CA*	*Total*
Parallel (sec)	0.605	1.058	1.663
Sequential (sec)	6.793	41.605	48.398

In the testing, approximately total 13000 sensitivity calculations and 13884 N-1 contingency analysis (CA) runs were performed. As can be seen, the total computation time for a complete N-1 CA of the large-scale power network model could be achieved in less than 2 seconds with the parallel approach, and with an acceleration ratio of approximate 29 as compared with the sequential (no parallelism) approach.

B. *CEP Rule*

Six-type basic CEP rules were implemented and tested. The performance results are shown in Table-III. As can been seen, the execution time of the basic (simple) rules were very fast, in the order of million-seconds. The actual CPE rules were more complex, which could implemented as composite rules (composition of the basic rules). The execution time of the composite rules should be in the order of seconds.

TABLE III
CEP Rule Execution

Type	*Description*	*Time*
1	Model bus/branch update	< 1 ms (10800/s)
2	Bus/branch-level index calculation	< 1 ms (3000/s)
3	Model deserialization	150 ms
4	Topology analysis rule	< 1 ms (39000/s)
5	Loadflow calculation (3 NR steps)	350 ms
6	Model-level index calculation	4 ms (250/s)

Through the performance testing, presented in this section, the two main components: 1) grid analysis model; 2) CEP engine, in the new online analysis architecture have shown high performance. The new architecture and the associated components together could provide a strong technical foundation for the implementation of the future generation online analysis system to achieve the second-order overall system response speed.

VII. Conclusions

The current DSA system used in the dispatching control centers in China is a near real-time analysis system with response speed in the order of minutes. With the development of the ultra-high voltage AC/DC national grid in China, there is a strong need to develop a fast real-time online DSA system with response speed in the order of seconds.

Based on the review of the state-of-the-art in online analysis, we have concluded that the focus of most online analysis R&D efforts up-to-date are at the individual subsystem level, trying to enhance and/or optimize a particular part of an online analysis system. There is a need to study the online analysis response speed issue from the overall end-to-end system perspective, especially investigating the online analysis system architecture.

Four distributed data processing and computation architecture patterns relevant to online analysis systems used in the dispatching control centers in China have been discussed. With help of the architecture patterns, the current online analysis system architecture was reviewed, and limitations/ issues associated with the current architecture were outlined. To address the limitations/issues, a new online analysis system architecture has been proposed. The primary goal of the new architecture is to increase the response speed to the order of seconds.

A reference implementation of the proposed online analysis system architecture to validate the feasibility of the proposed architecture was done in a laboratory environment using 6 virtual machines hosted on 2 high-performance physical machine servers. It has been observed that the software systems and modules behaved as designed.

The preliminary performance testing results indicate that the new architecture could provide a strong technical foundation for the implementation of the future generation online analysis system to achieve the second-order overall system response speed.

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