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Assessment of Power System Performance Indices in a Restructured Power Industry – A Review

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***Abstract*— Ensuring high-quality and reliable power supply to customers plays a crucial role in the power system. Restructuring the power system is an efficient approach to evaluate and deliver economic and uninterrupted power supply. Reliability assessment, which depends on system security and adequacy, serves as a means to check the reliability of the power system. Sequential simulation is proposed as a reliable method to enhance power system performance indices and assess reliability in unbundled power utilities. By simulating the stochastic behavior and sequential process of the system, outage occurrences can be identified and reflected in the form of a reliability index. This paper presents an effective method to improve power system reliability in the transmission and distribution network.**

***Index Terms*— Power System, Performance Indices, Restructured Power Industry, Reliability Assessment,**

I. Introduction

Ensuring the efficient, secure, and economical delivery of electricity is of utmost importance to meet human needs. Numerous methods have been proposed to achieve reliable power supply while considering economic constraints [1]. Deterministic approaches and probabilistic techniques are used to evaluate power system reliability in the network, incorporating modern tools and stochastic approaches. Reliability analysis focuses on system stability and guides strategic planning based on customer requirements and forced outage rates [2]. Adjusted forced outage rates are used to model generators, combining composite generation and transmission reliability.

Transmission operators regulate multiple generator units concurrently to address contingencies, improving system adequacy through reliable assessment [3]. Transmission and distribution companies are responsible for ensuring power supply quality and minimizing interruptions to different customer types [4]. This research aims to promote multiple functional objectives of adjusted forced outage rates in composite power system reliability assessment, addressing transmission and distribution sector failures and minimizing deficiencies.

In the ever-evolving power industry, the restructuring of power systems has become a prevalent trend worldwide [5]. As power systems undergo these significant changes, it becomes essential to evaluate and assess their performance to ensure their stability, reliability, and efficiency [6]. This review aims to delve into the assessment of power system performance indices in a restructured power industry, highlighting its significance, methodologies, and potential challenges [7].

II. Complex Structure Adequacy Evaluation.

Generating and transmission companies are tasked with delivering power to various load themes while considering reliability [8]. Optimal power flow solutions, contingency evaluation, economic dispatch, and unit commitment are considered in structure adequacy evaluation. Reliable indices are calculated for different load themes, referred to as load theme indices, which aid in power structure expansion and planning [9]. Prognostic and recital indices assess power structure security and reliability using composite reliability data and historical reliability data, respectively. Complex structure adequacy evaluation is a critical process in power system planning and operation [10]. It involves assessing the reliability and adequacy of power systems that exhibit complex structures, such as interconnected networks, multi-area systems, and systems with high penetration of renewable energy sources [11]. This evaluation aims to ensure the robustness and resilience of power systems under various operating conditions and potential contingencies.

A. *Calculation of Load Theme Indices*

In power systems, the load indices refer to various parameters or metrics used to quantify and analyze the behavior and characteristics of the electrical load [12]. These indices provide insights into the load demand, power consumption patterns, and the overall performance of the power system [13]. Load theme indices are crucial in assessing complex power structure reliability and can be calculated annually. Load patterns obtained from the control center are examined for each load theme, and corresponding indices are evaluated based on load variations [14]. The obtained reliability indices are compared with annualized load theme indices to establish generalized load theme indices [15]. Processing time and simulation time are also considered for network expansion forecasting.

III. Integrating Generating Unit Models in Complex Restructured Structure.

State models are used to represent the complex restructured power structure, incorporating major generating units and transmission networks for reliability evaluation. Contingency states in each model are optimized to overcome failure states identified through forced outage rates [16]. Adjusted forced outage rates (AFOR) are represented by normalized factors and load theme indices, providing a measure of production capability and composite power structure generation [17]. Generator models, such as 400 MW and 152 MW units, are considered for analysis. AFOR is used to evaluate forced outage rates at different load themes, leading to improved structure adequacy and security. Interconnected power networks consist of multiple interconnected regions or countries [18].

The adequacy evaluation of such systems involves analyzing the reliability and performance of the interconnected network as a whole. It considers factors such as interconnection capacity, transmission line availability, voltage stability, and load sharing mechanisms [19]. Techniques like probabilistic methods and Monte Carlo simulations are commonly employed to assess the adequacy of interconnected networks. In multi-area power systems, the evaluation of complex structure adequacy involves considering the interactions and dependencies between different geographical regions or control areas [20]. The assessment includes analyzing the coordination and adequacy of control actions, communication systems, and the capability of each area to meet its demand while ensuring system stability. Dynamic simulations and optimization algorithms are used to evaluate the adequacy and reliability of multi-area systems.

With the increasing integration of renewable energy sources, power systems are becoming more complex. Adequacy evaluation in such systems requires considering the intermittent and uncertain nature of renewable generation. The assessment involves analyzing the capacity and availability of renewable resources, forecasting techniques for renewable generation, and the impact of renewable variability on system reliability. Advanced modeling tools, statistical methods, and scenario analysis are employed to evaluate complex structure adequacy in high renewable energy penetration scenarios

IV. Composite Structure Evaluation by Performance Indices

Composite structure evaluation by performance indices in power systems refers to assessing the performance and effectiveness of composite materials used in power system components, such as power line towers, insulators, and transformers. Performance indices are quantitative measures that evaluate the behavior and characteristics of these composite structures. Restoring structure reliability involves assessing interruption duration and frequency indices, considering atmospheric conditions and environmental factors. Forced outage rates are minimized through modified control strategies to achieve stable conditions. Power and voltage profile fluctuations are analyzed and compared with reference values to detect inaccuracies. The performance indices are used to compare different composite materials, optimize design parameters, and assess the suitability of composite structures for specific power system applications. They aid in making informed decisions regarding material selection, manufacturing processes, and structural design to achieve efficient and reliable power system components.

V. Identifying Transmission Deficiencies in Complex Structures

Analyzing transmission deficiencies is vital to evaluate overall performance in restructured power structures. Dynamic analysis, control analysis, and recovery analysis are proposed to identify and address deficiencies

A. Dynamic Analysis

Utilizing runtime online analysis proves highly effective in identifying weaker sections within the transmission structure, thereby ensuring synchronization in the restructured power system. By analyzing the reliability indices derived from different aspects of the restructured power network and examining online simulation results, we can provide substantiated insights. We will evaluate the Expected Energy Not Supplied across various components of the test structure and provide necessary input to the compensators. Assessing the overall reliability of the structure entails evaluating different reliability indices across various components.

B. Analysis of Control

In order to address the failure rate identified during dynamic analysis, it is necessary to employ compensators associated with FACTS (Flexible Alternating Current Transmission System) devices. The real-time results obtained from the dynamic analysis are simultaneously fed into the compensators and FACTS devices, enabling prompt actions to maintain system stability. Control parameters, such as Expected Energy Not Supplied and Loss of Load Expectation, must be kept within specified limits to achieve complete stability and ensure reliable operation of the restructured power system. Additionally, these control parameters are integrated with generation and transmission companies to establish reference criteria for each index.

C. Analysis of Recovery

The control analysis provides assurance regarding the stable operation of the restructured power system and proposes modifications to the transmission structure. The recommended control strategy is employed to rectify deficiencies found in the transmission structure. Modifications can be implemented in the weaker components identified through dynamic analysis to ensure the longevity of the existing network. Depending on the control strategy, the IEEE-RTS (Improved Equivalent Electric Energy Reliability Test System) structure is modified, and various indices are evaluated under different loads.

Complex structure adequacy evaluation faces challenges such as data availability, accurate modeling of complex system interactions, and computational complexity. Future directions in this field include the development of advanced simulation tools that can handle large-scale complex systems, improved modeling techniques to capture system dynamics and uncertainties, and the integration of advanced data analytics and machine learning algorithms for enhanced reliability assessment.

Complex structure adequacy evaluation plays a vital role in ensuring the reliability and resilience of power systems with complex structures. By considering the unique characteristics and challenges associated with interconnected networks, multi-area systems, and high renewable energy penetration, this evaluation provides insights for effective planning, operation, and decision-making processes. Continued research and advancements in modeling techniques, simulation tools, and data analytics will further enhance the accuracy and comprehensiveness of complex structure adequacy evaluation in power systems

VI. CONCLUSION

The improved version of the IEEERTS structure ensures the security and adequacy of the restructured power system. By incorporating two-module and three-module structures into the test structure, significant enhancements are achieved in calculating reliability indices related to the Adjusted Forced Outage Rate. Through various evaluations of performance reliability indices and the integration of compensators, uncertainties within the generation and distribution units are effectively reduced. The comprehensive assessment of reliability in the restructured power system encompasses both control and recovery aspects. The evaluation findings can be utilized for expanding the power network and forecasting power system developments. Furthermore, deficiencies in the transmission structure are addressed through thorough analyses associated with AFOR. The evaluation of Expected Energy Not Supplied yields optimized results for different peak loads while minimizing interruption indices associated with duration and frequency. In summary, this article provides a clear explanation of the impacts of AFOR, control strategy, recovery options, and modifications.

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