Research Journal of Management Reviews. Vol., 7 (1), 21-28, 2022
Available online at http://www.rjmrjournal.com
ISSN 2149-9168 ©2022
DOI: 10.52547/rjmr.7.1.21

An intelligent decision-making control system for managing electrical power outages in power grids

Negin Rajabi *

Electrical Engineering Student, Instrument Control Trend, University of Isfahan, Isfahan, Iran

*Corresponding Author Email: Rajabinegin@ymail.com

Abstract: Background and Aim: The purpose of this study is to investigate the intelligent decision-making control system for managing electrical power outages in power grids. Research Method: The research method is controversial because it does not follow the humanities research structure. The present study can be considered a scientific-applied method because it has improved and supplemented the tools and models used by the humanities by using the results of basic research. Findings and Conclusion: The present study is based on power outage management and multi-criteria decision-making theory and provides decision-makers necessities.

Keywords: intelligent control system, management, outage, power

Introduction

The power industry is known as the most sophisticated man-made machine. Power grids have emerged since 1880 and, over time, have expanded widely in size and complexity, and the methods of production, transmission, distribution, and equipment related to these systems have been steadily improved in terms of efficiency and reliability. These improvements are often due to the rapid growth in the need for high power in power grids and is a necessity.

On the other hand, increasing the dimensions of a power grid is accompanied by increasing the number of lines, substations, transformers, switches, etc. As a system increases in size, the performance and communication between the equipment of that network also become very complex. Therefore, it is necessary to take a moment to get the general information of this system at a central point, now called the energy control center, to make accurate decisions. On the other hand, the essential performance of control centers should be based on increasing the reliability of the system and technical, economic, and social considerations (Goerge & Kusic, 2018).

In traditional systems, digital computers were used to process input information and detect errors and specific and specific decisions made by computers, and the primary and complex decisions were made and operated by human resources, which requires expertise. It is specific, and at the same time, it depends on the conditions of the whole human resources. On the other hand, given that the electricity industry is currently on the verge of fundamental changes and is moving from a monopoly structure to a healthy competitive structure, this restructuring, while changing the operational needs of the system, will also form a series of new functions for decision-makers (Terrance & Nielsen, 2012). In addition to the above, distribution systems will become complex systems that require an indefinite and unstructured operating space under the new conditions. As a result, the safe and economical operation of the system will require improved and modern management methods. One of the complex issues that challenge distribution systems is managing that system in an emergency. These systems are often exposed to natural disasters such as storms etc. and unnatural disasters such as load shortages, which cause widespread and long-term disruptions in energy distribution to consumers. Therefore, power outages in distribution systems must be managed.

Many thinkers have equated management with decision-making. From the beginning, man, who lived only with his identity until the present age, when he recognizes his identity with complex organizations, has always interacted with the concept of decision making. In other words, human beings have always sought to maximize their desirability, and in this way, they had to always choose one of the options before them, despite the many limitations and having multiple goals, with a combination of options. Hence, the science of decision-making has always been associated with human beings and has been widely developed with the emergence of various structures and, in short, with rapid environmental changes (Yeh et al., 2019).

Following the development of this science, many mathematical models have been offered, words such as limit, purpose, index, criterion, etc., have a specific identity and definition, and many models have been created to systematize the decision-making process. Therefore, many researchers have focused their efforts on this area and introduced more appropriate and accurate models to improve decision systems and make decision-makers more successful. Let us consider the decision with a systemic approach. We find that the decision process is an operation that identifies the options and their optimal combination after entering the necessary data and information and provides it to its users as a system output. Gives; Therefore, it can be said that the rapid growth of information technologies and many other sciences and technologies owes to the importance of decision making. Therefore, if we study this matter more carefully and obsessively, we will find that the primary use of these sciences and technologies is to increase the accuracy and speed of access to information and reduce the complexity of information to achieve a correct decision (Tsao, 2004). Although many advances have been made in decision science and knowledge of applying mathematical models in it, there are still many weaknesses and shortcomings, and it is necessary to use the extensive research and studies of developed models. Explain Terry for decision-making and decision-making. This research is based on research and the knowledge and experience gained from them, tries to improve the decision-making process, and provides new models for greater adaptation of decision-making systems to the real world. One of the proposed methods in power outage management in distribution systems is intelligent systems. Conventional and new methods such as decision-making theory are expected to be used simultaneously to manage outages in the power grid. Smart devices complement traditional management so that a powerful adaptation to change conditions and the ability to make quick decisions with inaccurate information processing is provided (Tomsovic & Falcao, 2012).

The issue of distribution management has changed dramatically over the past two decades. In this discussion, the main emphasis is on power quality issues and achieving the most economical methods in definitive management and when they occur. In this regard, a comprehensive and detailed study of nutrition and consumption is significant. On the other hand, different methods of system management should be explored. Considering the various economic and non-economic criteria and emphasizing the various points raised by various experts, the issue of the distributed management system should be examined. In addition to the above, the need to consider and consider uncertain parameters, including various economic conditions, reliability of the power supply system and change the system's structure in the future, etc., makes the project very complex. At present, the competitive status of systems is of particular importance, and in this situation, the desired quality of nutrition is one of the essential criteria. In restructuring the electricity industry, the issue of power outage management plays a key role. Of course, deregulation and competition create a new level of uncertainty in the system, complicating the decision-making process in the management of determinants and making them responsible. In other words, in the discussion of power outage management, a series of new criteria should be added to the decision-making process.

In short, the phenomenon of power outage management can be considered as a multi-criteria decision-making process despite uncertainties. The main goal of this process is to achieve optimal strategies in controlling outages so that issues of reliability, economic issues, and customer service are taken into account, while maintaining the system's speed, accuracy, and intelligence.

The purpose of this project is to design an intelligent control system to make decisions in these cases.

Basic information is essential for any decision issue. This basic information is called decision criteria, discussed in mathematical planning models as objective functions. In mathematical programming theory, it is assumed that the objective functions are known, while these functions are not fully known in practice. This issue is more prominent in decision-making issues whose criteria in most cases are qualitative quantities, and because of this issue, evaluating issues with decision-making theory has its complexity. The quality of the criteria makes the issue of decision-making much more complex, and accordingly, several issues have been raised about the decision criteria (Eric Jacquet-Lagreze, Yannis Siskos, 2017).

In most management studies, the basic principles of the subject matter are discussed, and the defined needs are assessed, including economic issues through many critical yet complex criteria such as system reliability, environmental prices, energy prices, economic constraints, political and social assumptions, losses. The problems that occur in the outages, etc., overshadow the management of the outages in the distribution system and at different levels. There is no specific design or optimal method that meets all the criteria with the relevant emphasis in most cases. In other words, we may come up with various designs and methods with specific properties with different opinions about the existing criteria.

Thus, the importance of using multi-criteria decision-making theory models in various topics, including the subject of the present dissertation, becomes more apparent. In these models, comparative analyzes have been presented that show a logical and acceptable balance between different criteria (Hobbs & Horn, 2019; Kavrakoglu & Kiziltan, 2016).

A valuable and appropriate model of multi-criteria generalization theory should be able to establish a logical relationship between different criteria, both quantitatively and qualitatively, considering economic and non-economic issues. Multi-criteria decision-making theory is a design strategy with a wide range of applications in a wide range of criteria that allows a comprehensive analysis of the subject matter.

This comprehensive analysis provides a decision database of a range of acceptable design methods that ultimately prepares the conditions for optimal decision making. In this new theory, there is the ability to integrate inaccurate information into the decision-making process. For a process may be defined.

In this theory, with the proposed structure, it is possible to design indefinitely so that a framework with a structure is provided for the analysis of decision-making theory. In this context, both probabilistic and risk assessment methods are possible, and the hybrid decision-making method is possible.

Theoretical Foundations

The following are definitions related to the project, which have been used during the project.

Options: Options mean the decision-making potentials of deterministic management in terms of their effectiveness. For example, the decision to cut off energy to different areas of a distribution system can be an option. Also, adding new power generation systems during downtime creating new links between different parts of a distribution system to reduce damage and losses in a system, can also be considered other options in decision-making. Each option can have one or more different values. Each specific option has defined properties and values such as type, capacity, location, and time of power outage.

Solutions and Simulation Studies: A solution is a combination of an option and uncertainties. Simulation studies related to power outage management include the cost of damage at the time of outages, system reliability, environmental impacts of outages, and economic studies. These studies are performed using models and analytical tools and are guided by decision-making criteria.

Uncertainties: Uncertainties in a system are coefficients related to states about which there is either limited information or no previous information about them. For example, a sudden increase in load, change in energy prices, and unforeseen events are considered uncertainties in the system. These uncertainties can be modeled through the distribution of probabilities or as unknown, constrained, and unstructured variables.

Criteria: Criteria reflect the multiple dependencies of the distribution system on the deterministic management control system. Through this information, the relative preference of the options over each other is measured. Examples include economic, financial, efficiency, environmental, or socio-economic effects. In general, criteria are functions of options and uncertainties. The overall goal of the determinant management system is to minimize and maximize each criterion relatively.

Load cut-off: In simple terms, load cut-off can be defined as a power outage for an area. Among the reasons for load, interruption are problems in production, damage to the transmission system or various parts of the distribution system, short circuits, or overload of consumers.

If the electrical power in a network is completely cut off, it is called Blackout, and if part of the sources is still in the network, it is called Brownout, in which case the voltage level of the network will be less than the minimum defined voltage level.

In power grids, there should be a close match between production and demand to avoid overloading the grid equipment, which can cause severe damage to the equipment. Under certain conditions, the separation of a part of a network causes current fluctuations in adjacent parts, which, while not desirable, can lead to a series of errors in large parts of the network. In other words, the problem may start in a small area and spread to a large area.

Findings

Outages in power grids

Distribution systems are responsible for the bulk of the distribution of electrical energy to consumers. These systems often suffer from widespread and long-term outages of energy distribution to consumers due to natural disasters such as storms, etc., or special network conditions. Obviously, network management is critical in such situations. In this situation, due to the large volume of customer calls, operators stop pursuing information and manual techniques, and the need to use new techniques is felt. In this regard, a limited number of energy distributors use advanced systems (Terrance & Nielsen, 2012). In these systems, customers' contact information generates power outage tables. This method is very accurate, fast, and advanced compared to the manual method.

The electricity industry is undergoing significant changes and moving from a monopoly to a healthy competitive structure. This restructuring while changing the operational needs of the system. It will also shape several new functions for decision-makers (Yeh et al., 2019).

On the other hand, due to the importance of electrical energy, electricity networks are looking for suitable methods to perform various operations while maintaining power quality. Therefore, these networks face the problem of optimal management of power outages. One of the methods is to design and install a fault management system for power grids to achieve this goal. Although providing these systems is very difficult and, at the same time, very expensive, this industry is trying to provide very high capabilities for redistribution of energy quickly and accurately (Tsao, 2004). In designing these systems, while many technical challenges are significant, several critical non-technical issues, including social, cultural, etc., overshadow the ultimate success of these new systems and Should be considered.

Because power grid operations control centers face a large amount of information in times of emergency, it is challenging to decide on power outage control given the many criteria that exist. For this reason, these networks have turned to decision-making theory methods and power outage management systems to find appropriate solutions to analyze these problems through information technology.

Electricity distributors have used manual and computer methods to determine and evaluate power outages in recent years. Some of these energy distributors use manual techniques and customer contact information to evaluate these outages (Hobbs & Horn, 2019).

As noted in various references, electronic advances have primarily occurred in the last twenty years, and while almost all consumers have used this feature, the use of this equipment is increasing. Consumers to the quality of power and power supplies is a logical consequence of this trend. Currently, although there are standards to determine the quality and reliability of the power system, power quality issues for several applications are still more than this range Are (Kavrakoglu & Kiziltan, 2016).

Given that the electricity industry structure has more or less changed throughout the world over the past decade and has been developed in line with the use of equipment sensitive to power quality issues, power supply quality issues have become very important. In this regard, some researchers have discussed the quality of power supply in three main groups (Chen & Hwang, 1992).

Power continuity (number and time of long-term outages) Voltage and current quality (amplitude, waveform, frequency and .... service (the topic of competitive structures)

Considering that power outage is one of the leading indicators of nutrition quality, this indicator is further examined.

Power outages in grids Distribution systems play an essential role in distributing electricity to consumers in grids. These systems are often exposed to natural disasters such as storms, etc., and technological disasters, including load shortages, which cause widespread and long-term disruptions in energy distribution to consumers. Because it is not possible to accurately predict these outages, and due to the lack of sufficient information on the supply or non-supply of electricity, unwanted re-energization of electricity takes a long time.

Electricity distributors have used manual and computer methods to determine and evaluate power outages in recent years. Some energy distributors evaluate these outages using manual techniques and customer contact information.

Although in emergencies, due to the large volume of customer calls, operators are reluctant to acquire information and manual techniques, the need to use new techniques is felt. In this regard, a limited number of energy distributors use advanced computer systems (Triantaphyllou, 2012). In these systems, customers' contact information generates power outage tables. This method is very accurate, fast, and advanced compared to the manual method, but again, due to the existing limitations, it is not complete, and the definite tables in this system are not very accurate due to the use of customers' contact information to determine the exact location of errors. The location of existing errors due to customer calls may lead to incorrect results.

The main reason for the inaccuracy in determining and evaluating the determinants in the above method is the lack of reliable information that has been taken from the system itself. To be accurate enough, intelligent methods can be used to determine and evaluate determinants accurately. This system is based on accurate information and is one of the applications of intelligent systems in the electrical energy distribution system.

The first and most important need of an intelligent system to accurately evaluate the outages in a part of a distribution system is to have reliable information from different points and specific situations. This information is critical during power outages in various parts.

There are two general views in determining the efficiency criteria of the network. The first view introduces the parameters related to the mains voltage as functions indicating efficiency, while the second view introduces the parameters related to power outages as performance-determining functions. In this section, we try to examine the advantages and disadvantages of power outages as a criterion for expressing the efficiency of the network and explain the comparative advantage of the second view over the first view.

Of course, at first, it may be a little strange to use definitive network parameters as a measure of efficiency instead of network voltage and its overall benefits. However, the existing rationale justifies this choice (Triantaphyllou, 2012).

First, it is better to point out that not having electricity can be related to having electricity as a function. This can be easily summarized in the following relation.

Production - demand = power outages

Assuming this relationship is correct, it can be changed as follows.

Generation + power outage = demand

This relationship is acceptable in terms of the amount of electrical power, but losing electricity in a certain period is not equal to the value of having electricity in the same period can not be divided into two categories of having and not having electricity is considered a category. Giving an example can make the problem easier to understand. Suppose we are preparing a scientific text to have a power outage for a few moments, however short, for a few seconds. In that case, we will certainly never equate the value of a few seconds of electricity with the value of losing electricity in the same few seconds, and this will give more motivation for Acceptance of the second view in the use of definite parameters in the evaluation of network efficiency creates. Usually, power grids have accessibility higher than 99.9%, which if the first view is desired, this number must be measured with high accuracy. Consider the following numerical example for different networks with 99.996% and 99.997% access capabilities.

Network analysts find the difference between the two numbers insignificant. However, if we look at these numbers from the point of view of power outages, the difference is significant and extensive. In other words, the duration of power outages in one network is twice that of Chapter 3 of Decision-making theory, power outages in networks, and other network management methods. However, it should be noted that using such criteria as criteria with an opposing view in systems High reliability will be applicable (Ballestro & Romero, 2018).

Definition management system

The decision management system is presented in a space that includes decision-making methods. The complex issues facing the distribution system can be analyzed in this space. One of these complex cases is related to emergencies and network outages. The quality of performance of the cut-off management system is highly dependent on the information and experience of electrical industry experts. In many cases, the information needed to make a decision is vague and must be made in an uncertain environment. There are several ways to work in an indefinite space. The oldest methods for working in this space are probability-based methods. Probability is an excellent tool for this type of space as long as the information is available. In cases where statistical information is not available, fuzzy sets can be used. Fuzzy sets have high efficiency in indeterminate space (Trueman, 2017). The use of fuzzy methods modifies the modeling potential of human inference in indeterminate space. Also, while making possible the use of language variables in computer methods, this method is also used for the principles of the feasibility of a phenomenon. Feasibility can be expressed numerically between zero and one. This possibility can be used as a level of trust in a phenomenon.

This issue is introduced in the discussion of fuzzy sets as a membership function. In other words, the membership function expresses the level of trust that a member or element has in the fuzzy set. This level of trust depends on several factors. In the discussion of power outage management and the decision to select a part of a network to cut off power in the event of a shortage, these coefficients can include population, type of load, the presence of sensitive centers, etc (Asgharpour, 2018).

Fuzzy sets are similar to conventional set theory, involving multiple operators. In fuzzy sets, most operators do not have the same definitions, and it is up to the user to select the appropriate operators to model the decision steps.

Due to the conditions governing the power outages, in the following sections, a new model of variable weights is proposed for the criteria, and new relationships are developed to use fuzzy sets in the decision matrix.

The general structure of the determinant management control system

In summary, the general structure of the deterministic management control system can be expressed in five primary categories of work. These five categories of work are:

1- General and detailed study of the problem 2- Construction of decision database 3- Identification of different options 4- Design and determination of the final and desirable system 5- Analysis of the designed system (Triantaphyllou, 2012).

Each of the above is briefly explained below.

2- General and detailed review of the issue of decision making,

It starts with selecting a set of criteria, options, and uncertainties. Options are different modes of the determinant management system. Definitive management is also examined from several perspectives, including the perspective of power quality and reliability. Therefore, while finding sufficient knowledge of the options and criteria at the beginning of the decision-making discussion, it is necessary to examine the conditions governing them. It should also be noted that each option with a particular uncertainty and with specific criteria represents a solution.

2- Building a decision database

Each solution defined in the first stage can be evaluated using management tools such as economic optimization, simulation of damage during downtime, and financial analytical models. With a comprehensive analysis of each solution, it is possible to access various criteria of that solution, or in other words, the decision database, and based on this information, different solutions and options are compared based on well-defined criteria (Ballestro & Romero, 2018).

Identifying acceptable options a critical point in designing a control system for determinants is defining and identifying acceptable options related to the given criteria. Most of the methods used in decision analysis in the electricity industry are multifunctional methods and trial and error methods. In a multi-criteria model, different deterministic management options are ranked based on defined indicators, while in the analytical trial and error method, different deterministic management options can be ranked based on the method's accuracy.

4- Designing and determining the final and optimal system

From the acceptable solutions, which can be obtained through various methods, the decision-maker can choose a unique solution that meets the decision maker's demands and points of view as the final design. In many cases, the decision-maker may choose a combination of solutions or make new decisions by adding and even, in some cases eliminating minor criteria and uncertainties (Wang & Archer, 2018).

5- Analysis of the designed system

At this stage, using accurate and practical information of a power distribution system, the system designed to control the management of outages is tested, and the results are compared with the real cases while analyzing. The results of comparisons can determine the accuracy and capability of the designed system.

Decision making with fuzzy sets

Conventional mathematical programming and simulation models are never satisfactorily used for uncertain information. The development of techniques related to intelligent systems has provided practical ways to work with uncertain information. An intelligent system can only match the decision-making process of expert human beings in a range of problems. These systems are more applicable to problems with a limited scope and are well-defined because the information that these systems use is obtained through experience and visits (Tsao, 2014).

New and modern distribution systems must be reliable, flexible, and economical. As mentioned before, one of the main factors that overshadow the reliability of distribution networks is outages. With all the efforts made to reduce the definite amount in these networks, this phenomenon occurs and usually exists as a fact. For this reason, the management of outages in distribution networks is a necessity and should be considered. As mentioned before, there are several categories of interruptions, but the thematic focus of this dissertation is related to interruptions due to lack of load. There are many criteria in the management of these determinants performed by decision-making theory. The type of criteria and how to examine them in the management of determinants have already been discussed. Considering that one of the essential points in decision-making theory is the transparency of criteria and in the discussion of power outage management in distribution networks, there is a variety of criteria in terms of the type of criteria, so in this project, we have tried to make decision-making theory using different criteria. As mentioned earlier, many of the criteria used in managing power outages are fuzzy.

Moreover, considering that these criteria significantly affect the final decision result, the study of power outage management using multi-criteria decision-making theory in the presence of vague criteria is one of the essential parts of this study, and a new model for These types of decisions are suggested. This model makes it possible for the information to enter the model qualitatively and quantitatively. Also, in this model, a function to determine the degree of accuracy of the final result based on fuzzy information is proposed.

Decision-making is a scientific, social, and economic endeavor. For this reason, in the presented model, an attempt has been made to obtain the correct and reasonable choice despite the uncertainty and ambiguity in the criteria. Engineers are usually involved in two different types of decisions.

2- Operational decisions

2- Strategic decisions: The methods mentioned in the previous sections can be used in each of the above decisions. The problem arises when the information is incomplete or vague, and fuzzy. Most multi-criteria decision-making theory methods have two main phases (Hong & Choi, 2020).

In the first phase, the points of view and judgments of experts or related people are collected, and in the second phase, using the information collected in the first phase, the ranking or prioritization of various options is performed. In some methods related to the complexity of decision making, criteria and their impact on multi-criteria decision-making theory have been determined and clarified (Hobbs & Horn, 2019). In some other methods, the issue of multiple criteria with internal communication is also mentioned (Li et al., 2004).

With the advent of fuzzy theory in 1965, this theory has been used in fuzzy decision-making problems. However, these theories still have several issues, including problem analysis, despite the fuzzy sets.

For the first time, the basis of multi-criteria decision-making theory based on fuzzy sets was established by Mr. Zimmerman (Gu & Zhu, 2014). Different multi-criteria decision-making theories were investigated, and finally, this theory was proposed based on fuzzy sets using fixed weights for criteria.

Conclusion

The present study was based on the management of power outages based on multi-criteria decision-making theory. Using the new model, the issue of decision-making was examined, and its compliance with the mental necessities of decision-makers was tested. In the second model, in addition to the above, the possibility of the dynamic weighting of criteria was discussed, and this possibility was investigated by applying the weight distribution curve of criteria. Thus, it is easy to enter these dynamics in the model using the proposed model and considering the dynamic conditions prevailing in electricity networks by applying the distribution curve of criteria.

The proposed methods are not specific and can be fully implemented in software environments. Therefore, in practice, they can be used as methodical mathematical models to analyze multi-factor decision problems, including managing power outages in networks. In this research, in addition to the approach used in presenting the proposed models in a multi-factor decision-making space is generally new, the possibility of using these models in power grids, especially in the management of its determinants, is also a kind of idea. In the proposed models, innovations have been created, some of which are discussed below.

1- Possibility to consider the effect of criteria on each other 2- Using modified variable weight 3- Providing an experimental relationship for variable weights 4- Applying standard weight distribution curves in weight coefficients 5- Presenting a decision model with fuzzy composite sets - A case study in a real sample network 7. Adaptation and adjustment of the proposed relation to the existing conditions of the studied network.

References

Goerge, L., & Kusic, (2018). Computer Aided Power System Analysis. IEEE Trans. On Sys., MAN and cybernetics, Part C, 28(2).

Yeh, C. H., Willis, R. J., Deng, H., & Pan, H. (1999). Task oriented weighting in multi-criteria analysis. *European journal of operational research*, *119*(1), 130-146.

Tsao, C. T. An Impact-Adjusted Fuzzy Multiple Criteria Decision Making Model.

Eric Jacquet-Lagreze, Yannis Siskos, (2017). Preference dis-aggregation: 20.

Hobbs, B. F., & Horn, G. T. (1997). Building public confidence in energy planning: a multimethod MCDM approach to demand-side planning at BC gas. *Energy policy*, *25*(3), 357-375.

Kavrakoğlu, I., & Kiziltan, G. (1983). Multiobjective strategies in power systems planning. *European Journal of Operational Research*, *12*(2), 159-170.

Chen, S. J., & Hwang, C. L. (1992). Fuzzy multiple attribute decision making methods. In *Fuzzy multiple attribute decision making* (pp. 289-486). Springer, Berlin, Heidelberg.

Trueman, R.E. (2017). An introduction to quantitative methods for decision making. Holt, Rinehart and Winston inc.

Asgharpour, M.J. (2018). Multi attribute decision making. Tehran University Publications.

Triantaphyllou, E. (2012). Multi criteria decision method: A comparative Study. Kluwer academic study-publishers, applied optimization series, 44.

Ballestro, E., Romero, C. (2018). Multiple Criteria Decision Making and its applications to economic problems. Boston, Dordrecht, London: Kluwer Academic publisher.

Wang, S., & Archer, N. P. (2018). A Neural network based fuzzy set model for organizational decision making. IEEE Trans. On Sys., MAN and cybernetics, Part C, 28(2).

Tsao, C.T. (2014). An Impact-Adjusted Fuzzy Multiple Criteria Decision Making Model. MCDM 2014, Whistler, B. C., Canada, Aug.

Hong, D. H., & Choi, C. H. (2020). Multi-criteria Fuzzy Decision-making Problems Based on Vague-set Theory. Elsevier, Fuzzy set and systems 114, 103-113.

Li, H. X., Li, L. X., Wang, J. Y., Mo, Z. W., & Li, Y. D. (2018). Fuzzy Decision making Based on Variable Weights. Elsevier, Mathematical and Computer Modeling, 39, 163-179.

Gu, X., & Zhu, Q. (2014). Fuzzy multi-attribute decision-making method based on eigenvector of fuzzy attribute evaluation space. Elsevier, Decision Support Systems.

Tomsovic, K., & Faleo, D. M. (2000, July). Advanced power system controls using intelligent systems. In *2000 Power Engineering Society Summer Meeting (Cat. No. 00CH37134)* (Vol. 1, pp. 336-339). IEEE.

Nielsen, T. D. (2002, January). Improving outage restoration efforts using rule-based prediction and advanced analysis. In *2002 IEEE Power Engineering Society Winter Meeting. Conference Proceedings (Cat. No. 02CH37309)* (Vol. 2, pp. 866-869). IEEE.