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Review on Smart Power Distribution Networks: A Sustainable Developmental Approach

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ABSTRACT: Smart power grid distribution network is very paramount in building a sustainable Electricity network for smart grid operations. As stipulated and stated in the agenda 2030 sustainable development goals project (agenda goals; 3, 7, 9, 11, and 13), it's pertinent to create, research and develop an enabling environment within the power grid horoscope with these agendas in view. This helps the design of reliable and quality distribution system to replace the traditional distribution networks which produce carbons and other harmful chemical substances in to the environment. Recently, the distribution system has been burdened with numerous dynamic loads and energy demands due to the current Covid-19 situation which has brought many to work from home. The Smart distribution network as reviewed in this paper is a critical component and final stage in providing optimum power solutions to customers. Discussed in this paper is the reviews of developmental approaches to smart power distributions, since it networks perform critical functions and bears social responsibility by adopting large and small hydro-dams, solar, wind, and other clean energy sources, for delivering power to its end users safely and effectively.

KEYWORDS: Sustainable Electricity; Smart Distribution network; Power supply dependability; Power economics; Smart grid

1. INTRODUCTION

The major function and social obligation of a power distribution company is to offer consumers with affordable, reliable, and high-quality electricity (Zhang et al, 2011). The distribution network connects the users to the end user connection and is an important aspect of the power system. The dependability of the distribution network system's power supply has a direct impact on the quality and level of the power supply (Yang et al, 2011). Currently, various issues exist in Africa's power grid, such as a weak power distribution network, faulty communication, and a relatively low degree of distribution smartness. According to a statistical analysis conducted during the last decade, the failure of the distribution network is responsible for approximately 85% of user power outages (Ali et al, 2013). As a result, whether the distribution network is dependable and has a substantial impact on users, it is critical to evaluate and improve the distribution network's dependability.

With the rapid growth of the national economy, the need for energy is increasing, and power supply dependability in production and management operations is becoming increasingly vital. It performs critical functions and bears social responsibility by adopting hydro, solar, wind, and other clean energy sources, and then safely and effectively delivering power to end users. It is critical in implementing the sustainable development concept and constructing a clean, efficient, and long-term modern energy system (Li et al, 2013) (Peng, 2014). The degree of attention far below the transmission power system affects distribution system dependability analysis concerns in the study of power system dependability analysis. This is primarily due to faults in the power generation and transmission systems, which can have catastrophic implications (Sun, 2010). However, as the demand for high-quality power grows, the dependability of the power distribution system is becoming increasingly important. The future evolution of the power market will necessitate more research on the dependability of distribution systems (Zeng, 2011) (Ding & Kang, 2011). It is to ensure the quality of power supply in order to achieve an important means of modern electric power industry, the distribution network construction and transformation play an important role in promoting production technology and management in the power industry, and then improving the economic and social benefits.

It is critical in implementing the sustainable development concept and constructing a clean, efficient, and long-term modern energy system. The current development state and existing challenges across the globe's distribution network are reviewed in this study, as well as the impact of the sustainable development concept on power supply dependability and quality. A number of approaches and actions, such as improving the quality of distribution network development, speeding up the transformation, and upgrading the power distribution network, are being promoted. In addition, the future research and development trend of the world's distribution network is discussed, as well as various recommendations for improving the distribution network's power supply dependability and power quality capability.

2. SMART DISTRIBUTION NETWORK DEPENDABILITY AND POWER QUALITY RESEARCH ISSUES

Power system dependability studies began in the 1960s. Dependability analysis is now an important part of planning and decision-making in local and international distribution systems (Fan et al, 2012). The dependability of power systems has become a required basic index (Sun & Kang, 2014). In fact, the challenge of power distribution system reliability is that the user can obtain a high degree of reliability in the power supply of the electric power system. When it comes to power supply dependability, the most common user concerns are the most sensitive and degree of power outages, which have more realistic implications, particularly for the power system at the distribution system's end.

Power distribution system dependability is a measurement of the system's power and capability in terms of accepted quality standards and the quantity necessary. The two components of distribution system reliability are adequacy and security. Aside from serving as a transmission conduit for power to reach terminal users, Smart distribution system dependability necessitates not only maintaining adequate voltage levels and the maximum allowable fever within the load limitations of each loop, but also remaining within the system stability limit. The reliability of the power supply system is usually separated into two parts: distribution system dependability and power system dependability (Cheng et al, 2015).

The dependability of the distribution system is crucial to the overall dependability of the power system. The distribution system is complex in dependability studies, and even the use of large computer devices is insufficient to fully realize and meticulously analyze the distribution system as a unified whole (Song & Chen, 2012). On the other hand, each subsystem of the distribution system has its own characteristics, failure modes, dependability index, and analytical methods. The electric energy is produced in the power generating system, transported to the distribution point via the transmission system, and then distributed to the user via the power distribution system. The goal of distribution system dependability study is to provide a decision-making basis for power system design and operation, so that the power system can be cost-effective and long-term in order to ensure power quality.

The following are the key approaches and tasks of power distribution system dependability research: 1.Research on a model for calculating component and system dependability in a power distribution system. Using a statistical method to determine the component's dependability index, from which the system's dependability index was, determined. 2. Identifying the weakest link in the distribution system in order to increase the system's dependability. 3. Investigating the best balance of dependability and economy (Song & Chen, 2012).

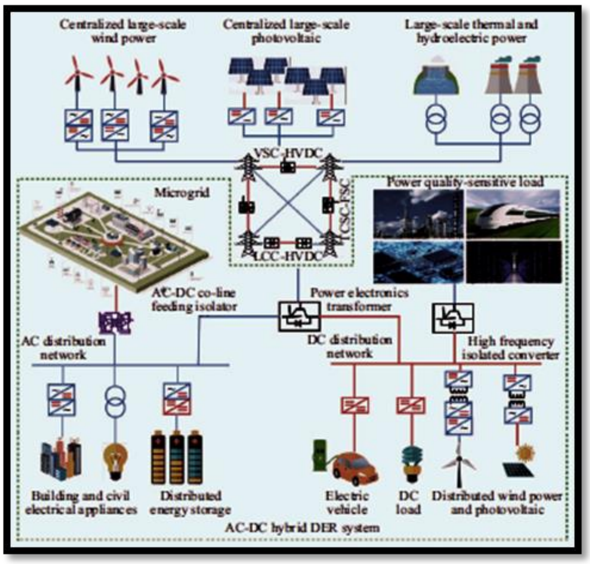

Figure 1. Futuristic element of a dependable power system

The primary distribution system components, such as the Distributed Generations accessing converter and synchronization devices, D-F.A.C.TS devices, power quality governance devices, Direct Current protection, isolation devices, and integrated distribution terminal units, exhibit the development trends of intelligence, modularity, and high power density. As shown about in **Fig.1** (Lui et al, 2019), (the model has pattern which made it possible for the distribution network's power flow to transition from free to partially to fully controllable.

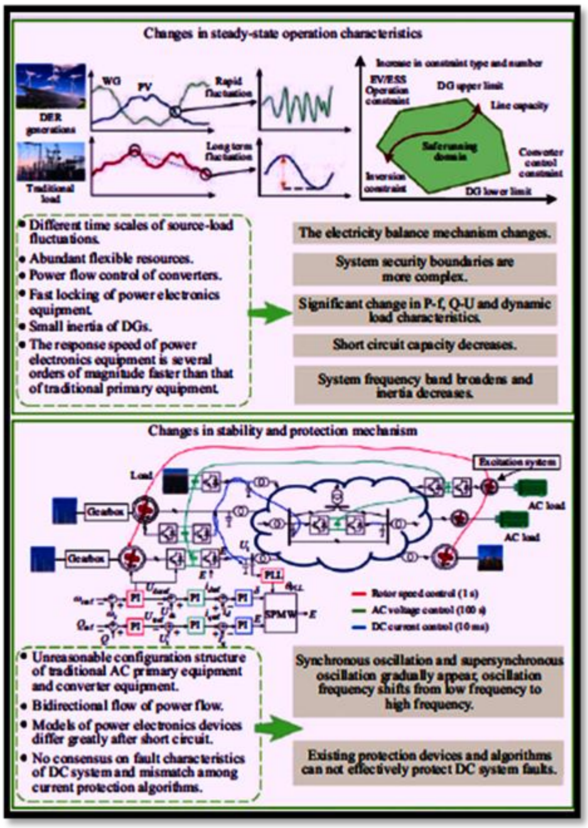

Figure 2. Comparing the conventional distribution system with the operational features for hybrid distributed energies system.

Discussed in **Fig. 2** by (Lui et al, 2019), is the unreasonable power electronics device configuration which will cause short-term stability issues, like the system oscillating at high frequencies. Additionally, because of the significant distinction between the short-circuited model of a power electronics device and the bidirectional power flow, the conventional relay protection mechanism is no longer appropriate. More individuals will automatically participate in the system's energy management in the future. As a result, the current form of centralized control and passive management must be replaced with a hierarchical and progressive control system. The structure design of the Alternating Current – Direct Current hybrid system are established, as well as the usage of a large number of power electronic equipment, provide the foundation for the development of this control system. A hierarchical progressive control system employs several control strategies at various system levels and time frames.

3. SMART DISTRIBUTION NETWORK RESEARCH METHODOLOGY

To develop a rigorous methodological approach for computing the dependability index for a better performance; the system's dependability is studied, and the model's correctness is increased, in order to implement various effective techniques, including approximation methods. The calculation is straightforward and quick. The analytic technique is the most often used method in the research of distribution system reliability, and it may be further categorized into the following categories: 1) network equivalent approach; 2) state space method; 3) failure mode and effect analysis method; 4) minimal path method; 5) minimal cut set method; 6) fault tree analysis method; and 7) fault diffusion method Feeder partitioning technique.

The most recent networking technology is utilized to collect production-related data and integrate and share information, as well as build and change distribution networks. It improves the gathering of real-time equipment condition data and makes full use of inspection of record data, equipment maintenance, and testing data. To create the groundwork, strengthen the real-time distribution information and production information management integration, build and operate the integrated data management platform, and share data integration for data analysis and optimization.

The Internet of Things technology collects sound, light, heat, electricity, mechanics, chemistry, and biology through various sensors, RFID tags, infrared sensors, global positioning system (GPS), laser scanners, and other equipment to carry out the location of all kinds of information, information exchange, and communication, and achieve intelligent recognition, positioning, and communication on the item. The Internet of Things technology may better handle communication between distribution terminals and distribution masters, as well as the distribution network of all equipment and parts connected to the Internet of Things, to better address distribution terminal number issues, such as frequent changes.

New technologies and equipment should be actively utilized in the building and transformation of distribution networks, and medium voltage distribution network equipment should be insulated into non-oil, compact, and intelligent development. In order to fulfill the reliability of power supply, the knot line mode of urban medium voltage distribution network should aim to be compact and easy to implement distribution network smartness. Select distinct power supply areas of the medium voltage distribution network based on local conditions, but the same city or region of the medium voltage distribution network should be eliminated as much as feasible.

To fully utilize and integrate in large power supply enterprise information resources such as: area dispatching automation, low mark table real time information of real-time data acquisition system and marketing system modernization, and production management information system of equipment state, distribution network system and equipment parameters, operation information to achieve comprehensiveness.

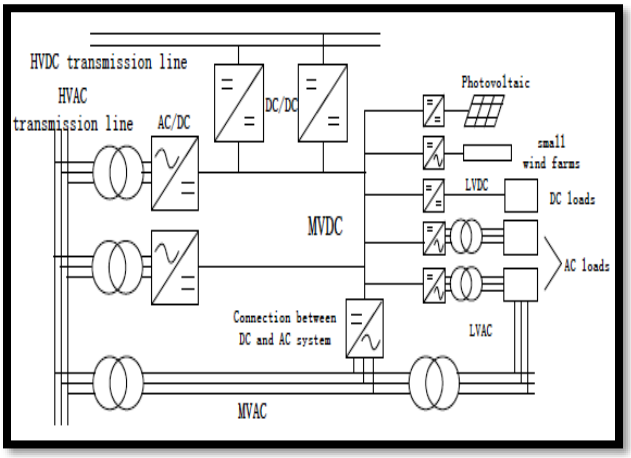

Figure 4. Optimal AC-DC parallel system for power distributions

Power electronic converters and the Direct Current cables connecting them make up the majority of the technology of a Direct Current distribution system. A parallel Direct Current – Alternating Current distribution system would be the initial step for Direct Current distribution because the Alternating Current network now dominates the electricity system. **Fig. 4** (Weihao et al, 2012) displays a parallel Direct Current – Alternating Current distribution arrangement.

4. INFLUENCE OF SUSTAINABLE DEVELOPMENTAL APPOACH ON EXISTING DISTRIBUTION SYSTEMS

Cable, overhead lines, overhead and cable mixed lines, outdoor ring network cabinet, cable distribution box, distribution (including box type substation), column transformer, column switch, open and close, meet the family line, metering devices, and distribution smart system devices are all part of the Smart distribution network system. The goal of power distribution system dependability is to measure the power supply of the power system in order to reduce impediments and maintain a specific level of stability in the power system. The following primary impacts are found in present distribution system dependability research:

Existing distribution system dependability study methodologies or components for unit calculation, or entire system analysis and then compute the equivalent Because of the vast number of components in the system and the complexity of the network topology, the system requires a significant amount of computation. With the rapid development of the Smart distribution system, this flaw will be highlighted even more; for some particularly complicated networks, existing approaches make obtaining evaluation results difficult (Ter-Gazarian, 2015).

Existing distribution reliability study methodologies haven't taken into account the impact of bus and switch failures on the distribution system's dependability index. Because there are so many bus bars and switch distribution systems, the probability of a component failure is small, but it will result in a large number of load points and power outages, which will have more serious consequences, so ignoring these elements will result in inaccurate assessment results (Liu, 2014).

Existing dependability research methods typically do not take into account the state of equipment life cycle maintenance plan and distribution system bus and the number of switches, distribution network system upgrading and renewal of equipment based on the actual situation in the system's operation, data cannot be updated in a timely manner, resulting in the research result being incomplete (Quing & Qiyan, 2010).

Cable, overhead lines, overhead and cable mixed lines, outdoor ring network cabinet, cable distribution box, distribution (including box type substation), column transformer, column switch, opening and closing, pick the family line, metering devices, and distribution smartness device are all components of a distribution network system. The boundaries of management and accountability are not clear, multi-disciplinary, in terms of planning, building, and operation, system refurbishment. It is difficult and inefficient to cross-sectional coordinate and realize distribution network smartness on a big scale, and the investment value is not reflected comprehensively (Tan, 2012).

Distribution Smartness connects several professional operation and maintenance links, the basic data of distribution network is typically inaccurate and cannot be updated in real time, the reliability of distribution system components and systems calculation model, and the whole system analysis research and calculation results are unable to meet the needs of production, operation, and maintenance. The distribution system and equipment transformation coverage are restricted, information interaction is insufficient, and system integration application is more challenging, among other things (Pan et al, 2016).

5. KEY FINDINGS

Tables 1 and 2 display the economical analysis for various wiring modes at load densities; 10000kW/km2 and 30000kW/km2 respectively.

Table 1. **Economic data of Micro-grid to different connection Modes (density of loads = 10000kW/km2)**

Wiring modes	The annual cost value of unit load				
	No microgrid	MG1 access	MG2 access	MG3 access	Multiple access (including MG1, MG2, MG3)
Radial connection of overhead network	10.38	25.19	24.77	24.47	51.52
Multi-section and two-link connection of overhead network	16.53	30.15	29.76	29.43	54.03
Single-loop connection of cable network	42.68	55.48	54.68	53.94	75.59
Double-loop connection of cable network	72.55	87.06	86.21	85.72	109.33

Table 2. Economical data of Micro-grid to different connection Modes (density of loads = 30000kW/km^2)

Wiring modes	the annual cost value of unit load				
	No microgrid	MG1 access	MG2 access	MG3 access	Multiple access (including MG1, MG2, MG3)
Radial connection of overhead network	8.53	20.87	20.56	20.41	40.54
Multi-section and two-link connection of overhead network	13.43	23.46	23.19	22.98	43.63
Single-loop connection of cable network	38.63	47.08	46.62	46.16	59.47
Double-loop connection of cable network	66.23	76.07	75.62	75.14	89.65

5.1 Effective Economic And Reliability Analysis

The dependability and cost-effectiveness of various wire modes for micro-grid access are thoroughly assessed in the case of a load density of; 30000kW/km2, as illustrated in **Figures 5 through 8,** respectively (Zhao et al, 2018).

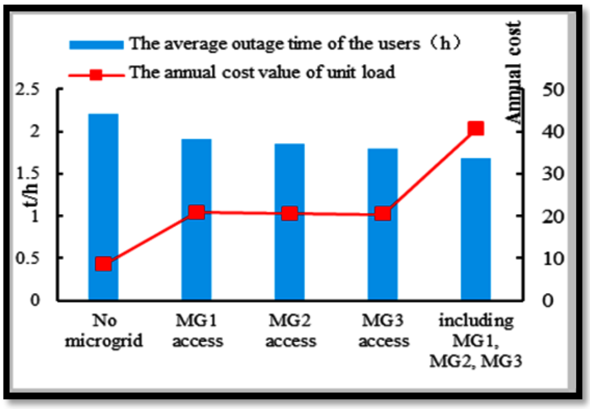

Figure 5. Economic and reliability analysis of radial connection for micro-grid

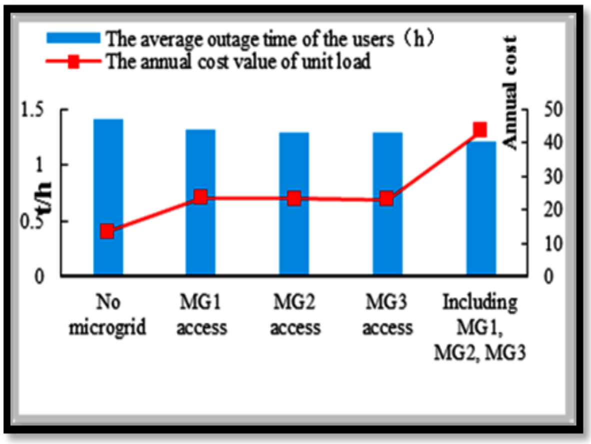

Figure 6. Economic and reliability analysis of double section and double-link connection

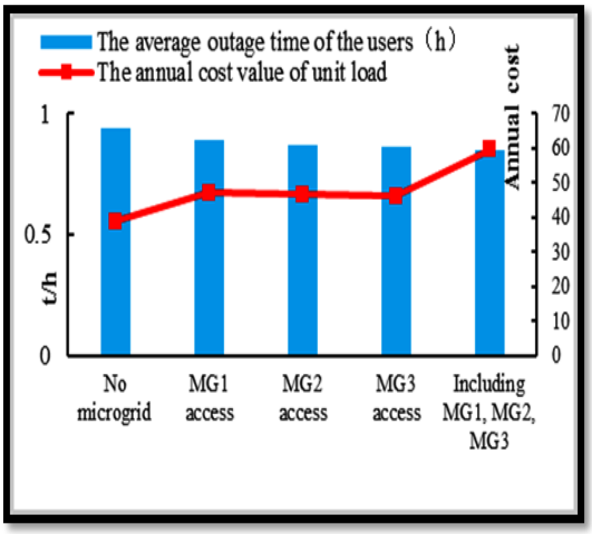

Figure 7. Economic and reliability analysis of single-loop connection

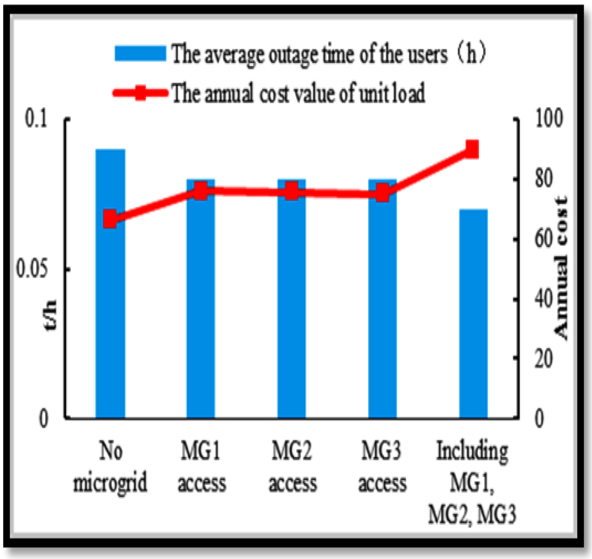

Figure 8. **Economic and reliability analysis of two-loop connection**

The following conclusions are reached from **Figures 5** through **8**: **A.** In the event of a circuit breakdown, the micro-grid can power a portion of the load when it is connected to the overhead radial grid, thus enhancing the reliability of the power supply. Because the power grid's connecting lines have the capability of power transfer and the micro-grid itself has the potential for failure, the impact of the micro-grid on the reliability of the power grid when it is connected to ring network structures is not immediately apparent. **B.** The effect of reliability enhancement is most noticeable when the micro-grid is linked to the far end of the radial line, and the comprehensive reliability and economic evaluation is optimal in this case. The reliability and economy of the ring network lines remain unaffected when the micro-grid is linked to various points along them. **C.** Multiple access micro-grids are slightly more reliable than single access micro-grids for the same circuit, but they are extremely expensive. The economic assessment in this paper takes into account the micro-grid investment. In reality, power supply companies can improve economic performance and dependability if consumers pay for the micro-grid's construction (Zhao et al, 2018).

Hence in summary, the modern electric power system can be thought of as having over 130 electrically coherent zones. These zones have developed as a result of the utility's efforts to meet electric charge growth, the placement of generating systems relatively close to customer load centers, and the configuration of an electric transmission and distribution network (wire, breaker, transformer, etc.) for customer satisfaction. These sectors have been linked over time to improve reliability and allow for the most efficient and cost-effective production use. Many locations are considered control areas, which work in tandem with other control areas in the region but are managed independently. Today's control areas can be thought of as partially self-contained and integrated with surrounding control areas. In the control regions, the current power system organization is mostly concentrated on central power plants. The system of power distribution, which connects these generating systems with customers, is restricted, as seen by the growing frequency of failed wholesale transactions.

It depicts the future evolution of the current power system in two dominant dimensions—one centralized, the other integrated, communications, sensors, and computer capacities—as opposed to more autonomous depending on how automation occurs.

The question of whether the future power system should be more decentralized or more centralized is the most important driver in this paradigm. Although the Committee does not favor one technique over the other, the course of action will have a significant impact on decisions on which technologies to pursue.

6. SUGGESTIONS ON POWER DISTRIBUTION DEPENDABILITY AND POWER QUALITY ENHANCEMENT

The power supply dependability and distribution system quality are being fiercely promoted as a result of the development and continued application of IPv6, big data, networking, cloud computing, reference calculation technology, smart cities, and new information technologies. The following actions and proposals are proposed to make full use of distribution system dependability research results, enhance allocation of power grid planning and construction, overhaul, modification, and operating levels:

1. Distribution network planning and construction must be coordinated with high voltage power network planning and construction, business expansion installation, distribution network overhaul and transformation, and municipal engineering. The planning should be closely coordinated

with the city planning department, and it should be incorporated into the city's growth. Distribution network planning should be integrated into urban distribution network design, and distribution network automation should be implemented progressively.

2. The locations covered by power distribution automation in metropolitan regions are typically concentrated in densely populated areas, such as street areas and pipeline complexes. Distribution automation is also regarded as a follow-up to the construction contents, since there is power pipe plug, cable laying trouble circumstances at the conclusion of the distribution operation years. The Internet of Things can handle the problem of communication between distribution terminals and main stations, as well as the issue of a high number of distribution terminals, frequent modifications, and so on.
3. Distribution network automation, distribution network lines and equipment condition monitoring and early warning and maintenance, distribution network operation management, distribution network intelligent inspection, emergency communications, mark measurement and load monitoring and management, distributed energy and charging station facilities, and distributed energy and charging station facilities should all use networking technology.
4. The goal of power distribution network intelligence is to increase the grid's observability and controllability, as well as the speed with which it responds to faults and the reliability of its power supply. Sensing and measurement are the foundation of smart grid to improve the basic conditions of distribution system reliability research ability and to realize visualization of field operations management, intelligent equipment management, line power facilities protection burglar alarm, and intelligent equipment patrol.
5. During the distribution system reliability research process, the physical model should take into account the impact of urban population, transportation, buildings, underground pipelines, and so on. municipal engineering, area dispatching automation, low mark table real-time information of real-time data acquisition system and marketing system modernization, and production management information system of equipment Factors such as distribution network system and equipment parameters, diverse information operation modes to accomplish comprehensive utilization, an ambiguous management boundary, undefined inter-professional responsibility, challenging cross-sectional cooperation, and so on. The mathematical model should account for changes in the structure and operation mode of the electricity grid, as well as the impact of changing weather conditions on liability.

7. CONCLUSION

Extensive reviews have been conducted on how researchers use power analysis software and tools like Matlab, power-world, and others to simulate and analyze various persistent and intermittent power quality and reliability issues on the Power grid system, Power distribution system, Power distribution transformers, Smart transformer, Smart distribution system, and Smart system operation management. Almost all of the researchers concluded that there are still more gaps that need critical attention to safeguard the power grid to meet the recent dynamic load demand based on the research done to demonstrate different models and their positive impacts on the distribution grid system aimed at providing quality, reliable, and resilient smart power.

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AUTHOR CONTRIBUTIONS

The paper conceptualization, methodology, software, validation has been done by Mr. Bismark Budu (1st author), formal analysis, investigation, resources, data collections, original draft writing preparation, visualization, has been done by Mr. Justice Ekow Abban (2st author). The supervision, editing, review writing and administration of the project, has been done by Dr. Vikram Kumar (3rd author).

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APPENDIX:

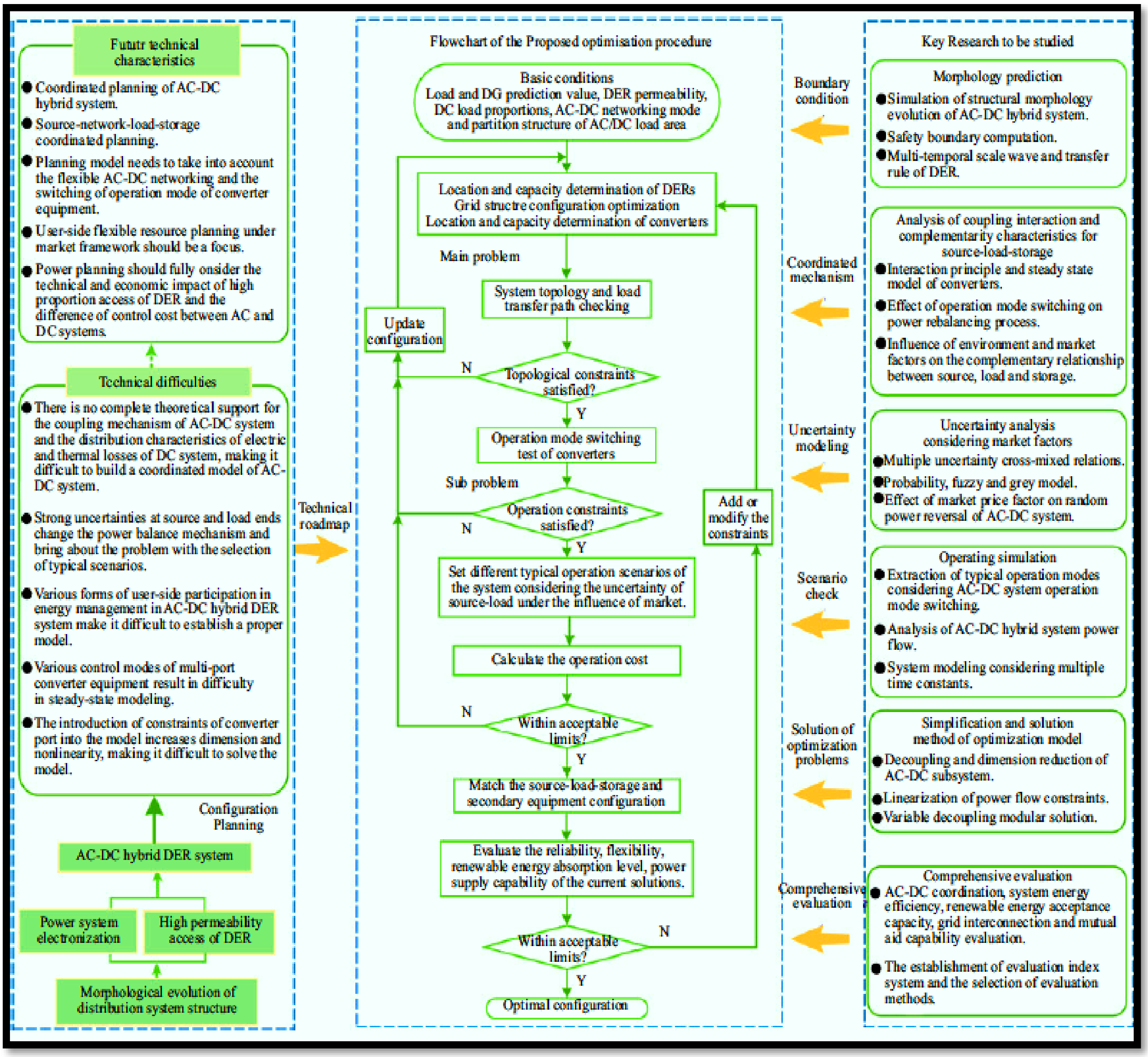

Figure 3. Research configurations for optimization of distributed energy systems