Analysis of Risk Proposed By Information System for Global Energy Interconnection

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Abstract

The globe is currently facing a slew of issues, including resource scarcity, climate change, pollution, and energy poverty, all of which are founded in humanity's significant reliance on and large-scale usage of fossil fuels. Addressing these issues is a critical undertaking for achieving long-term growth. The Global Energy Interconnection (GEI) is a contemporary energy system that is clean energy dominant, electricity focused, networked, and shared. The global energy interconnection (GEI) is the greatest manmade physical system to be developed in the near future, with intimate connectivity between power and information networks. Information system risks will have a significant influence on power system security. This work proposes a risk assessment model for linked physical-information systems based on a set of information system risk characteristics. A method for assessing risk is described. The usefulness of the suggested assessment model and evaluation approach is demonstrated by simulation results of a typical power system and information networks.

Keywords: *Risk; Information; Communication; Accidents.*

I. INTRODUCTION

The global energy interconnection (GEI) is a clean, electricity-centered, interconnected, co-constructible, and sharable contemporary energy system. It will create a platform for large-scale clean energy exploitation, transmission, and utilization on a worldwide scale, as well as support the global energy transition, which will include clean energy, decarburization, electrification, and networking. Building the GEI will enable the UN 2030 Agenda for Sustainable Development and the Paris Agreement to be fully implemented, ensuring that everyone has access to clean, dependable, and cheap modern energy and achieving complete and integrated economic, social, and ecological development. Since 2016, GEIDCO has conducted systematic and in-depth research on the world's energy interconnections, continents, significant areas, and nations in order to expedite the GEI's growth. GEIDCO has thoroughly studied relevant development strategy plans and policies of government departments in various countries, widely absorbed research results of relevant international organizations, institutions, and enterprises, and applied research methods, models, and tools to conduct in-depth research on the development vision, path, and major issues through extensive research and comprehensive analysis of global economic and social, energy, power, climate, and environmental data.

II. DEVELOPMENT CONCEPT OF THE GEI

Energy is the basic foundation of economic and social growth, and a reliable supply of energy is the most important guarantee of human progress. To address the challenges of achieving sustainable development, the key is to promote clean development and implement 'Two Replacements, One Increase, One Restore, and One Conversion,' which aims to build the GEI and accelerate the formation of a modern energy system that is clean, electricity-centered, interconnected, co-constructible, and sharable, ensuring that everyone has access to clean, safe, affordable, and efficient energy. We can discover a scientific answer to support global sustainable development by developing clean energy in this way.

The use of clean alternatives in energy production, such as hydro, solar, and wind energy, is known as Clean Replacement, while the promotion of Electricity Replacement in energy consumption, which replaces coal, oil, natural gas, and firewood with electricity, is known as Electricity Replacement. One rise in electrification and energy efficiency, as well as an increase in the share of electric energy in final energy consumption and a reduction in energy consumption, all in order to meet energy consumption demands. One Restore is dedicated to restoring fossil energy to its original state as an industrial raw material in order to increase the value of the resource for economic and social growth. To resolve resource constraints and pave the way for future energy development and sustainable development of mankind, one conversion means that CO2, water, and other substances will be converted to fuels and raw materials such as hydrogen, methane, and methanol, as well as minerals, using electricity.

The Global Environmental Index (GEI) is the most important method for dealing with climate change and achieving the aim of temperature management. For the globe to combat climate change and execute the Paris Agreement, the GEI delivers a technically possible, economically sound, operational, statistical, and transparent system solution. Replacement of carbon-based energy with clean electricity can be promoted during the GEI construction process to speed up the process of achieving global carbon emission reduction goals, decouple economic development from carbon emissions, and fully implement the Paris Agreement's core targets, such as mitigation, adaptation, financial and technical capability building, and transparency. CO2 emissions from worldwide energy consumption are expected to peak around 2025 and then decline to roughly 10 billion tons by 2050, less than half of 1990 levels. The aim of keeping global temperature rises under 2°C by the end of the century might be met if zero net emissions are reached by 2065. Accelerating the construction of the GEI will hasten the development of global clean energy and power interconnection, allowing energy system carbon emissions to decline sooner and achieve zero net emissions with low negative emissions as soon as possible, allowing the 1.5°C temperature control target to be met.

III.GEI INFORMATION SYSTEM RISK QUANTITATIVE ASSESSMENT

Due to the integration of physical and information systems, the GEI information system's hazards have greatly grown. Attacks on GEI information systems have the potential to affect not just information systems, but also physical systems through the limits of physical information systems. Aside from human attacks, GEI is also plagued by communication issues and natural calamities.

3.1. Human attacks

The quantity of data that has to be transferred and processed in the smart grid to achieve high efficiency, self-healing, high reliability, and security qualities will be substantially bigger than it is now. Information security is becoming increasingly crucial as physical-information systems become increasingly intertwined, and human assaults can be hazardous. Information attackers can target one or more communication nodes in the information network, causing data uploading and transmission to fail.

Important nodes are more likely to be attacked in human assaults. Attackers prefer to do as much harm as possible for the least amount of money. Each communication node's chance of being targeted by human attackers may be stated as

$$P^i{}_{\text{Event}} = \frac{o_i}{\sum_j o_j} \quad (1)$$

where o_i is the importance of communication node i.

3.2. Communication quality problems

Communication technology has progressed from PDH (Plesiochronous Digital Hierarchy) to the present SDH with the advent of smart grid (Synchronous Digital Hierarchy). Currently, the majority of power system data in China is sent via a transmission mechanism that combines SDH optical fibre connection with other communication devices. The number of communication nodes is growing as the smart grid is upgraded. Simultaneously, the likelihood of communication equipment failure rises.

The Poisson distribution can be used to model the chance of communication equipment damage owing to poor communication quality. Let λ_i be the equipment's average rate of accidents, and the probability of no accidents be:

$$\bar{P}^{i} = \frac{e^{-\lambda_{i}}(\lambda_{i})^{0}}{0!} = e^{-\lambda} \tag{2}$$

In the accident of power communication system:

$$P^{i}{}_{\text{Event}} = \left(1 - e^{-\lambda_{i}}\right)e^{-\sum_{j \neq i} \lambda \mathrm{j}} \tag{3}$$

Equation (3) shows that each device's failure probability is independent of the others, and that just one device failed in each accident.

3.3. Natural disasters

In China, the principal transmission lines of regional power grids are currently composed of optical fibre. When natural catastrophes such as hurricanes, floods, earthquakes, or mudslides strike, the communication network may be devastated, reducing or even paralysing the network's transmission capability. Historical data statistics can be used to estimate the likelihood of a natural catastrophe causing damage to all communication systems in the region.

3.4. Information system risk quantitative assessment

Since the 1980s, power system risk assessment has been a priority, however most studies have concentrated on the primary system. The major system risk assessment of the power system is now being examined in depth. There are pretty excellent analysis and assessment methodologies that have been used to the functioning of electricity grids. However, when it comes to information systems, there is still a scarcity of study on total system risk assessment. Furthermore, little study has been done on the role of information system risk in the primary power system.

The information system node failure probability model is built based on many risk considerations. Information attackers prefer to target the most critical communication nodes when it comes to human assault factors. The condition of communication devices deployed at each node plays a significant part in the security of the information system in terms of communication quality issue element. Natural catastrophes have the potential to cause numerous nodes in an area to fail at the same time. For the sake of modelling, the likelihood of regional device damage is considered to be 1/n (n is the number of areas). The flowchart (Figure 1) looks like this:

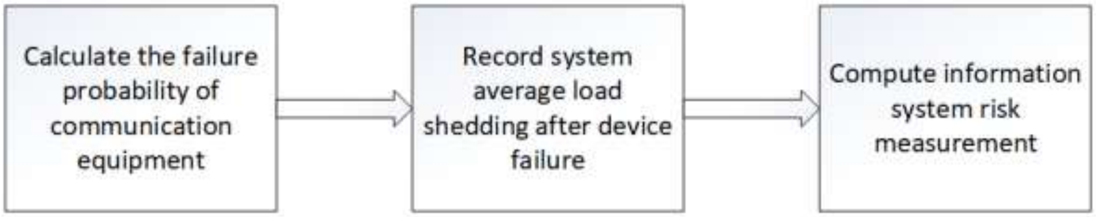

Figure 1. Information system risk assessment flow chart.

The status of information system security may be determined by information system risk assessment. Information system risk assessment is the foundation for allocating information system defence resources in the most efficient way possible. Information system security strategies and security problem solutions can be offered based on the risk assessment results to guide the operation of the information system.

IV. GEI INFORMATION SYSTEM RISK QUANTITATIVE ASSESSMENT

4.1. Natural disasters

Our simulations are based on the physical side of GEI represented by the New England power system, and the information side of GEI represented by two communication networks depicted in Figure 2.

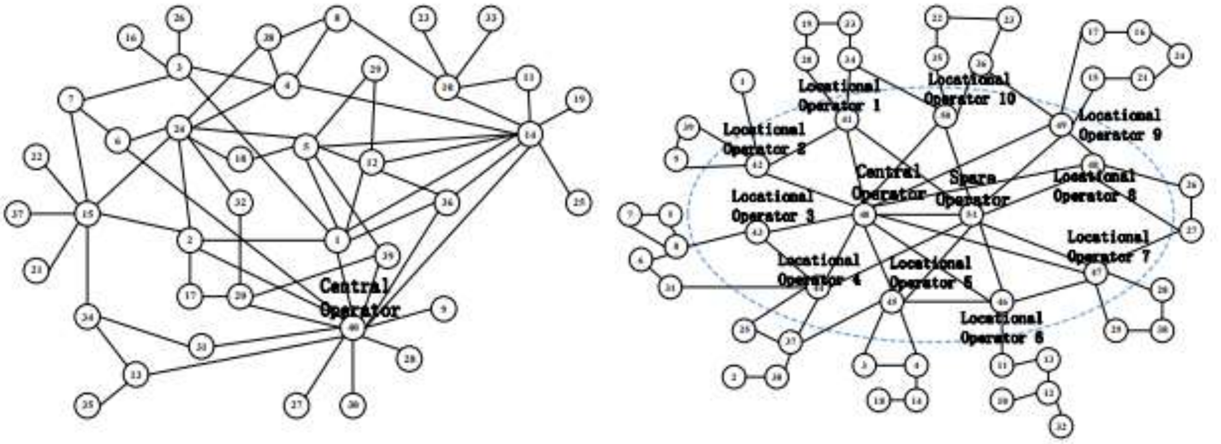

Figure 2. Random communication network and binary communication network.

4.2. Severity of accidents

Figure 3 depicts the average load shedding in two communication networks when each communication node fails. The failures of communication nodes 3, 14, 16, 21 cause widespread load shedding in the random communication network. Due to the breakdown of nodes 3 and 16, the original power system is split into two zones, which the operator is unaware of. Then there's the scheduling choice, which might result in chain failures. When nodes 15, 16, 21, 49 fail in a binary communication network, mass load shedding occurs, and the quantity of load shedding is plainly more than in a random communication network. The findings of two simulations reveal that different communication networks have distinct effects on the severity of accidents, with the binary network being more sensitive than the random network.

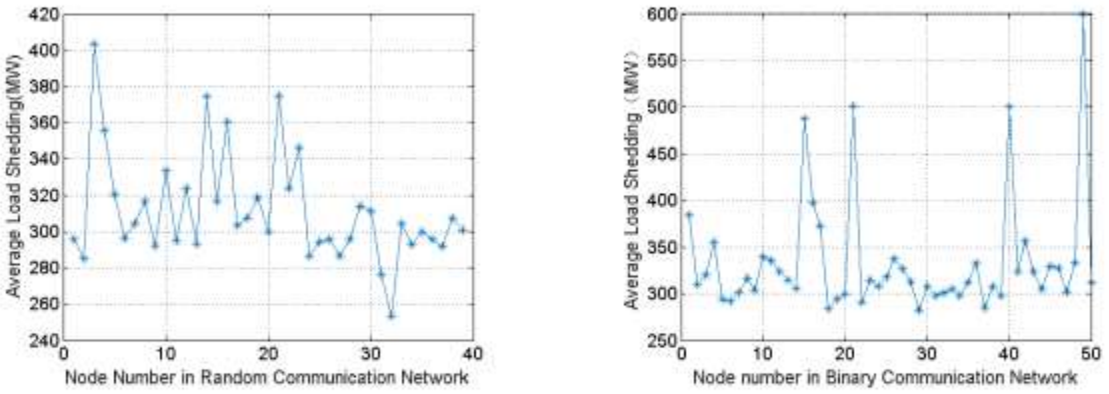

Figure 3. Average load shedding in different communication networks.

4.3. Possibility of accidents

The probability calculation formulae vary depending on the risk factor. Figure 4 depicts the likelihood of node failure in two communication networks due to human assaults and communication issues. Because core nodes like 1, 2, 5, 14, and 24 are so important in the random network, they are more likely to be assaulted by human attackers. Communication nodes that operate in severe environments, such as nodes 17, 25, 26, 29, and 34, are thought to have higher communication quality issues. A binary network resembles a random network in appearance. Human assaults are particularly vulnerable to locational operation nodes that are critical. Communication quality issues are more likely to occur in communication nodes that operate in hostile environments. The simulation results imply that critical communication nodes must be more vigilant against human threats, while communication nodes in difficult environments require more upkeep.

4.4. Risk measurement

The risk assessment in the random and binary communication networks following failures caused by human assaults and communication quality issues. Under human assaults, the chance of node 14 failure is obviously greater than the risk of other nodes in a random network. Meanwhile, the risks posed by communication quality issues to nodes are spread at random. It works in a similar way to a binary network. Locational operation nodes (41-50) have a larger risk of human assault than standard nodes, and the dangers posed by communication quality issues are dispersed randomly. This is because human attackers prefer to target the information network's most susceptible node, but communication quality issues are caused by severe circumstances and a lack of maintenance.

Figure 4 depicts risk measurements following natural catastrophes in two networks. The probability of natural disasters occurring is estimated to be 1/10 due to the variety of natural disasters and the varying frequency of occurrence of specific natural disasters (communication system is divided into 10 regions). In the random communication network and binary communication network, Figure 6 depicts the risk measurement of natural catastrophes.

In a binary communication network, the risk measures for regions 4 and 5 are higher than in a random network. The reason for this is that in a binary network, the central operator node connects with regular nodes via locational operation nodes. Because binary networks have fewer communication links than random networks, they are more vulnerable to natural catastrophes.

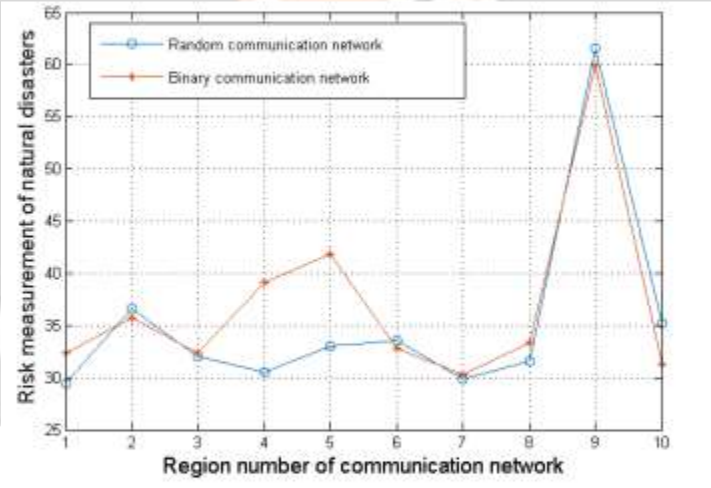

Figure 4. Natural disasters risk measurement in two communication networks.

The simulation results above show the hazards posed by many aspects of information networks. To indicate the severity of accidents, we compute the amount of average load shedding. The hazards of diverse components may be analyzed quantitatively when combined with the likelihood of risk factors, resulting in an overall risk profile that can be used to generate more targeted and responsive operational choices.

V. CONCLUSION

The GEI information system's quantitative risk model is suggested, which evaluates three risk factors: human attacks, communication quality issues, and natural calamities. The detrimental effects of accidents on power systems are investigated, and the information system's critical nodes are determined. The majority of current research focuses on assessing the risk of power systems and information systems, respectively. The coupling effects of physical-information systems have received little attention. The suggested risk quantification model and evaluation approach are the paper's key contributions. The usefulness of the suggested assessment model and evaluation approach is demonstrated by simulation results of a typical test power system and two communication networks.

VI. REFERENCES

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