

Framework for Artificial Intelligence Analysis in Large-scale Power Grids Based on Digital Simulation

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Abstract—The planning, design, operation, control and scientific research of power systems all require a variety of simulation analysis. Thus power grid simulation analysis is a fundamental supporting technology of large-scale power grids. In power grid simulation analysis, in addition to simulation calculations, there are many links for analysis and decision-making, relying on specialists. The introduction of advanced artificial intelligence technology provides a new method to improve the efficiency and accuracy of power grid simulation analysis. Nevertheless, the research of the related artificial intelligence technologies face a great deal of new challenges due to the complexity of the large-scale power grid simulation data, including massive volumes, high dimensionality, strong coupling and complex correlations. Also a great deal of knowledge and experience need to be integrated in the process of analysis. In order to deal with these challenges, based on the existing works, this paper focuses on the core scientific problem of artificial intelligence analysis and decision making related to the massive simulation results of large-scale power grids, and proposes an artificial intelligence analysis method framework for large-scale power grids based on digital simulation, which includes the power grid simulation analysis knowledge model with application method, the power grid simulation knowledge mining method and the artificial intelligence models with transfer learning ability of diversified grids as well as analyzing and calculation adjusting for large-scale power grid simulation results, etc. This work is expected to open up a new technical approach for large-scale power grid simulation analysis and provide strong technical support for the safe and stable operation of large-scale power grids.

Index Terms—Artificial intelligence, digital simulation, power system analysis.

I. INTRODUCTION

DIGITAL simulation analysis for power grids (referred to as power grid simulation analysis in this paper) is widely used in power grid operations, planning, design, etc., as a basic supporting technology of power grids [1], [2]. Power grid simulation is essentially a type of scientific calculation, primarily including power flow calculations and transient stability simulation. In this paper, the input data and output result data related to power grid simulation calculations are collectively referred to as simulation data.

Simulation data for large-scale power grids are massive, high-dimensional, sparse and spatio-temporally correlated (parameters, model and solution-described physical space). First of all, large-scale power grid simulation calculations have a variety of historical data accumulations, and produce a huge amount of data according to need. Second, large-scale power grid simulation data have differential or algebraic equation-described, highly complex linear and nonlinear relationships. Finally, due to the continuity of operation changes of large-scale power grids, there is a close sequential relationship between each step of the transient simulation calculation.

Since the 1970s, researches on power grid simulation and calculation programs have been started at home and abroad, and many power grid simulation software such as PSD, PSASP, and PSS/E have been developed. At present, power grid simulation technology based on the mechanism model has been able to provide strong support for the solution of the system state, but there are still many links in the simulation analysis process that need to rely on experts for analysis and decision-making, as shown in the white box in Fig. 1.

With the increasing complexity of power grids, this mode of work has gradually reached the large-scale power grids of ten thousands of nodes, which is extremely insufficient in the following aspects.

1) It incurs high labor cost. As the large-scale power grid simulation involves millions of parameters and variables, it is increasingly difficult to analyze and adjust the data, which requires a lot of manpower.

2) It relies heavily on expert experience. In the large-scale power grid simulation analysis, whether the problem can be found and the solution can be obtained primarily depends on the technical level and engineering experience of the experts.

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Ordinary technicians are not competent enough for complex and large-scale power grid simulation and analysis tasks

3) It is prone to errors and leakage. The simulation data for a large-scale power grid is highly complex, and it is difficult to extract and distinguish its internal laws.

4) It is difficult to control the analysis error. Due to the limitation of human energy and capability, the accuracy of large-scale power grid simulation analysis is difficult to be guaranteed.

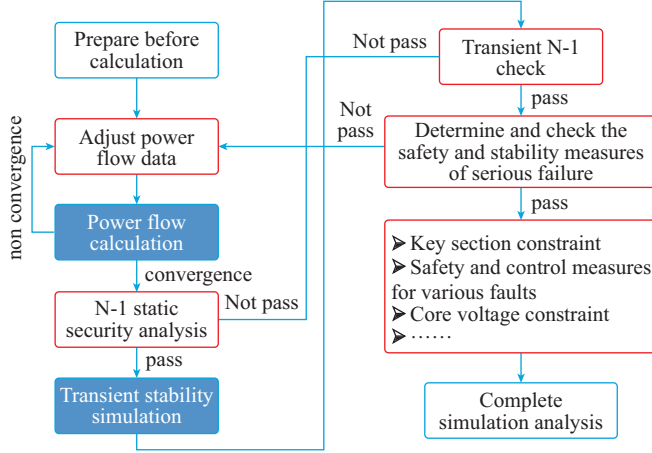


Fig. 1. Main links of power grid simulation analysis.

In recent years, the Artificial Intelligence (AI) technology has been significantly developed. In the new generation of AI technology represented by big data AI, cross-media AI, human-computer hybrid enhanced AI, etc., knowledge driven [3], representation learning [4], reinforcement learning [5] and transfer learning [6] are closely related to the simulation analysis of large-scale power grids.

The comprehensive application of these technologies in medical [7], business [8], transportation [9], translation [10], graphics [11] and many other fields have made significant breakthroughs, effectively reducing human investment, weakening expert dependence, reducing decision-making errors and improving analysis accuracy. For example, IBM's Watson AI medical diagnosis system passed the U.S. occupational physician qualification test in 2012, and has been used in dozens of hospitals in China alone. For many types of cancer, the diagnosis and treatment program provided by this system can reach nearly 90% of the consistency with the top medical experts, which can effectively reduce misdiagnosis and improve the accuracy and efficiency of diagnosis and treatment.

As early as the 1990s, some scholars have carried out data mining research for power grid simulation analysis and operational control by introducing machine learning methods [12], [13]. However, due to the complexity of power system analysis and the limitations of data analysis methods, up to now, no practical results have been achieved. In recent years, some scholars have carried out research on the application of AI technologies such as deep learning and reinforced learning to power grid simulation analysis [14]–[20], but the overall level is still in the initial stages, and there is still some distance from the achievements of systematic and practical applications.

This paper takes the analysis and adjustment process of power grid simulation data as the object, combining knowledge drive, representation learning, reinforcement learning and transfer learning, and discusses the core issues of the combination of AI technology with it. On this basis, a corresponding research framework is proposed from the aspects of knowledge modeling and application, knowledge discovery, power flow intelligent analysis and transient stability intelligent analysis for large-scale power grid simulation analysis.

II. CORE PROBLEM

The core of AI analysis of large-scale power grids based on digital simulation is constructing the AI for large-scale power grid simulation analysis and decision-making, which is primarily embodied in the following four aspects.

1) Deep fusion and evolution of knowledge is used for large-scale power grid simulation analysis. Large-scale power grid simulation analysis has a large amount of prior knowledge, which requires the integration of existing and incremental knowledge, the integration of qualitative and quantitative knowledge, the integration of related knowledge and practical knowledge, and the continuous integration of the results of knowledge discovery into the knowledge base, so as to effectively support the AI simulation analysis driven by knowledge.

2) Knowledge discovery techniques in datasets of massive volume, high-dimensionality, sparsity and complex spatio-temporal correlation data are used for large-scale power grid simulation analysis. Patterns and regularities in power grid operations are contained in the simulation data. Mining these patterns requires the integration of multi-source heterogeneous information in complex power grid simulation data and also building a unified low-dimensional vector representation. On this basis, models considering complex constraints and diversified application scenarios in practical power grid operations are used to effectively and efficiently discover useful patterns and knowledge by interactive human-computer knowledge evaluation.

3) Power flow mode is generated with AI in a large-scale power grid. Power flow calculations are the basis of large-scale power grid simulation analysis and calculations, aiming at the characteristics of convergence adjustment, power flow analysis, and the current state of adjustment for power flow calculations of a large-scale power grid, as well as making full use of the mass simulation data and the simulation platform, studying the knowledge-driven power grid operational mode to generate AI model, and to make it capable of migration among differentiated power grids.

4) Security stability of a large-scale power grid can be analyzed, autonomously adjusted and decided with AI based on digital simulation. It is necessary to make full use of massive simulation data and a simulation computing platform to study the knowledge-driven AI model for the characteristics of intelligent analysis, autonomous adjustment and decision-making for the safety and stability of large-scale power grids, and to make it capable of migration among differentiated power grids.

III. RESEARCH FRAMEWORK

A. Overall Research Framework

The research framework of a large-scale power grid AI based on digital simulation can be established from four aspects.

1) Targeting at deep fusion and evolution of knowledge for large-scale power grid simulation analysis, AI modeling and application methods of knowledge and experience of large-scale power grid simulation analysis are studied.

2) Targeting at knowledge discovery in massive, high-dimensional, sparse and spatio-temporally correlated data for large-scale power grid simulation analysis, models and methods for mining large-scale power grid simulation data are studied.

3) Facing AI generation for power flow modes of large-scale power grids, models and algorithms of AI analysis and adjustment of power flow modes of large power networks based on knowledge drive methods are studied.

4) Facing AI analysis, autonomous adjustment and decision-making for stability analysis of large-scale power grids, the model and algorithm of AI analysis and control for the stability of a large-scale power grid are studied based on the knowledge-driven method.

The relationship between these four aspects is shown in Fig. 2.

B. AI Modeling and Application Method of Knowledge and Experience in Large-scale Power Grid Simulation Analysis

The technical route of the AI modeling and application method of knowledge and experience in large-scale power grid

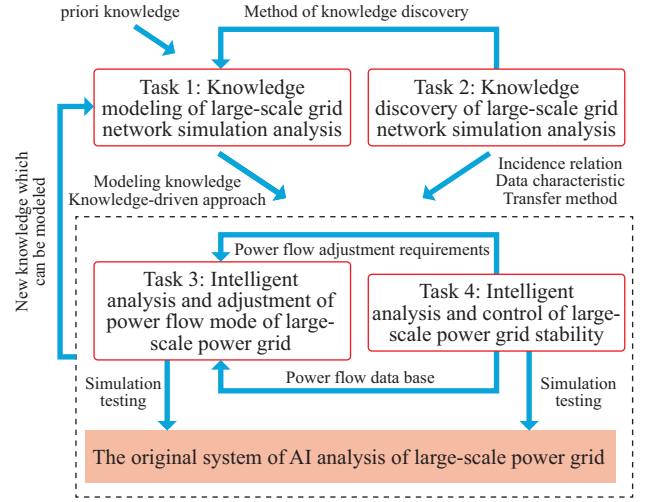


Fig. 2. Overall framework.

simulation analysis is shown in Fig. 3. The key links are as follows.

1) Knowledge Model and Autonomous Modeling Technology Facing AI Analysis of Large-scale Power Grid Simulation Data

The formalization model of large-scale power grid simulation experience and results fusion expressed by supporting multiple relationships based on the hypergraph model [21] can be built. The types of entities in the model are based on the entity of mechanism empirical knowledge and the variables of simulation analysis. The types of relationships include one from the mechanism experience and the other from discovery and acquisition. Then, entities and relationships are

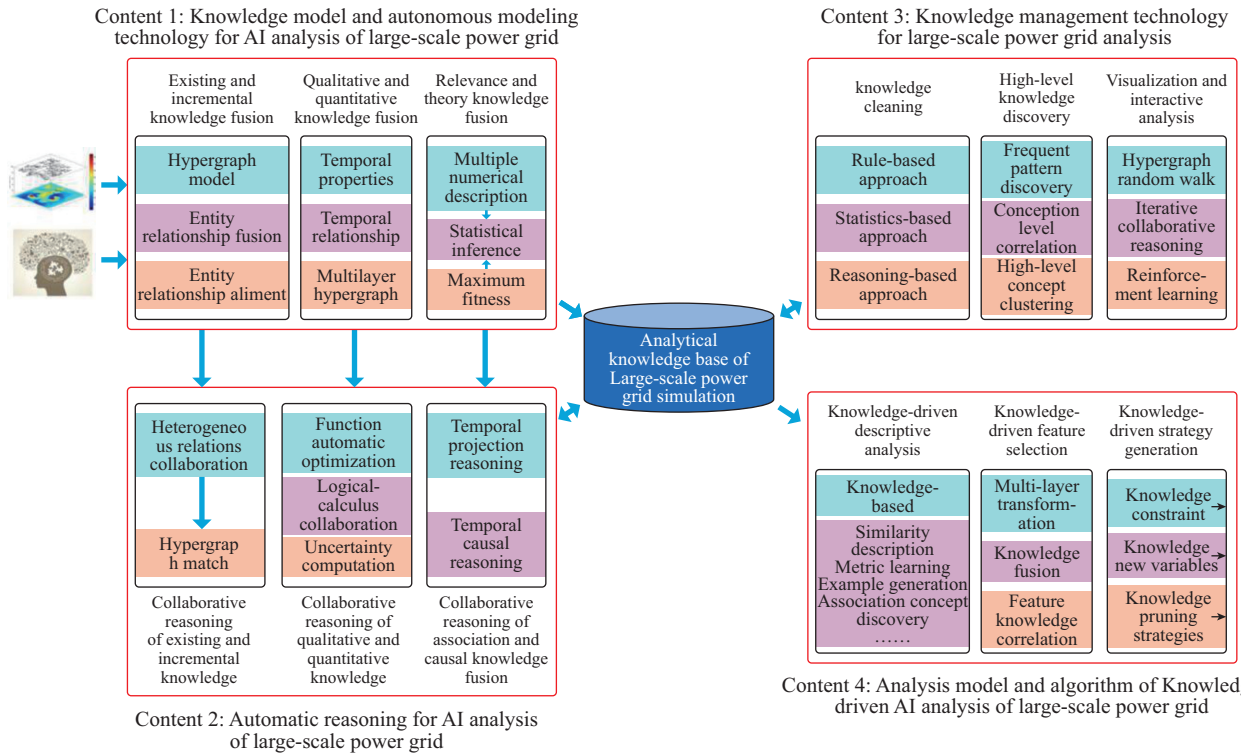


Fig. 3. Framework of AI modeling and application method of knowledge and experience of large-scale power grid simulation analysis.

aligned and merged based on domain knowledge and property characteristics.

Facing the timing characteristics of knowledge in the simulation analysis of large-scale power grids, the timing information is expressed in three ways:

- 1) The time attributes and the relationships between the entity and time attribute are added.
- 2) The relationship of entity, time expression and time series, including absolute and relative time series are added.
- 3) Based on the sequential relationship of the multi-layer hypergraph structure, the hierarchical relationship is used to express the temporal relationship.

Considering the diversity and uncertainty of the numerical values in the experience and knowledge of large-scale power grids, the description methods of various attributes such as distribution, probability and interval are designed.

A numerical attribute extraction algorithm based on statistical inference [22] is designed to maximize the fit of data value attributes to actual values in order to avoid overfitting.

2) *Automatic Reasoning Technology for AI Analyzing Knowledge of Large-scale Power Grid Simulation Data*

The characteristics of the empirical knowledge and knowledge discovery of the simulation analysis of large-scale power grids are analyzed in depth. And the collaborative reasoning technology oriented to the heterogeneous relationship between these two types of knowledge is studied. Then, the reasoning mechanism based on hypergraph matching is established to realize the mixed reasoning of experience and knowledge.

Based on the function automatic optimization mechanism, the automatic reasoning technology for quantitative relationships is proposed, which is used to realize the optimization of reasoning results in quantitative composite relationships.

By designing a new relationship between the fusion function and logic and a collaborative reasoning mechanism based on statistical design of fusion logic and calculus, the uncertainty of the relationship and the value satisfying the corresponding relationship can be calculated while generating the new relationship.

Then, automatic reasoning technology of the relationship between time projection and time causal is studied. The former researches the entity at a specific time point and their relationship reasoning method, whose key points are reasoning-oriented entities, their relationship time projection technology and reasoning method based on the time projection. The latter is a temporal relationship of subject-to-reason, which researches the temporal relationship between a new entity and event reasoned by the temporal relationship between entities and events.

3) *Analysis Knowledge Management Technology for AI of Large-scale Power Grid Simulation Data*

According to the characteristics of error diversity in the AI knowledge base of large-scale power grid simulation data, the strategies of designing knowledge base cleaning technology are based on rules, statistics and reasoning. In terms of the rule-based method, the cleaning rules based on graph and collection are designed, as well as the automatic discovery technology of cleaning rules based on frequent pattern discovery and the automatic cleaning algorithm based on graph

matching are also designed. In term of the method based on statistics, the statistical knowledge cleaning technology which integrates the uncertain graph model is designed. The reasoning algorithm is designed for contradictory objects, and error discovery is realized based on the reasoning of contradictions. Meanwhile, the knowledge base is cleaned by the tracing and resolution of contradictions. Aiming at the requirements of AI analysis of large-scale power grid simulation data on high-level knowledge and integrating knowledge discovery technology, frequent pattern discovery algorithms on hypergraph, multi-concept hierarchical association relationship discovery algorithm, clustering algorithm oriented to high-level concept and multi-attribute and hypergraph vertex classification algorithms are designed to realize high-level knowledge discovery. The sampling technique of hypergraph random walk strategy is designed so as to realize the visualization of massive complex knowledge base for AI analysis of large-scale power grid simulation data. Then, multi-level knowledge interactive visualization technology is designed. By calculating the uncertainty of knowledge in reasoning, the human-computer collaborative reasoning interface is generated based on the reasoning link with the greatest uncertainty, and the human-computer collaborative reasoning mechanism is designed based on the iterative method to realize the human-computer system reasoning. In addition, an interactive analysis algorithm based on intensive learning is designed to maximize the improvement effect of artificial feedback.

4) *Analysis Model and Algorithm of AI for Large-scale Power Grid Simulation Data Driven by Knowledge*

The research is carried out on the requirement of describing the analysis task in the analysis of large-scale power grid simulation data. The similarity description based on knowledge and the measurement learning algorithm based on knowledge [23] are designed to integrate knowledge into the measurement of objects so as to realize the knowledge-driven clustering and classification algorithms. The knowledge-driven classification is realized by designing a knowledge-based automatic generation of learning use cases and an on-demand extension of use cases. Then, the algorithm of frequent correlative concept discovery based on knowledge is designed to realize the correlative rule mining driven by knowledge. And the matching and inversion of knowledge-based machine learning results are designed to improve the interpretability of machine learning results. Aiming at the characteristics of diverse features and different semantics in AI analysis of large-scale power grid simulation data, the design is based on the multi-layer transformation technology such as knowledge-driven deep characterization learning technology, which integrates knowledge into features to fuse heterogeneous information, so as to learn the features of fusion knowledge. An association model of feature and knowledge is established, and an optimal feature selection algorithm is designed based on this association. Based on the form and solving process of the optimization problem in AI analysis of large-scale power grid simulation data, an autonomous evolution model of fusion knowledge is generated based on the two methods. One is to transfer the knowledge into an optimization problem. The other is the knowledge-

based transformation of variables. During the process of designing a solving algorithm for such an optimization problem, the problem is transformed continuously based on knowledge. On the one hand, the knowledge can be used to improve the precision and fitness of the optimization solution. On the other hand, the knowledge can be used to narrow the optimization solution space and improve the efficiency.

C. Knowledge Discovery in Large-scale Power Grid Simulation Analysis

The technical route of knowledge discovery and evaluation analysis of large-scale power grid simulation analysis is shown in Fig. 4, and the key links are as follows.

1) Effective Representation of Power Flow and Transient Stability Data for a Complex Grid Simulation

The purpose of power grid data representation learning is to learn effective representation of complex power grid data. By mapping complex topological data to low-dimensional vector space, the representation learning models [24] can effectively reflect the dynamic time-varying characteristics of the power grid while maintaining the power grid topology information, so as to significantly improve the calculation efficiency, alleviate the sparsity problem, and allow for effectively fusing the heterogeneous information. For different research and application purposes, the study of multi-type power grid data representation can be carried out for the following four aspects.

1) Based on the attributed graph embedding methods, the power grid topological structure and power grid node attribute information are mapped to low-dimensional space to obtain unified low-dimensional representation of power flow data.

2) For the parameter tuning caused by tidal current adjustment and the fine-tuning of power grid topology, dynamic

representation methods of tidal current data shall be explored, and a better representation model for tidal current adjustment of a large-scale power grid can be obtained;

3) Different priors and regularizers can be used to make the representation of time-varying transient data better to focus on those features that are relatively constant or rapidly changing;

4) Integrating the above works, shared representation of tidal data and transient data can be learned, and rich information contained in large-scale power grid simulation data in low-dimensional vector space can be more effectively represented.

2) Knowledge Discovery in Large-scale Power Grid Simulation Analysis Based Reinforcement Learning with Complex Constraints

The combination of generative adversarial network [25] and reinforcement learning can be used to generate valuable and interpretable representations and enable knowledge discovery from large-scale power grid simulation data. By using enhanced learning models, combining complex constraints and interacting with the simulation environment, the behavior of the large power grid can be predicted by integrating the judgment of human experts, and knowledge discovery can be achieved through the design of gradient strategies, depth value functions and reward functions.

In the traditional deep reinforcement learning models [26] with external memory network components, deep LSTM networks can be constructed to store a certain length of time sequence and context information. By integrating the function of perception, memory, reasoning, and feedback network structure, the model can have a certain memory and reasoning ability.

For a given simulation data set of a large-scale power grid, a preliminary deep network can be designed first and then iter-

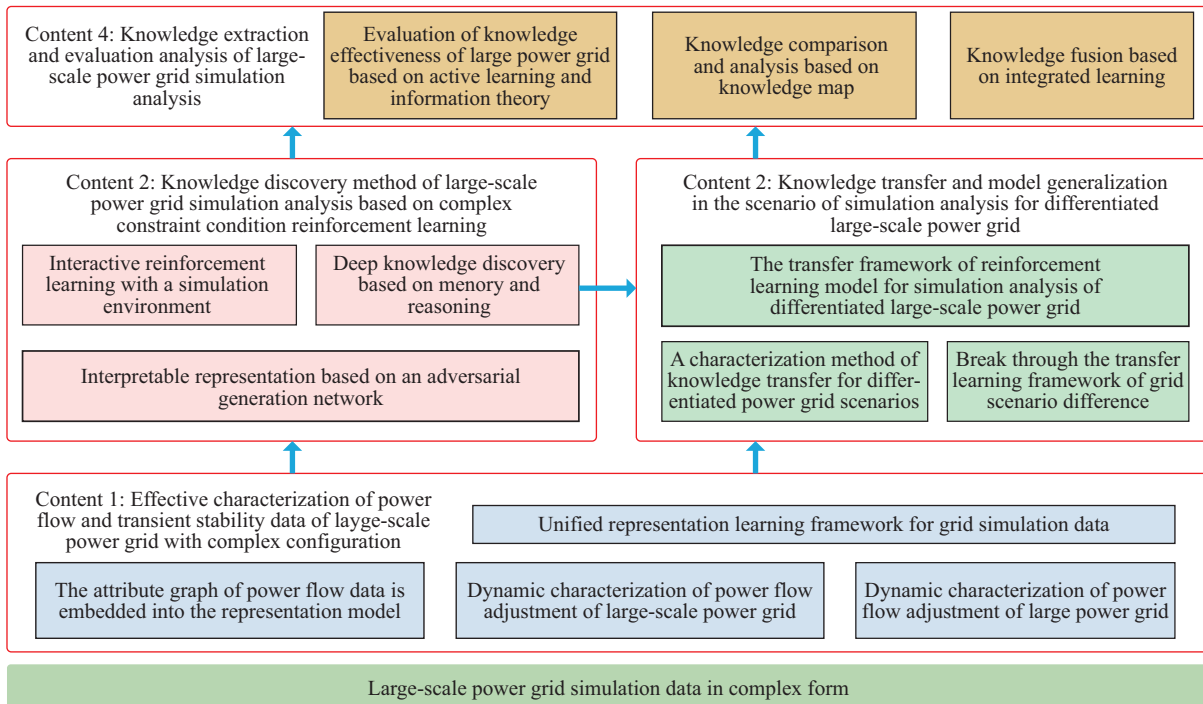


Fig. 4. Framework of knowledge discovery for large-scale power grid simulation analysis.

active reinforcement learning can be used to train the network, and its performance can be tuned using gradient growth along with the importance of neurons and connections and the accuracy on the validation set. Consequently, automatic structuring can be enabled, and the mining of intrinsic characteristics including large-scale power grid current automatic adjustment, security stability of the boundary and the key factors affecting the stability can be achieved.

3) Knowledge Transfer and Model Generalization in Diversified Scenarios for Large-scale Power Grid Simulation Analysis

In view of the differences of the voltage level, network characteristics, transmission strategies, power grid components and other aspects in different power grids, based on the internal correlation of physical laws, operational principles and other aspects in large-scale power grids, the learning performance in the target field is enhanced by establishing a unified representation of different power grid scenes as the carrier of the knowledge to be transferred.

For multi-task learning scenarios such as safety and stability control and power flow control in large-scale power grids, the learning of new tasks is optimized by using knowledge accumulation in the learning process of different tasks. Combining the transfer learning models with the reinforcement learning model, the information learned can be reused or transferred to other tasks to improve the learning efficiency and performance of other tasks. Considering the differences of network topology and parameters in different power grid scenarios, based on the definition of learning tasks, the problem structures are derived by using data samples in different power grid scenarios, and the transfer learning framework of different grid scenarios is proposed.

4) Knowledge Extraction and Evaluation Analysis of Large-scale Power Grid Simulation Analysis

For the knowledge of large-scale power grids from different sources, the data mining results are used as the data for modeling, and the differences and distributions of various models are analyzed by using the methods based on information entropy [27], transfer entropy and fuzzy theory, so as to lay the foundation for the subsequent knowledge export.

By constructing and combining multiple learners to complete the learning task, ensemble learning can be used to obtain a strong learner with significantly superior generalization performance than a single learner. Active learning and knowledge visualization methods can be combined to interactively enable users to browse, compare and explore new knowledge.

In view of model results and extracted knowledge, interactive user evaluation is designed to enable expert users to inspect model results and knowledge expression visually and establish preliminary qualitative cognition.

D. Intelligent Analysis and Adjustment of Power Flow Mode of a Large-scale Power Grid

The technical route of intelligent power flow analysis and adjustment of a large-scale power grid is shown in Fig. 5. The key links are as follows.

1) Autonomous Generation Method for a Power Flow Sample Set of a Large-scale Power Grid

Data preprocessing is carried out on the power flow sample, error data is identified and modified, and data fusion is completed. First, the power flow data of typical large-scale power grids with convergence can be collected, from either the historical data accumulated in the simulation analysis of a large-scale power grid or data generated in batches by power flow calculations according to the power grid unit combination and load curve. Then, based on these initial samples and knowledge-driven methods, the generation rules are established by using the existing knowledge and experience of power flow simulation analysis, and the required sample sets are generated by combining the methods of random disturbance and extended boundary. Finally, the sample set should include multiple types of data such as the adjustment behavior records of experts on the power flow data and the description of the power flow analysis results, so as to form the adjustment behavior sample of experts and meet the needs of training different AI models.

2) The AI Adjustment Method of Power Flow Convergence in a Large-scale Power Grid with Autonomous Learning Ability

Because of the complexity of convergence adjustment problems of a large-scale power grid, the solution needs to comprehensively use a different path of AI technology, including the following aspects:

1) The experts have many experiences on the convergence adjustment of power flow, therefore the experience and formal modeling can be summarized, by using the knowledge map [28] and probability graph model [29] technology, and a universal power flow convergence adjusting method of a large-scale power grid is proposed.

2) Based on a large number of operational samples of experts' adjustments for trend convergence, combined with corresponding power flow data, the identification and application of its internal laws can be studied based on methods such as deep learning and correlation analysis.

3) Based on massive power flow samples and characterization methods of the power flow of typical power grids, taking deep learning as the main algorithm, the implicit expression model of power flow convergence adjustment strategy is studied.

On this basis, the complementary and fusion strategies of the above three technological paths are further studied. Finally, using the transfer learning method in Section III-C, the AI method and model for the power flow convergence adjustment of large-scale power grids can be made to have a strong transfer ability among large-scale power grids.

3) An AI Analysis Method of Power Flow in a Large-scale Power Grid with Autonomous Learning Ability

The AI analysis of power flow in a large-scale power grid primarily involves the reasonableness evaluation of power flow and N-1 static security analysis. There are many theoretical and empirical achievements in the practical work, which can be formalized expressed with applied reasoning.

In another way, the new knowledge of the economy and safety of power flow can be generated by making full use of

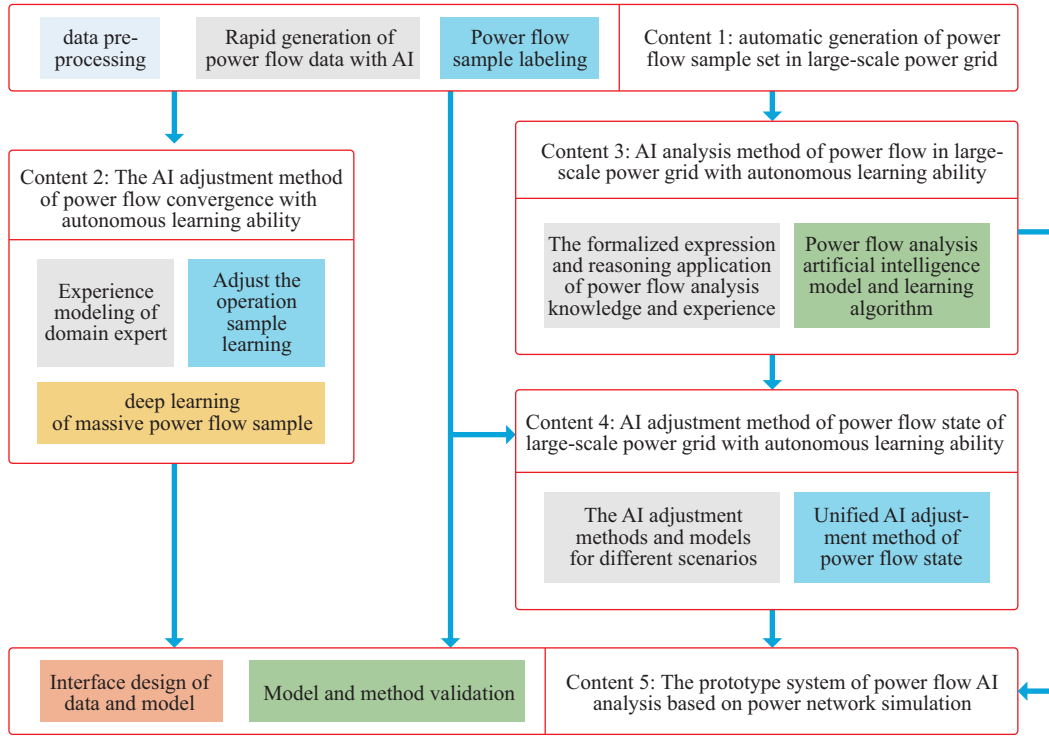


Fig. 5. Framework of intelligent analysis and adjustment of power flow mode of a large-scale power grid.

the data representation method. Then taking the knowledge-driven approach as the core, deep learning and generative antagonistic networks technology can be used comprehensively, in order to make the research results to effectively replace manual analysis and provide accurate direction for power flow adjustments.

4) AI Adjustment Method of Power Flow State in a Large-scale Power Grid with Autonomous Learning Ability

The adjustment of power flow state in a large-scale power grid involves different specific scenarios, such as adjusting the branch power to the set value range, adjusting the bus voltage to the set range value, etc. The problems and constraints involved are different. Therefore, on the basis of analyzing the characteristics of different power flow state adjustment scenarios, it is necessary to combine the existing knowledge and experience of power flow state adjustment with massive sample learning methods based on the knowledge-driven method, and establish an AI model for different power flow state adjustment scenarios.

Then, the unified model of different power flow state adjustment scenarios is studied, and the AI synthesis method of power flow state adjustment of a large-scale power grid is proposed. Finally, the transfer method of a different large power network is studied.

5) Prototype System Construction and Method Verification of Power Flow AI Analysis in a Large-scale Power Grid Based on Power Grid Simulation

Based on the existing large-scale power grid simulation analysis platform in China Electric Power Research Institute, the prototype system of power flow AI analysis of a large-scale power grid is constructed. And the feasibility and effectiveness

of the methods mentioned above are verified and improved through the prototype system established.

E. Intelligent Analysis and Control of Security Stability of a Large-scale Power Grid

The technical route of intelligent analysis and control of security stability of a large-scale power grid is shown in Fig. 6. The key links are as follows:

1) Autonomous Generation Method of Sample Set of Stability Analysis and Control Strategy of a Large-scale Power Grid

In view of the characteristics of a large-scale power grid with a lot of physical measurement information and statistical information, the pretreatment method of original data is studied by making full use of prior knowledge. In order to realize dimensionality reduction of the original data, representational learning and deep learning are used to automatically extract the stability feature of a large-scale power grid. Using AI knowledge modeling technology, the existing knowledge of large-scale power grid stability analysis, artificial experience and other knowledge are summarized and formalized. Through the reasonable choice of a system operation mode, fault location and fault type, the basic sample set is obtained and marked.

Furthermore, extensive operational and other methods are used to generate massive sample data, so as to expand the basic sample set and increase the representativeness and diversity of the sample set. Aiming at the problem of data imbalance in the generated sample set, this paper studies the automatic compression method of simulated samples for different stability problems and different data distribution to increase the equalization of the sample set. According to the

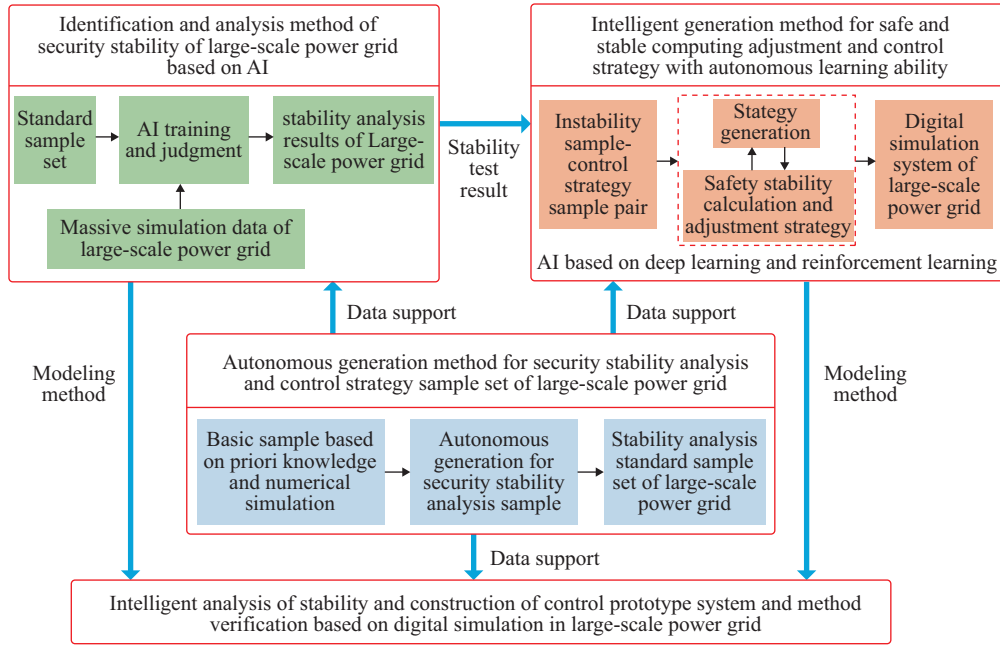


Fig. 6. Framework of intelligent analysis and control of a large-scale power grid stability.

actual demand of security stability analysis and control of a large-scale power grid, the stability discriminant sample set, dominant instability mode sample set, weak link sample set, critical failure sample set and control strategy sample set are established respectively to realize the autonomous generation of safety stability analysis of a large-scale power grid and control strategy sample set.

2) AI-based Identification and Analysis Method of Security Stability of a Large-scale Power Grid

The applicability evaluation index of the algorithm given for an intelligent comprehensive analysis system for security stability of a large-scale power grid based on a variety of AI algorithms is established. The major operational characteristics of power grids that affect the security stability of large-scale power grids are analyzed and determined, then the assessment method of the correlation degree between these major operational characteristics is put forward, and the AI model to guide the power flow adjustment of large-scale power grids based on the analysis result of the correlation degree is established. In view of the different characteristics of the differentiated power grids, the method to improve the transfer learning ability of the established AI comprehensive analysis system for security stability of a large-scale power grid can be studied.

3) AI Method for Calculation Adjustment of Security Stability and Control Strategy Generation of a Large-scale Power Grid with Autonomous Learning Ability

In view of the high dimension of adjustable components, continuous controllable variables, and complex time sequence characteristics of the control strategy of a large-scale power grid, the deep learning and reinforcement learning algorithm applicable to the adjustment of the security stability calculation of a large-scale power grid and intelligent generation of control strategy are studied. According to the established instability

sample-control strategy sample pair, the AI algorithm is used to extract sample data characteristics, and the corresponding AI model is trained to obtain the intelligent generation system of a security stability control strategy.

Furthermore, according to the massive simulation data of the large-scale power grid that needs to be analyzed, the instability scenarios, weak links, and key faults can be found through the stability intelligent comprehensive analysis system, and the control strategy can be generated by using the security stability control strategy. The control strategy is evaluated by the digital simulation analysis platform of a large-scale power grid. Based on the evaluation results, the method applicable to the autonomous adjustment of the control strategy is studied to improve the speed and effectiveness of the generation of the intelligent control strategy. In view of the different characteristics of the differentiated power grid, the AI generation algorithm and the model transfer ability method to improve the established security stability calculation adjustment and control strategy are studied.

4) Prototype System Construction and Method Verification of the AI Analysis and Control of a Large-scale Power Grid Based on Power Grid Simulation

Based on the existing large-scale power grid simulation platform equipped in China Electric Power Research Institute, the AI analysis and control prototype system for the stability of a complex large-scale power grid is constructed. The feasibility and effectiveness of the methods mentioned above are verified and improved through the prototype system established.

IV. CONCLUSION

Advanced large-scale power grid simulation analysis requires AI technology to match it. This paper introduces the research framework and implementation plan of a large-scale

power grid AI analysis combining AI technology with large-scale power grid digital simulation analysis technology, so as to solve problems such as analysis, mining and numerical adjustment of simulation data of a large-scale power grid with high dimension, sparse and complex space-time correlation. The research and implementation of this framework requires experts and scholars in the two fields of power grid simulation analysis and AI to carry out cross-domain collaboration, which is also the basic mode of application of AI technology in the industrial field.

This paper lays a foundation for the establishment of AI for the adjustment and analysis decisions of simulation calculations of a large-scale power grid with autonomous learning ability and the realization of efficient and accurate analysis of a large-scale power grid AI. It also provides a feasible research framework for the combination of AI technology and existing technology in relatively mature professional fields.

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