A Data Mining Method for Satisfaction and Confidence of the Bank Customers

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Abstract

Trust is the main concern of the Bank's customers regarding electronic and Internet services. The trust of both customers is logically and experimentally important to each other, and banks need to take more steps as service providers to maintain their customers. It is necessary to increase the factors affecting the satisfaction and reliability of customers in banks using data mining. In this paper, we examine the factors affecting the increase of customers' confidence in banking and Internet banking services and the impact of any perceived credit factor by public and private banks, service providers, and infrastructure providers in electronic banking. The presented method is based on scientific data mining algorithms such as clustering and classification of the decision tree J48 and the neural network, as well as a quick and practical application of the miner. Data are analyzed using a questionnaire with the bank customers of 25 Tejart bank branches in Tehran. The experimental results demonstrate that the accuracy of the decision tree classification algorithm is 84.04 and the neural network is 72.3%.

Keywords: Trust, Bank, Data mining, Classification, Customers.

1. Introduction

In the past, organizations were only thinking about finding new customers and the improvement of customer services had no importance. Finding a new customer was a victory for the organization and there was no particular attention to existing customers. Now, the situation has changed and the maintenance and improvement of profitable customers is the first purpose of organizations. In today's society, customers are seen as a key and central factor for organizations. The orientation of all the goals, strategies, and organizational resources is attracting and keeping profitable customers.

So, the quality of service for customers in their loyalty as well as maintaining and developing bank relations and competitive position is a strategic challenge. Many expenses are spent to understand this concept and to achieve practical solutions to its strengths. Loyalty is a phenomenon that can be seen among customers who repeat purchase behavior and provide a positive attitude towards the company. Managers have successfully concluded that building consumer loyalty and keeping it can be done only in the light of their trust in organizations. Thus, changes in the direction of marketing and emphasis on customer orientation are based on trust in organizations rather than voluntary opportunity. Also, electronic customer loyalty is one of the important consequences of electronic customer relationship management. It ultimately leads to higher retention rates of these customers in organizations. An increase in customer loyalty can reduce marketing costs and increase the customer's demand.

Therefore, loyalty to business survival is one of the main priorities of organizations. The organizations emphasize creating sustainable and profitable relationships with customers

in today's challenging and competitive environment. A prerequisite for survival in saturated markets is not only attracting and satisfying customers but also establishing long-term relationships with them. This is the online world that is increasingly competitive and customers can just press a button to compare the products and services of their competitors, and its competitive advantages are achievable. This paper discusses related works in Section 2. Section 3explains our proposed method, whileSection 4 is about the implementation of the model. Section 5 contains the experimental results, andfinally, we give concluding remarks in Section 6.

2. Literature Review

Data mining is an integral part of customer relationship management. An assumption that companies can by identifying the characteristics and interests of their customers, establish successful relationships with them, has been mentioned in [8]. The impact of e-banking in increasing the bank's customer satisfaction has been investigated and concluded that the electronic services of the bank are the operational needs of customers. Also, it has been shown that the developed relationship with customer satisfaction has a direct linear relationship. Some results show that factors such as the speed of transactions, confidentiality, trusteeship, knowledge of employees, attitude, and attention to customer personality have a significant impact on customer satisfaction. The other results show that Internet banking has a very positive impact on employee attitudes and it reduces service delivery costs and improves service quality [1][4].

E-banking user's behavior was investigated by Foundation. In this study exchanges and electronic support measures and the access method to public computers for electronic banking were examined. Milne and Boza examined the possibilities of e-commerce features and customer confidence because of concerns about the use of banking services [6][2].

Kim Chang and colleagues noted in their study that generally believed security, improves confidence. And the perception of security and high trust certainly increase the use of e-commerce. This

study provides a theoretical basis for scientific and academic studies and for providers of security systems who are related to electronic payment [5][7].

Liu Yang and colleagues have used classification algorithms in the field of customer trust and satisfaction in their work. OsameAbo Abbas in the same year used a clustering algorithm in the field of customer satisfaction and Abdullah has done the comparison between various classes' methods and clustering on different types of data by the use of WEKA software [8].

According to the report research of the institute (Data Monitor) which is one of the most important analysis centers of banking information in Europe, statistics of electronic banking systems in eight countries of France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, and the United Kingdom reached from 4.5 million people in 1999 to about 22, million in 2004. In 2005 more than 75 percent of companies in developed countries, at least use one of the electronic banking services [9].

Come Score Company in a study that was about the confidence-building of bank customers, has concluded that Spain after Canada, Netherlands, France, Sweden, Great Britain, New Zealand, and Belgium is the eighth country in the world that can penetrate e-banking and its reason is a trust of customers. In 2014 Jana Kriman and colleagues examined in a study the different types of data mining techniques about trust-building and satisfaction and analysis.

3. The Presented Method

In this research, we use Tejarat bank data and questionnaires, and census sampling is implemented among all key customers of Tejarat Bank in 25 branches of Tehran. The content validity is used to determine the validity of the questionnaire. The reason for choosing the key customers is that all new marketing approaches would insist on maintaining the major customers of organizations. The total number of main customers of the studied bank according to the bank statements are 1585 people of whom 91.45 percent of them with the return rate of 1450 questionnaires participated.

Then in considering some completed forms excluded due to non-compliance with reliability. Ultimately, 1300 questionnaire forms including 626 women and 674 men with different ages and educational levels are studied. Factors affecting the development of their confidence using data mining software Rapid Miner are investigated and analyzed.

4. The Presented Method

A total of 44 questions in 6 groups are selected and defined and a conceptual model is developed to identify the factors leading to trust in the answers of key customers using the questionnaire. The first 5 questions are related to customers' personal information including gender, location, occupation, age, and education. The next 39 questions in this model are divided into six main variables including:

•The first group related to the bank factors including providing information and useful advice which contains 6 questions.

• The second group is related to bank staff factors which are 3 questions.

• The third group related to the bank's reputation, including 8 questions.

• The fourth group consists of 4 questions related to the provision of complementary services.

• The fifth group related to the bank's clients, which includes 7 questions.

• The sixth group related to bank technology and its processes which include 11 questions.

To achieve the research objectives, the research method is based on the crisp method. There are different methods for the implementation and execution of data mining and one of these very strong methods is the Crisp method. The method consists of identifying the system, data understanding, data preparation, modeling, evaluation, and development of the system. The steps of this method are consistent with the phases of the project.

4.1-First phase: Business and Data Identification

This research is conducted based on data management communication with clients of Tejarat Bank. According to the study questionnaire, its validity based on controlled content is done among 25 branches of that bank. The presented model of this study is a comprehensive model including six customer-oriented and trust structures. Brand Credibility, Customer Satisfaction, Loyalty Commitment, Continued Commitment, Word of mouth Recommendation (WOM), Switching Propensity. The questionnaire is prepared according to the communication services and these six structures. The role of customer confidence in banks with customer retention and customer agreement and provided services are provided.

4.2 The second phase: Data Processing

This step of the Crisp method includes data selection, data cleaning, and preparing data for data mining. Data cleaning is the quality control phase which is done before data analysis [1].

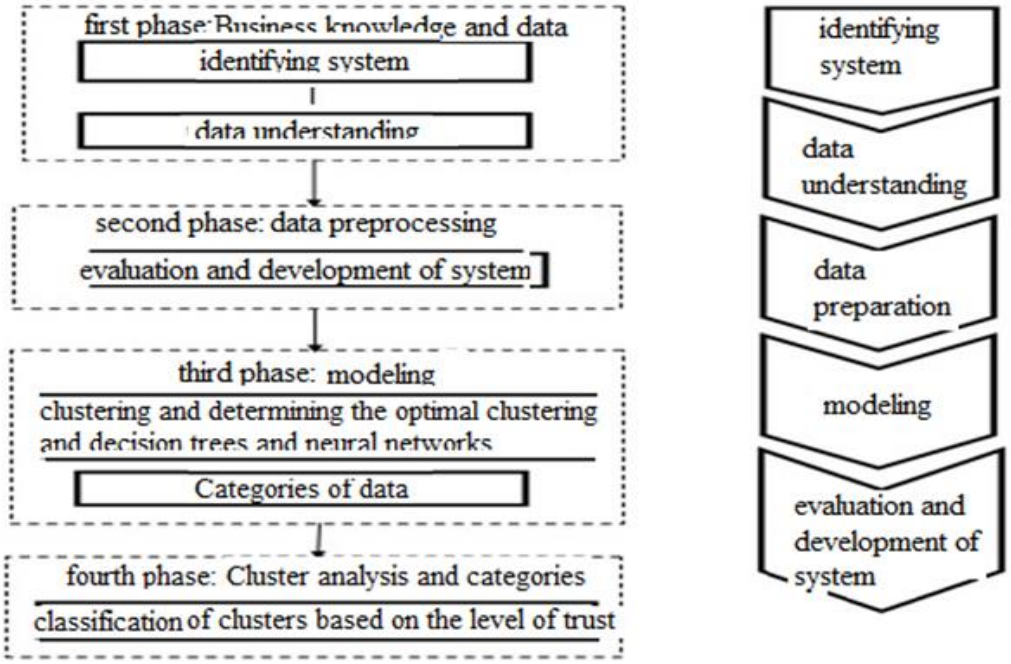

Fig.1.phases of the project implementation based on the Cresp method [3][4]

One of its responsibilities is filling or removing missed data. Missing data can be omitted if the number of non-value characteristics in a sample isn't too much, and missing values can't be filled in manually. In available data too since missing values are considered important fields. Therefore, some of them are eliminated, and from 1585 records. So, the number of investigated data is reduced to 1300 cases.

4.3- Third phase: Modeling

After studying the data and their preparation, now can go back to modeling. At this point, using data mining techniques, predictive models are discussed. Modeling is done with the help of Rapid Miner software.

✓ Modeling with KMEANS

In this stage of modeling, the KMEANS algorithm is used for clustering data. The KMEANS algorithm is a method of clustering data that because of its speed and simplicity widely used. Different method is used for clustering. However, the reason for using this method is that the optimal number of clusters is calculated using the index. This issue has output validity of clustering.

Rapid miner software is used for clustering. Bank data are divided based on trust into 6 groups and a group with personal information. Clustering is done using the KMEANS method, and then the optimal number of clusters is selected using the Davies-Bouldin index [10].

$$R_i = max_{i=1,\dots,n \;\; ci\neq j} R_{ij} \tag{1}$$

$$DB_{nc} = DB_{nc}\frac{1}{n_c}\sum_{i=1}^{nc} R_i \tag{2}$$

$$DB_{nc} = \frac{1}{C}\sum_{k=1}^{C} max\left\{\frac{s_c(Q_K)+s_c(Q_1)}{d_{ce}(Q_K,Q_1)}\right\} \tag{3}$$

DBnc:Is the mean similarity between each cluster and the most similar cluster to it. The number of clusters is tested with software. The best case is when the Davies index is less between clusters. In this study, 2-7 clusters are tested, evaluated, and implemented. The best case is for K=4 which can be seen in Table 1.

Table 1. KMEANS clustering for an optimal answer

K	Davies Bouldin
2	5.498
3	5.167
4	4.602
5	5.649
6	5.742
7	5.908
8	5.837

The number of each cluster is as follows, respectively: first cluster 150, second cluster 363, third cluster 396, and fourth cluster 391. Validation parameters are used to assess the accuracy of clustering to compare different clustering methods or to compare the results of a method with different parameters. These indicators include:

- Dunn index;
- Davies Bouldin Index;
- Root-mean-square standard deviation and R(RS) root;
- SD validity index;
- S _Dbw validity index.

In this paper, the Davies-Bouldin Index is used because this index calculates the mean similarity between each cluster with the most similar clusters to it. It can be concluded that, whatever the amount of this index is higher, better clusters have been produced. But, in the Rapid Miner software, as the amount of this index is negative, its minimum case will be the best amount.

✓ Modeling with KMEDOIDS

This algorithm is shown with the Partitioning Around Medoids (PAM) performance [10], and its property is that K is the first representative object (Medoid), and is selected arbitrarily from n object of the database. Each remaining object is clustering with a medoid that has the most closely resembles it. Then this strategy frequently replaces one of the medoid objects with the non-medoid object So that the quality of clustering results is improved. This quality is estimated using a cost function that the average of dissimilarity between an object and its medoid measures the cluster. In other words, this method is very similar to the previous method. The difference is that in the prior, each cluster is shown with an average of that cluster's objects (cluster center). But in this method, each cluster displays one of the objects located near the center of the cluster. The basis of this method is showing each cluster by one of the data which is located near the center of the cluster, and instead of using of cluster center as a reference, can be used medoids, which means the data which located in the most central part of the cluster.

In this method, a representative of each cluster is selected first, then the distance between the individual points is calculated and finally, the total cost function is counted. In the next step, we change one of the preferred points and then follow the same steps again. If the difference between the current total cost and the previous total cost is negative, a transfer is done and the representative of the cluster is changed. These steps must be tested for every point. The cost of transfer (S) can be calculated after changing the medoid of the cluster as follows: if it wasn't positive, the transmission of the intended medoid is ideally suited.

$$S = \text{Current Total Cost} - \text{Past Total Cost} \quad (4)$$

To find the cost function or total cost, the cost per data is calculated from its cluster center, and finally, these numbers accumulate together. When the aforementioned issue is clustering with the Kmedoid cluster method, more time is consumed compared to the previous Kmeans. Also, the results of the Davies Bouldin Index of this part compared to the previous one are high. When comparing the clustering algorithms, simplicity, accuracy, speed, and better results are taken into consideration. Therefore, the results of both clustering can be seen in Table 2.

✓ Modeling with neural network

Table 2. Comparisons of two types of clustering

Measurement	Parameter	KMeans	KMedoids
Davies Bouldin	K=4	4.602	5.867
Avg.within centroid distance	All clusters	30.030	27.978
Execution Time	Processing speed	4min	30min

At this stage, the predictive models are provided using data mining techniques. Modeling is performed using the Rapid Miner software. The neural network classification algorithm is created using input variables and the determination of the target variable. To build a neural network model some variables such as gender, age, education, occupation, speed of service, bank employees, bank brand, technology, and staff dealing with customers are determined as predictor variables, and internet banking variables, quality and speed of service provided are determined as a target variable. Then, data is divided into two parts: training and testing, 90 percent for education and 10 percent for the test.

The neural network has an input layer, some hidden layers, and an output layer. Each node receives input, processes it, and produces output. To determine whether each input will receive to output node or not, depends on its weight. To predict field validation the neural network software is used which contains three groups: Perception, Neural Net, and AutoMIp. Among the three types of networks, Neural Net shows better accuracy in output. For this network, some parameters such as training cycles with 500, learning rate with 0.2, and Error Epsilon equal to 1.0E-5 are used. At this stage, the learning accuracy is 72.3 percent.

✓ Modeling with decision tree

Predictive models are discussed using data mining techniques. Modeling is performed using the Rapid Miner software. At this point, decision tree algorithms, including J48, and C5.0 are created using input variables and determination of target variable. To build decision tree models some variables such as gender, age, education, occupation, speed of service, bank employees, bank brand, technology, and staff dealing with customers are determined as predictor variables, and internet banking variables, quality and speed of service provided are determined as a target variable. data is divided into two parts: training and testing, 90 percent for education and 10 percent for the test. A decision tree is a combination of some logical requirements (if-then rule). Decision trees aren't just a demonstration of the decision-making process but can also be them to solve classification problems. Usually, a set of rules extracted from a decision tree, are the most important studies that come from them. In the created model in this application for dividing branches, the Gini index is used. In this study, the confidence standard for created rules is determined 80 percent. The reason for choosing this model is that the calculation shows the intended indices have the highest accuracy among the models that are implemented. Index calculation is presented in the assessment section.

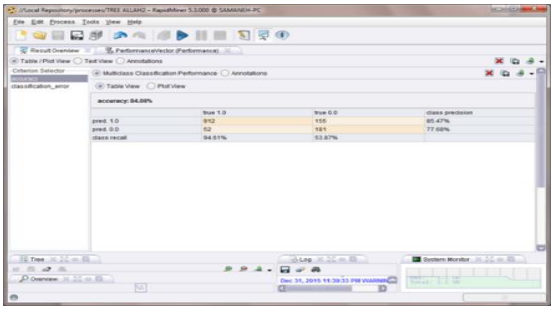

Fig.2. the accuracy made by decision tree J48.

5. The experimental results

The highest and the best clusters are related to the third and fourth clusters, each of them has 396 and 391 records. The reason is that data distance and their similarity are much less than others. Then, the second and fourth clusters have 363 and 391 records and finally, the first cluster has 150 ones.

✓ Analysis of the first cluster

This cluster with 150 records has the lowest population. Members of this group are women, 70 percent of them are living in Tehran and 75 percent of them are employees. Indeed, 50 percent of them are young and they have bachelor's degrees. They are satisfied on average with the provided information and bank consultations. Employee behavior with customers in this cluster is at a high level. They have medium satisfaction with the bank technology and SMS notification of the bank is at a high level.

✓ The second cluster analysis

The population of this cluster is 363 people that have the third largest population. The members of this group are women and they are self-employed. Indeed, 14 percent of customers in this group are elderly and 32 percent are middle-aged, 18 percent of customers of this group have a master's or higher educational degree. They are satisfied with the provided information and bank consultation on average. The employee's behavior toward customers is at a high level in this cluster. They are moderately satisfied with the bank's brand, and their satisfaction with the SMS notification and technology of the bank is at an average level.

✓ The third cluster analysis

This cluster with 396 people is in the first place. The people of this group are men, 95 percent of them are living in Tehran, 20 percent of them are self-employed and 80 percent are employees. Also, 46 percent of customers in this group are young and 35 percent have a high school diploma. They are on average satisfied with the provided information and bank consultation. The employee's behavior with customers in this cluster is at a medium level. They are satisfied with the bank's brand moderately. Their satisfaction with technology and SMS notifications is at a medium level.

✓ The fourth cluster analysis

This cluster with 391 populations is in second place, 71 percent of this group members are men and 29 percent are women. Indeed, 68 percent of them live in Tehran and they are self-employed, 44 percent of customers of this group are young and 49 percent of them have an associate degree or lower. They are satisfied with the provided information and bank consultation on average. The employees' behavior with customers at this cluster is at a medium level. They are moderately satisfied with the bank's brand. Their satisfaction with technology and SMS notifications of banks is at a medium level.

Conclusion

Nowadays, customers have many options to select the type of service and its provider. Managers in banks should be aware of the fact that if they don't pay attention to each customer specifically, the customer will be able to choose another bank for getting services. Therefore, many banks are trying to be customer-oriented institutions, unlike product-based companies. Marketing managers if can explore customer behavior and predict it, then will be able to have long-term and better relationships with customers. Flexibility, intimate relationships, and hostelry access are affecting parameters in gaining the trust of customers. Customers, mostly due to the basic

rights and lack of handling the complaints aren't satisfied. Therefore, in this case, the bank can improve its weakness to gain the trust of customers

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Optimal and Economic load Distribution by Adjusting all Types of Controllable Variables With the Aim of Reducing Production Costs and Minimizing losses

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Abstract

Smart Grids are the result of the activation of consumers in the power system and their role in the planning and operation of the power system. The communication, control and measurement infrastructure asa smart communication bridge establishes two-way communication between consumers and the power network and provides the basis for the effective implementation of the load response program as well as direct load control. The purpose of solving the problem of economic load distribution in the power system is to plan the output of production units in such a way as to provide the required load demand with the lowest possible cost. In addition, it satisfies the constraints of equality or inequality of all units. In this research, PSO optimization method is taken into consideration by considering voltage deviation, voltage loss and system load capacity as part of the objective function.

Keywords: economic load flow, voltage deviation, system load limit, voltage losses, PSO algorithm

1- Introduction

Engineers and researchers often face problems in various sciences whose complexity is increasing day by day. These issues are usually expressed in an optimization problem. For a problem, it may have different solutions, and to compare them and choose the optimal solution, a function called the objective function is defined. This function depends on the nature of the problem and its proper selection is one of the most important optimization steps. Sometimes it is considered in multi-objective optimization simultaneously; Such optimization problems, which include multiple objective functions, are called multi-objective problems.

The goal of optimization is to find the best acceptable solution according to the constraints and needs of the problem. The progress of computers over the years has led to the development of optimized problem solving methods, so that many instructions have been compiled during this period. Methods for solving optimization problems can generally be divided into the following two categories, classic methods such as dynamic programming methods,New methods such as heuristic and meta-heuristic methods.

In the studies related to planning and operation, the uncertainties of the power system are analyzed using probabilistic methods. In fact, deterministic load

distribution uses certain deterministic values such as the power produced by generators and the required power of loads in order to evaluate and measure the system position and load distribution. Therefore, deterministic load spreading ignores all the uncertainties of the system, such as generator shutdown rates, network structural changes due to changes in the power demand of loads. But in today's modern systems, due to the uncontrollable nature of the primary sources, many power fluctuations have been introduced into the power system and grid. In order to consider uncertainty, there are different mathematical methods for unrealistic analysis; Probability methods, fuzzy systems can be mentioned among others. There are three general methods in probabilistic load distribution evaluation: analytical methods, approximate methods and Monte Carlo simulation method. In the analytical method, load distribution equations are linearized to make it possible to use them in probability functions, as in references [1], where analytical methods are used for probabilistic load distribution analysis. In approximate methods, there is no need to linearize load distribution equations. In this method, the number of evaluated points is reduced to minimize the computational load and storage. The third method, which is the Monte Carlo simulation method, is based on the repetition process and is based on two important characteristics, which include the generation of random numbers and random sampling. In this method, for the non-deterministic variables of the problem, a number of values are generated randomly, according to the probability distribution functions of these variables. The main advantage of this method is the simplicity of its implementation and implementation. For example, references [2] are articles that have been reviewed based on the use of the Monte Carlo method in possible studies of load distribution in power systems. In general, it can be pointed out that in most of the articles, such as [3] and [4], which aim to analyze and investigate the planning and performance of microgrids based on the non-deterministic and intermittent behavior of renewable energy sources (Figure 1), solving optimization problems through Random methods are used.Reference [5] has investigated systematic planning in electricity and gas transmission networks by considering uncertainty. Reference [6] deals with the planning of energy hubs in multi-energy systems in the transmission network with reliable reliability. An integrated and multi-regional longterm planning model in multiple energy systems is presented in [7], which considers the value of gas supply from production to energy consumption through gas pipelines. An integrated multi-directional course of expansion of production and transmission networks and natural gas network in the Great Sea is presented in [8]. In reference [9], a non-linear programming model mixed with integers considering reliability and uncertainty is presented.In reference [10] of the point estimation method, to determine and check the uncertainty of wind and solar power in the objective function (Figure 2), which is the optimization of the cost function, while power losses are ignored.

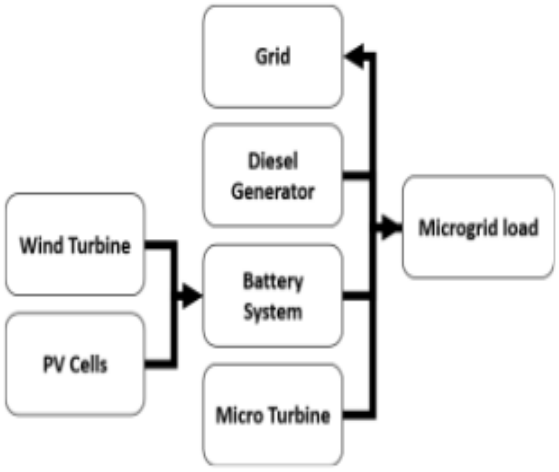

Fig.1. Layout of microgrid structure under study

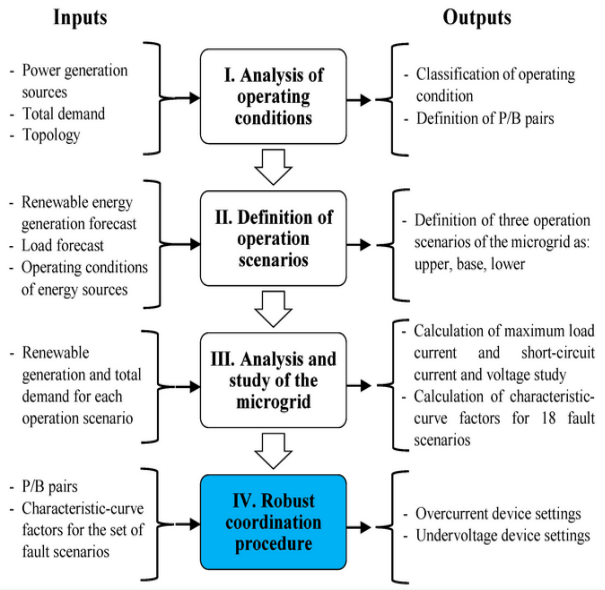

Fig.2. Four-stage procedure for the DPAU

In reference [11], the PSO algorithm has been applied to a sample microgrid that includes traditional distributed generation units, renewable energy sources such as wind and solar power, and batteries, in order to optimize the objective function. In reference [12], in order to show that the presence of renewable energy sources such as wind turbines and photovoltaic systems, along with other traditional sources of power generation in the microgrid, improves the reliability index. The power of renewable energy sources has been obtained through Monte Carlo sampling (Figure 8), Weibull and beta distribution functions, and also the results show that the power produced by wind and sun improves the uncertainty of these powers and the random deficits of the system.In reference [13], the problem of optimal load distribution related to several microgrids in the presence of load-related uncertainties and using probabilistic models related to the powers produced by small-scale renewable sources have been investigated. The power required by the load, solar radiation, and ambient temperature, which are among the factors affecting the power produced by the photovoltaic system, are modeled based on normal distribution functions and the power produced by wind generators by the Weibull function. In reference [14], a standard system of 30 tires consisting of energy storage and renewable energy sources is studied and by modeling a multi-objective problem through heuristic and meta-heuristic algorithms, it is claimed that the proposed method to minimize the cost of fuel and pollution as well as improving the line voltage profile is suitable (Figure 3) In this reference, the power produced by the wind power plant is modeled through the point estimation method based on the Weibull distribution function.

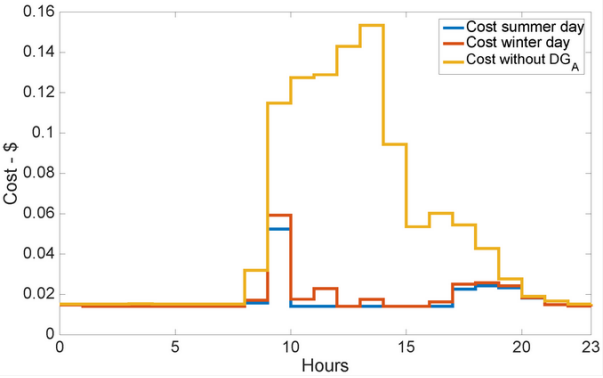

Fig.3. Energy cost of power with and without Distributed Generation (DG) on a summer day and a winter day

In a smart microgrid, the flows injected by the distributed energy resources (DER) and by the common connection point can be adapted to minimize the energy cost. Design and quality constraints usually cause the problem to grow rapidly with the number of network nodes. In this research, we provide a solution for the optimization problem, which significantly reduces the complexity according to the existing techniques.

In power systems, it is very important to produce optimal power and reduce the costs of operation and construction of power plants. In recent years, extensive studies have been conducted on optimization and cost reduction in power systems. In these systems, it was first assumed that in an interconnected power system, the active production power of all generators would be a constant value, but due to many operational problems, it was appropriate to produce and optimize this value with a coherent planning. How much active power each unit of the power system produces, as much as it takes the active power used by the system and the total cost of producing this power is reduced, is known as the issue of spreading an economy. By using economic load distribution, it is possible to calculate the amount of power plant production with the lowest cost by referring to mathematical relations. In power systems where mathematical calculations are not used for optimal power production, it was assumed that for the minimum energy production, the energy produced in times of low network load, from the most efficient power plant, consumes the required energy of the network, and with the increase of the network load . Power generation by this power plant continues until the efficiency of the power plant reaches.

According to the the economic and environmental issues and increasing the capacity of different parts of the power system, network development with traditional methods is not the answer. On the other hand, the current power system is not able to meet the load growth. Therefore, detailed economic and technical planning is needed in this field. In old programming, they often model one type of energy. Due to the possibility of replacing natural gas and electric energy and converting different energy carriers, there is a close connection between these two networks. In general, the integration and planning of the simultaneous development of electricity and gas distribution networks in terms of lower investment costs, more benefits for subscribers, facilitating market competition, guaranteeing energy security, reducing pollutants, market profits, etc, is of special importance.The purpose of optimal load distribution is actually the adjustment of all

types of controllable variables, such as the voltage of generators, tap transformers, parallel capacitors and inductors, and other control variables in such a way as to meet a set of physical and operational constraints, production costs and losses. are minimized and other objective functions are satisfied.

2- Modeling the network optimization problem

In this research, DC microgrid modeling has been done on the network with wind and solar productions with local voltage controllers on the buses of distributed productions. An economic load distribution problem is presented to minimize the operation costs in the DC microgrid in the presence of renewable sources with voltage controller in real pricing conditions, where the operation costs include the cost of distributed generation and grid electricity. Also, by considering load distribution equations, it is possible to calculate losses and consider it as one of the system costs.The optimization problem modeling includes two parts: cost modeling and network power equation modeling. The optimization variables used in this research are: input or output power of the storage system, power received or sent to the network, bus voltage. Economical load distribution determines the most efficient, low cost and reliable operation of a power system by the proper distribution of energy generation resources to supply the system load. The primary goal is to minimize the total cost of production by considering the limitations of production resources.

A. Cost modeling and network power equation modeling

The problem of economic load distribution determines the amount of load for power plants in order to reduce costs. Its formulation is also presented as an optimization problem to minimize the total fuel cost of the total power plants that supply loads and losses. The limitations of the load distribution problem are also divided into three general parts, network load distribution equations, voltage controller on buses, and voltage and power limits of sources. The equation that is the energy conservation principle in the problem of electricity planning and optimal load distribution is expressed according to the following relation:

$$P_{renewable} + P_{utility} + P_{ESS} - P_{load} - P_{loss} = 0 \quad (1)$$

According to the above ratio, the total power produced by all units in the circuit must be equal to the total consumption of the system. The amount of network losses is shown in (2):

$$P_{loss} = \frac{1}{2} \times \sum_i \sum_j Y_{ij(DC)} \left(V_{i(DC)} - V_{j(DC)}\right)^2 \quad (2)$$

The presence of local voltage controllers on the distributed production bus is one of the issues that will be addressed. The equation related to the voltage controller in distributed production buses, which is considered as a constraint, is expressed in (3):

$$C_{total} = C_{utility} + C_{ESS} + C_{loss} \quad (3)$$

$C_{utility}$is the cost of network electricity, which is calculated in (4):

$$C_{utility} = \begin{cases} \frac{\lambda_{buy} P_{utility}}{\Delta T} & P_{utility} \geq 0 \\ \frac{\lambda_{sell} P_{utility}}{\Delta T} & P_{utility} \leq 0 \end{cases} \quad (4)$$

In this formula, λ_{buy} is the electricity purchase price, $\lambda_{sell}$is the electricity sale price, and ΔT is the number of optimization periods in one hour. To model the cost related to losses in the system, it is related to equation (5). In fact, losses are made according to load distribution calculations, which will be examined more precisely.

$$C_{loss} = \frac{\lambda_{buy} P_{loss}}{\Delta T} \quad (5)$$

P_{loss} is the transmitted power loss.

B. System load limit

The voltage stability in the power system is affected by the distribution system, therefore, this is also included in the load capacity index of the system. The main influence of the distribution network on the voltage stability of the upstream network is determined by the transmission lines. For ease of calculations, the upstream network can be simulated by means of Tonnon's equivalent circuit. The basis for calculating this index is using the theorem of maximum power transmission.Therefore, the voltage stability boundary theorem occurs when z_L/z_0=1. At this moment, the maximum power is equal to:

$$S_{cr} = \frac{E_{th}^2}{2Z_0\sqrt{[1+cos(\phi_0 - \phi_{Leq})]}} \quad (6)$$

The index is defined:

$$VSM_s = \frac{S_{cr} - S_{Leq}}{S_{cr}} \quad (7)$$

The load limit of the system is the maximum load that can be placed on the system while the load distribution equations maintain their solvability. One of the characteristics of the load limit index is its ability to introduce the security margin of the system in the form of tangible physical quantities, and it can create a clear engineering understanding of the system's operating status for the user. This index can express the operating status of the system and its security margin in the form of an increaseable system load.According to these features, this index has been chosen as a selective index to evaluate the degree of security of power systems from the point of view of static voltage stability.

In Figure 4, a load characterized by impedance $Z_L < \varphi$is fed through a transmission line by a voltage source with amplitude V_s We know that parallel admittance can be ignored in distribution lines. Therefore, regardless of the parallel admittance of the transmission line, the passing current is equal to the load current, and considering the representation specified in the figure 8 can be written:

$$\frac{V_s - V_1}{R + jX} = \frac{P_1 - jQ_1}{V_L^*} \quad (8)$$

Where R and X represent the resistance and reactance of the transmission line and V_L

specifies the complex conjugate at the load node.We assume that the source voltage, V_s is the reference voltage, and we assume that its angle is zero. Also, we assume the angle of the load node to be zero, so from the above equation we will have (9)And then (10):

$$\frac{V_S\angle 0 - V_L\angle -\delta}{R+jX} = \frac{P_L - jQ_L}{V_L\angle\delta} \quad (9)$$

$$\frac{V_S V_L\angle\delta - V_L^2}{R+jX} = P_L - jQ_L \Rightarrow V_S V_L\angle\delta - V_L^2$$

$$= (P_L - jQ_L)(R + jX) \quad (10)$$

By separating the real and imaginary parts, we will have (11):

$$V_s \cos\delta = \frac{1}{V_L}(V_L^2 + RP_L + XQ_L)$$

$$V_s \sin\delta = \frac{1}{V_L}(XP_L - RQ_L) \quad (11)$$

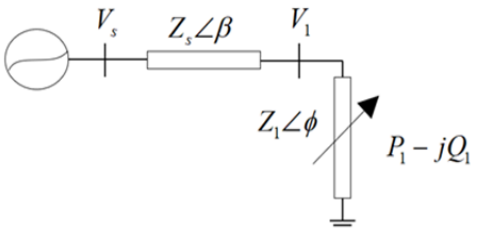

Fig.4. A system consisting of a single line

Using the above two relations:

$$(V_s \cos\delta)^2 + (V_s \sin\delta)^2 = V_s^2 \quad (12)$$

$$V_s^2 = \frac{1}{V_L^2}(V_L^2 + RP_L + XQ_L)^2 + \frac{1}{V_L^2}(XP_L - RQ_L)^2 \quad (13)$$

After simplifying the (13), the following final relations is obtained:

$$V_L^4 - [V_s^2 - 2(RP_L + XQ_L)]V_L^2 + (R^2 + X^2)(P_L^2 + Q_L^2) = 0 \quad (14)$$

The above relation has four possible solutions. Despite this, under the normal working conditions of the system (that is, within the voltage stability range), this equation has two acceptable solutions, that is, a solution that is real and positive.

C. PSO particle algorithm

Particle swarm optimization (PSO) is a population-based optimization technique inspired by the social behavior of birds, fish breeding, or insect swarms. It is a heuristic search algorithm used to find the optimal solution for a given problem. The algorithm starts by initializing a population of particles, where each particle represents a possible solution to the problem. Guided by its own experience and the experience of the crowd, each particle moves through the search space and tries to find the optimal solution.

The PSO algorithm is a heuristic search algorithm that repeatedly adjusts the position and velocity of a population of particles to find the optimal solution for a given problem. The algorithm is guided by the experience of each particle and the swarm as a whole. It is a popular optimization algorithm due to its simplicity, efficiency and effectiveness in solving a wide variety of problems.

The Particle Swarm Optimization (PSO) algorithm usually includes the following steps; Initialization,Assessment, Global best update, Speed and position updates andtermination.Steps 2 to 5 are repeated for a fixed number of iterations or until a stopping criterion is met.In each iteration, the velocity of a particle is updated based on the current velocity, personal best position, and global best position. A particle's position is updated based on its current position and updated velocity. The world best position is updated if a particle has a personal best position better than the current world best position.

The PSO algorithm seeks to optimize a fitness function by adjusting the position of particles in the swarm. By repeating these steps, PSO seeks to find the optimal solution in the problem domain.Suppose we have P particles and denote the position of each particle in each iteration t as X_i(t). In addition to the position, the velocity of each particle is also expressed by V_i(t) and in the general case for the next iteration, the position of each particle is updated as follows:

$$X_i(t+1) = X_i(t) + V_i(t+1) \quad (15)$$

or as:

$$x_i(t+1) = x_i(t) + v_x^i(t+1) \quad (16)$$

$$y_i(t+1) = y_i(t) + v_y^i(t+1) \quad (17)$$

The speeds are also updated simultaneously as follows:

$$V_i(t+1) = wV_i(t) + c_1 r_1\big(Pbest_i - x_i(t)\big) + c_2 r_2(gbest - X_i(t)) \quad (18)$$

where r_1 and $r_2$are random numbers between zero and one and constants w ,c_1 and$c_2$are the parameters of the particle algorithm. $Pbest_i$is the position with the best value ever extracted by all particles in the ensemble.

3- Optimization results

In this research, in order to test the proposed method, a DC microgrid including 38 buses has been used (Figure 5). Dispersed production sources are widely distributed on the level of microgrids. These sources include wind turbine, solar cell and energy storage system which is connected to bus number 17 and on the other hand, two fossil production sources are also connected to bus number 37 on the other side of the microgrid.

Various scenarios have been evaluated under optimization and stability and loss indicators have been compared. Information on load, impedance and admittance values of the lines is provided according to Tables 1 and 2.

A. The first study scenario

In this case, it is assumed that initially all production sources do not play a role in power exchange in the microgrid and are inactive in some way. In this case, the voltage profile before and after optimization will be as shown in Figure 5. This figure shows that if all production resources fail and do not contribute to the amount of power exchanged with the network, then after optimizing the economic costs, the amount of network losses and also the amount of voltage deviation compared to before the optimization It has dropped significantly, which shows the improper functioning of the

distribution system.Table 3 shows the values obtained before and after optimization for this mode.

B. The second study scenario

In this case, it is assumed that only the wind power plant is active in the network and other production sources have no role in generating network power. The analysis of optimal load distribution possibilities for the microgrid considering the total wind power has been evaluated. In the general conditions of the first study, to minimize the cost without taking into account the losses and taking into account the losses and simultaneously minimizing the cost and pollution without taking into account the losses and taking into account the losses, the cost of the wind generator is considered and the expression $cost_j$ in (19) is expressed:

$$Cos\,t_j = \sum_{j=1}^{n_g} C_j(P_{gi}) + C_{w\,in\,d} \qquad (19)$$

$$= \sum_{j=1}^{n_g} \left(a_j + b_j.P_{gj} + c_j P_{gj}^2\right) + C_{op.wind} * P_{wind}$$

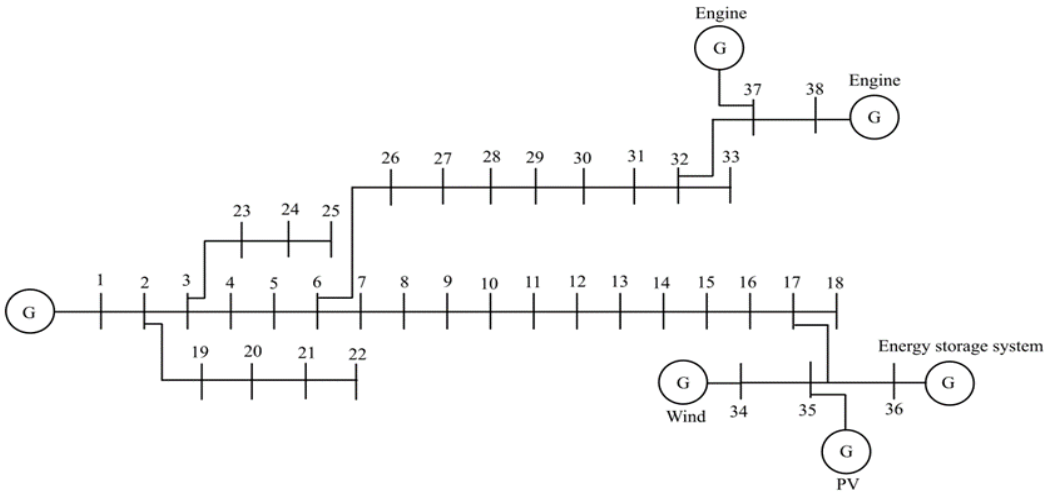

Fig.5. Single line diagram of the desired microgrid

Table 1. Load information

Load 2	P=100 Kw, Q=60 Kvar	Load 11	P=45 Kw, Q=30 Kvar	Load 20	P=90 Kw, Q=40 Kvar	Load 29	P=120 Kw, Q=70 Kvar
Load 3	P=90 Kw, Q=40 Kvar	Load 12	P=60 Kw, Q=35 Kvar	Load 21	P=90 Kw, Q=40 Kvar	Load 30	P=200 Kw, Q=600 Kvar
Load 4	P=120 Kw, Q=80 Kvar	Load 13	P=60 Kw, Q=35 Kvar	Load 22	P=90 Kw, Q=40 Kvar	Load 31	P=150 Kw, Q=70 Kvar
Load 5	P=60 Kw, Q=30 Kvar	Load 14	P=120 Kw, Q=80 Kvar	Load 23	P=90 Kw, Q=50 Kvar	Load 32	P=210 Kw, Q=100 Kvar
Load 6	P=60 Kw, Q=20 Kvar	Load 15	P=60 Kw, Q=10 Kvar	Load 24	P=420 Kw, Q=200 Kvar	Load 33	P=60 Kw, Q=40 Kvar
Load 7	P=200 Kw, Q=100 Kvar	Load 16	P=60 Kw, Q=20 Kvar	Load 25	P=420 Kw, Q=200 Kvar	Load 34	P=20 Kw, Q=5 Kvar
Load 8	P=200 Kw, Q=100 Kvar	Load 17	P=60 Kw, Q=20 Kvar	Load 26	P=60 Kw, Q=25 Kvar	Load 35	P=10 Kw, Q=10 Kvar
Load 9	P=60 Kw, Q=20 Kvar	Load 18	P=90 Kw, Q=40 Kvar	Load 27	P=60 Kw, Q=25 Kvar	Load 36	P=10 Kw, Q=20 Kvar
Load 10	P=60 Kw, Q=20 Kvar	Load 19	P=90 Kw, Q=40 Kvar	Load 28	P=60 Kw, Q=20 Kvar	Load 37	P=10 Kw, Q=5 Kvar

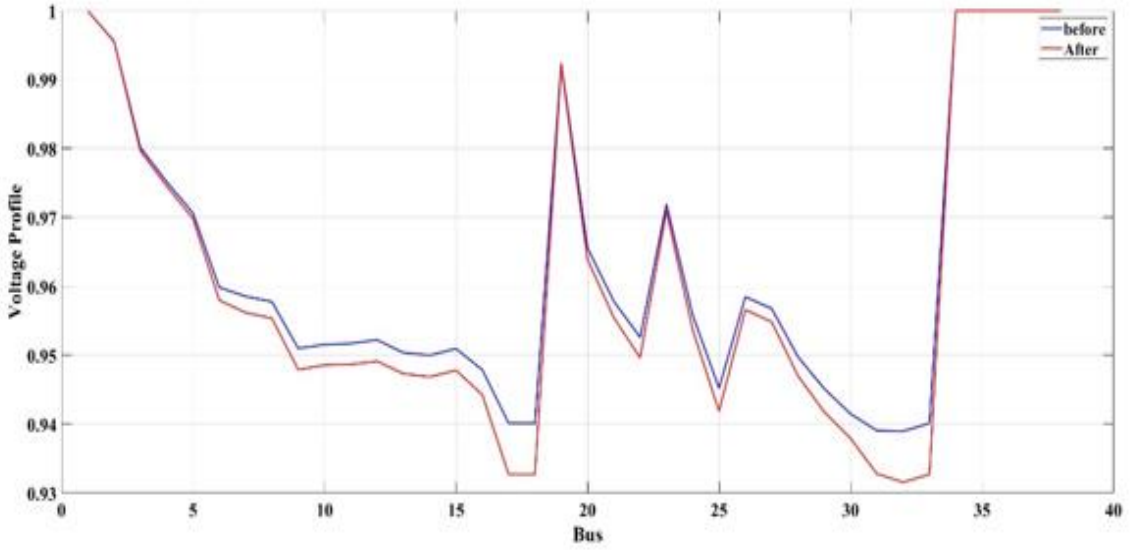

Fig.6. Voltage profile

Table 2. Comparison of evaluated indicators and parameters

	Before optimization	after optimization
Total operating cost ($/MWh)	462.9615	522.3834
total losses	42.9204	703.3529
voltage deviation	0.26111	0.3995

Where C_{wind} is the cost of the wind generator in ($/h), $C_{op.wind}$ isthe operating cost of the wind generator in ($/MWh) and p_wind is the power of the wind generator in (MW).Figure 7 shows the voltage profile before and after the optimization, which clearly states that after the optimization, the voltage profile of the buses has improved and also the amount of voltage deviations is acceptable compared to the previous state. It has gotten better. Figure 8 also shows the optimized amount of the objective function, which reached its minimum value in thirty iterations.Table 3 shows the comparison of evaluated indicators before and after optimization. According to the recorded values, the operating cost has been reduced to an acceptable level after optimization. The power loss has also decreased to a suitable extent; Also, the amount of voltage deviations after optimization has reached 0.1188.

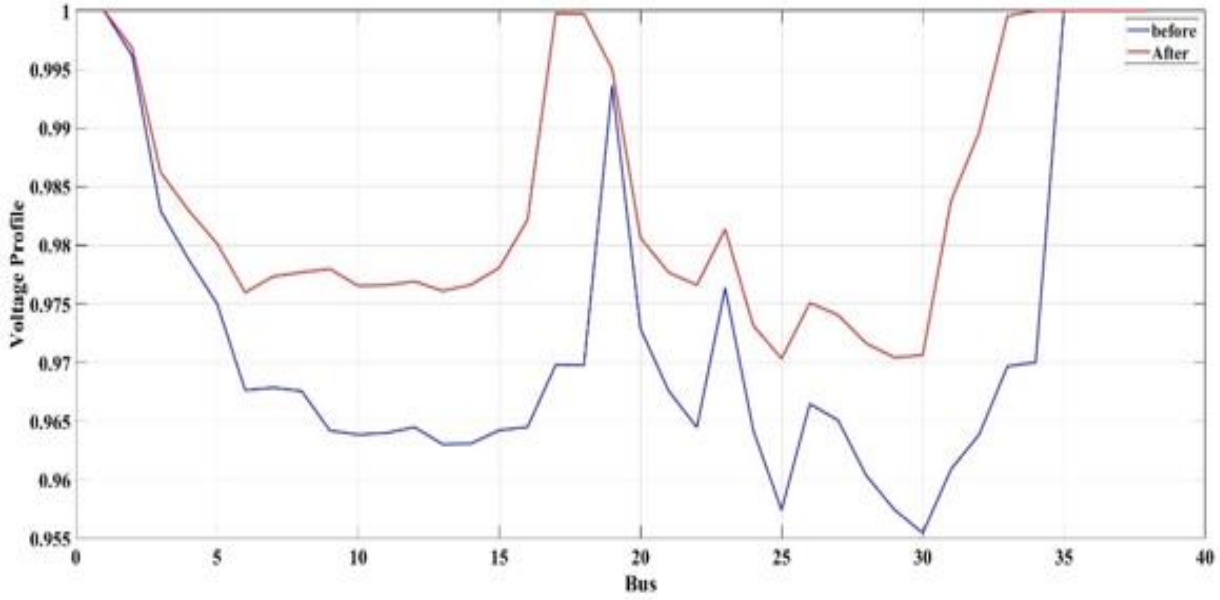

Fig.7. Voltage profile

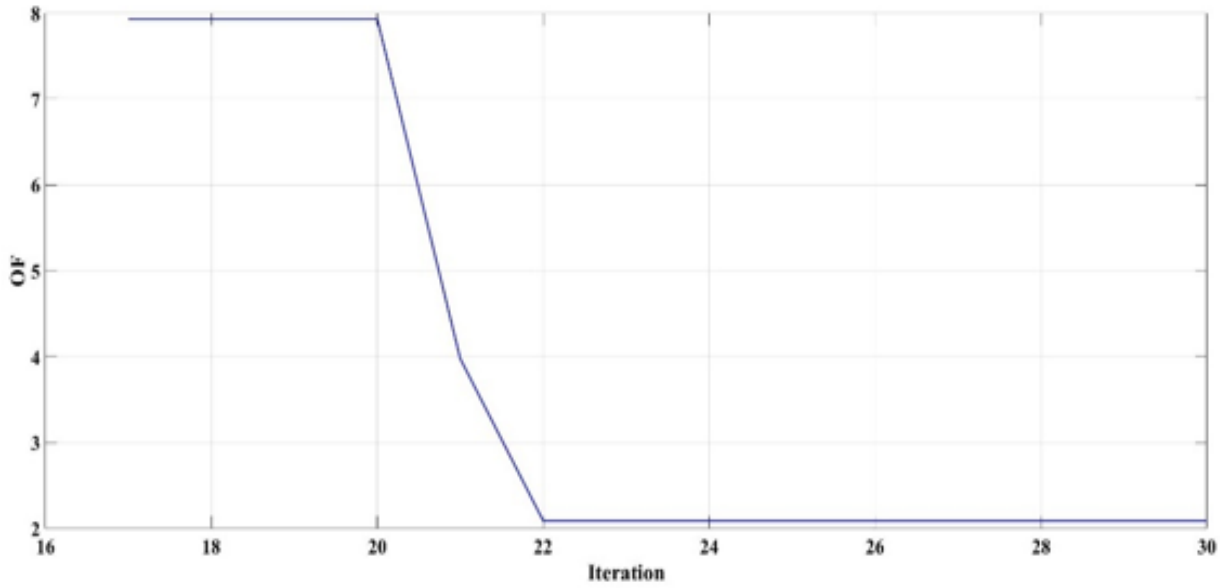

Fig.*8.* *Optimized objective function*

Table 3. Comparison of evaluated indicators and parameters

	Before optimization	after optimization
Total operating cost ($/MWh)	514.3656	438.7806
total losses	12.4132	3.2178
voltage deviation	0.1894	0.1188

C. The third study scenario

In this case, it is assumed that the wind and solar power plants are active in the microgrid and other production sources are still inactive. In this case, it is expected that the power losses and operating costs as well as the voltage deviation will improve after the optimization mode compared to before, which Figures 9 and 10 show this process well. Also Table 3 shows the evaluated indicators before and after optimization for this scenario.

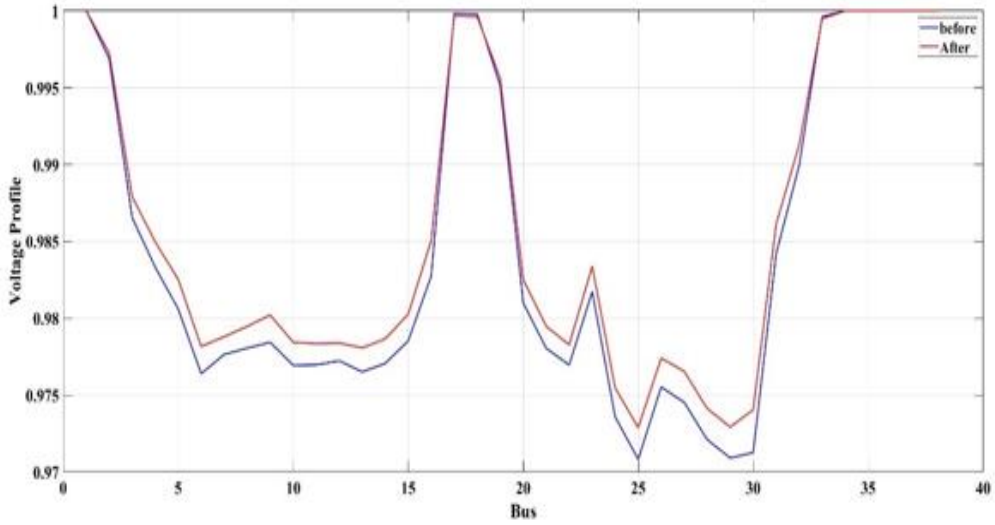

Fig.9. Voltage profile

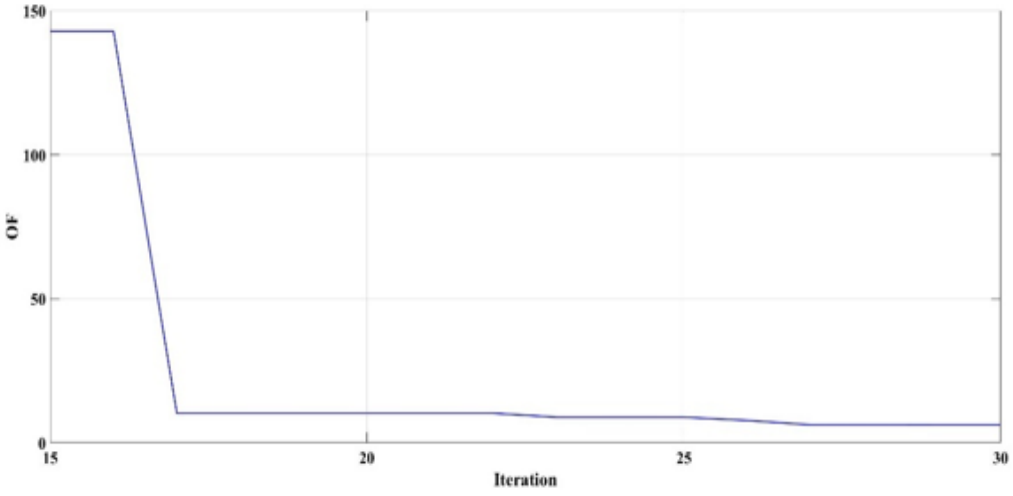

Fig.10. Optimized objective function

Table 4. Comparison of evaluated indicators and parameters

	Before optimization	after optimization
Total operating cost ($/MWh)	520.03	455.9418
total losses	0.1695	0.1543
voltage deviation	0.1166	0.1078

Conclusion

In today's modern systems, exploitation and optimization is essential. Microgrids are a small-scale example of centralized electrical systems and are used for various purposes such as minimizing losses, minimizing operating costs and voltage deviations, improving reliability and the possibility of using distributed generation units based on renewable energy sources. On the other hand, renewable energy sources such as wind power plants and photovoltaic systems due to their high efficiency, low cost of electricity production, easy access to these energy sources in most hours of the day and night, the ability to produce power on a large scale and ensure the quality of power production, more than any of the existing technologies for the exploitation of renewable energy sources have been expanded in the power system.

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Risk Assessment of Accidents in Chaharmahal and Bakhtiari Power Distribution Company using Tribod-Bets and AHP Method

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Abstract

Analyzing accidents in order to identify their causes is one of the most important stages of accidents. With the help of descriptive-analytical analysis, this research deals with the evaluation, analysis and analysis of recurring incidents in the electricity distribution company of Chaharmahal and Bakhtiari province using Tribod-Beta and AHP methods. Considering the most important factor of human error, the Tribod-Beta method is one of the best methods in the analysis of incidents in electricity distribution companies. It has been drawn, to know the causes and problems related to the change, we will review the correction to prevent the occurrence of similar incidents. Considering the importance of the issue and confirming the non-interference of personal taste in the analysis of accidents, we weight the results using the AHP method. According to the obtained results, it can be said that non-observance of safety principles with 50% frequency and with the highest standard weight (0.5 and 0.1958) is one of the most risky causes of accidents in four frequent accidents.

Keywords: Incident analysis , Rooting of incidents , Tribod-Beta and AHP methods

1.Introduction

Today, the electricity industry is one of the vital infrastructures of other industries and plays an important role in the industrial and economic development of developing countries due to the gross domestic product. Every year, various incidents occur with the expansion and development of this industry, which cause serious damage to human resources, which are the most important and influential pillar in advancing the goals of the electricity industry. [1,2] According to the Occupational Safety and Health Administration (OSHA) report, 86% of casualties are in the electricity generation, transmission and distribution sector, which leads to the loss of 12,976 working days per year. Also, OSHA and NIOSH institutes, by examining 244 major accidents, have reached the following five scenarios that led to the accident:

28% of direct contact of employees with power lines, 21% of direct contact of employees with electric network equipment, 18% of contact with the electric network, 17% of worn out or damaged equipment of the electric network and 16% of conductive equipment contact with electric lines [3,4].

The word "accident" is defined as an unforeseen event that interrupts the performance of an activity and may be associated with injury or financial damage. The basis of incident control is the creation of appropriate control and defense systems in such a way as to prevent the intersection and interaction of the risk factor and the target factor. Investigating the root causes can help a lot to solve safety problems in the organization and have a significant effect on reducing accidents. Among these reasons, we can point out errors in the design, defects in the policy and poor training. The use of incident analysis techniques in a radical and structured way such as tripod beta technique

in the organization can provide important results such as reducing costs, reducing damages and most importantly, working in a safe environment, all of which These results will lead to increased productivity. In addition, the use of these techniques in the topic of modern risk management can be very useful in identifying risk in a reactive manner. Considering the importance of personal non-interference in risk assessment decision-making, AHP method can be used.

In the health and safety system, the most important part is the identification and assessment of risk caused by danger (accident). Risk assessment is the process of identifying, analyzing and evaluating potential risks related to a specific activity or situation. This process consists of three main parts: risk identification, risk estimation and risk assessment [5,6,7,8]. For risk assessment, he pointed out different methods, including: job safety analysis (JSA), process hazard analysis (HAZOP), broken state analysis and its effects (FMEA). With the increase and complexity of incidents, risk assessment techniques are progressing and updating [9,10]. In this regard, due to the number of accidents in electricity distribution companies, we must look for methods for risk assessment that are flexible and correctly address the role of human factors as one of the causes of accidents.Studies have been conducted in the world on the risk assessment of accidents that occurred in electricity distribution companies, which can be cited as follows:

In 2023, Mohsen Sadeghi Yazdi and his colleagues have conducted a study on the safety risk index in the electricity distribution industry. This process was carried out using the fuzzy hierarchical method (FAHP) on three individual, environmental and organizational components with the participation of 30 experts. In this study, the personal component (PC) with a weighted average of 0.537 and the Cronbach's Alpha coefficient for each of the individual, environmental and organizational components were calculated as 0.90, 0.85 and 0.82%. [11]

In 2021, a study was conducted on the analysis of incidents that occurred in Tehran Electricity Distribution Company, and the data from 2010 to 2017 was collected from the database of the safety department. The results show that 75% of the accidents occurred in the summer due to the heat of the air and insufficient skills of the employees [12].

In 2022, Moin Kayani and his colleagues investigated the safety climate and its structural dimensions in an electricity distribution company. The questionnaire contains 43 questions in 11 dimensions, which have been analyzed using spss software. The results show that among the safety climate factors, the highest score was related to safety training (87.3 percent) and the lowest score was related to work pressure (80.2 percent) [13].

In 2019, Adel Mazloumi and colleagues have conducted a study on the evaluation of human errors in the operation of electrical installations of the Greater Tehran Power Distribution Company. Using the analysis of SHERPA worksheets, researchers have analyzed 3399 errors, of which 39.57% were functional errors, 32.04% were review errors, 7.32% were retrieval errors, 19.67% were communication errors, and 1.80% were selection errors. [14]

In 2021, a study was conducted on the identification of hazards and risk assessment in the electricity distribution company of Yazd province. Researchers evaluated 198 risks using HAZIDSTUDY and FMEA methods, and the result of this research was that 5.05% of risks were in the intolerable range, 24.95% of the risks were in the moderate range, and 70% of the risks were in the tolerable range [15].

2. Analysis method

This research is descriptive-analytical. In this research, we analyze four frequent incidents that occurred from 2012 to 2023 in the electricity distribution company of Chaharmahal and Bakhtari province. In this research, we use the Tribod Beta and AHP method due to considering the direct causes, indirect causes, obvious causes and hidden causes of the accident. In the Tribod-Beta method, we use the investigator software to draw the event tree and use the AHP method to weight the criteria and sub-criteria.

2.1. Tribot - Beta evaluation method

Today, the use of hazard identification and risk assessment methods is expanding in various industries, so that currently there are more than 70 different qualitative and quantitative risk assessment methods and techniques in the world. These methods and techniques are usually used to identify, control and Reducing the consequences of risks is used. Most of the existing methods of risk assessment are suitable methods for assessing risks and their results can be used for management and decision making regarding the control and reduction of its consequences without worry, each industry can use this method depending on its needs. have different advantages and disadvantages compared to each other. Therefore, one of the duties of the existing health and safety management system in every industry (HSE) is to check all the methods of assessing risks and dangers and choosing the appropriate method for implementation in the respective industry and organization. In general, it can be said that from the type of method used in risk assessment and the depth of its assessment, the ability of the existing safety system can be understood to some extent, and as a result, the safety management method in the mentioned industry [6,7] Therefore, due to the high sensitivity of safety in the electricity industry and considering the unfortunate consequences, the need for continuous monitoring of reinforcement, evaluation and elimination of hazards in the field is felt. Therefore, after studying and reviewing the existing methods and techniques, the Tripod-Beta method in terms of cost, execution time, simplicity, ease of showing the relationship between human errors, training, implementation and implementation without the need for software, graphical description of the event and analysis Incidents have been selected from two aspects of control and defense in the electricity industry. The theory of this method is based on the Swiss cheese model, and due to its methodology and standard tables, it is widely used and cited in various organizations and industries. It provides relatively comprehensively. By using this method, it is possible to identify the superficial causes, preconditions, and hidden causes that caused the occurrence of unsafe behavior and conditions, determine the path of the accident, and identify the defects in the control and defense systems that are caused by failure to act. He stated that they caused the accident in time [16,17,18]. The basis of this analysis is based on three pillars, Hazard, Target, and Event. Tribod - Beta tree is as follows:

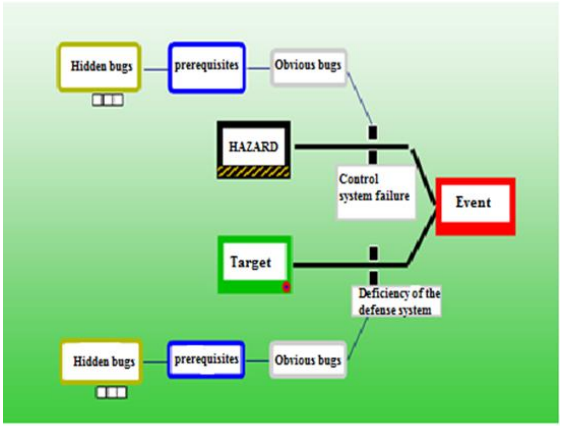

Fig.1. Tree of this incident by Tribod- Beta method

The method of analyzing incidents based on the Tripod Beta model

1. Draw the tree and determine the risk, goal and event
2. Specifying protection systems (control and defense)
3. Determining surface defects (unsafe practices or unsafe conditions)
4. Using checklists to determine preconditions and hidden problems 5. Determining the list of preconditions and hidden problems effective in the occurrence of an accident based on the checklist and entering them in the relevant table to manage hidden problems.

- Tribod-Beta chart symbols:

- **EVENT**

An event is a change of state that results from the interaction of a hazard on a target. Important events in electricity distribution companies can be mentioned as: transformer explosion, medium pressure electrocution, falling from the power base. [19].

- **HAZARD**

It's either a source of energy, matter, or the potential to be harmed, or damag. Like heat, electricity, flammable chemicals, height [20]

- **TARGET**

It is the subject or case that the risk has affected and probably caused damage to it, and it includes four groups as follows:

A- People (injury or damage to the health ofpersonnel or third parties)

B- Equipment/capital (damage to unit or equipment, loss of materials, interruption or stoppage of operations, damage to third party capital)

C- Environment (damage and pollution in the environment)

D- Validity(mass media controversy, public attention, protest, prosecution, commercial restrictions, regulations) [21]

The method of analyzing incidents based on the Tripod Beta model

1. Draw the tree and determine the risk, goal and event
2. Specifying protection systems (control and defense)
3. Determining surface defects (unsafe practices or unsafe

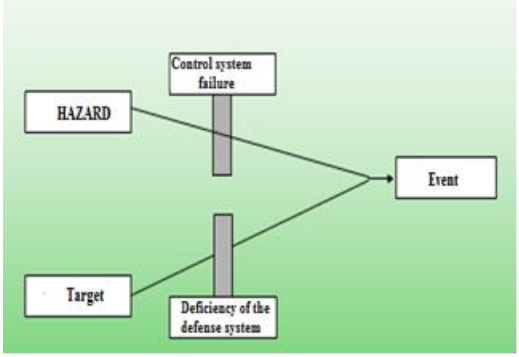

Fig.2. Events management diagram

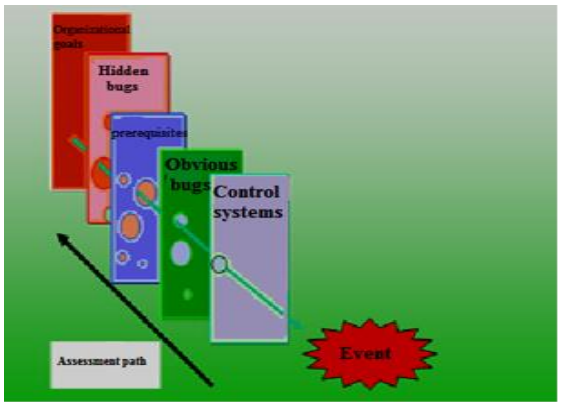

Fig.3. Path of finding the cause by the Tripod -Beta method

2.2. ANALYTICAL HIERARCHY PROCESS (AHP)

Hierarchical analysis process is one of the decision making methods. AHP stands for Analytical Hierarchy Process. This method is one of the most widely used methods for ranking and determining the importance of factors, which is used to prioritize each of the criteria with paired comparisons of options, which is called weighting the criteria [22,23].

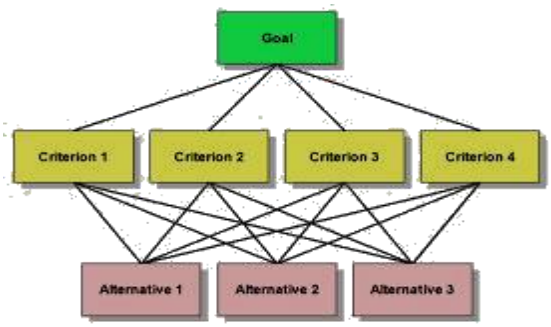

Fig.4. Hierarchical Process (AHP)

The first step of the AHP process is the selection of criteria and in the next steps , alternatives are evaluated based on the identified criteria. In this method, all factors and criteria are compared two by two and placed in the weighting matrix. The comparison scale is placed in the range of 1 to 9, as described in the following table [24]:

Table 1. comparison numbers of factors two by two

Description	Severity Of importance
Maximum superiority value	9
Superiority value is maximum to high	8
The value of excellence is very high	7
High to very high superiority value	6
High superiority value	5
Moderate to high superiority value	4
Average excellence value	3
Same to medium excellence value	2
Equal excellence value	1

To perform the hierarchical analytical process, we act as follows:

First step: We create a hierarchical structure with a goal at the top level, criteria at the second level and options at the third level.

second step: according to the relative importance of each criterion, a pairwise comparison matrix is formed and finally, the normal matrix is calculated.

Third step: In this step, according to the values of the normal matrix and the number of criteria, we calculate the weight of the criteria as follows

$$Criteria\ Weight = \frac{Iements\ In\ each\ row\ of\ the\ sum\ normal\ matrix}{RINumber\ of\ criteria} \quad (1)$$

Fourth step: Using the pairwise comparison matrix and the criteria weight of each element, we calculate the compatibility rate. Then, by summing all elements of compatibility rate, we get the weighted sum.

Fifth step: In this step, according to the weighted sum values and the weight of the criteria, we will calculate the compatibility vector as follows.

$$\text{Compatibility vector} = \frac{Weighted\ total\ values}{criteria\ weighted} \quad (2)$$

Sixth step: In this step, we calculate the largest eigenvalue of the matrix of pairwise comparisons (λmax) by dividing the sum of the compatibility vector by the number of criteria.

$$\lambda max = \frac{Compatibility\ Vector\ Sum}{Number\ of\ criteria} \quad (3)$$

Seventh step: In this step, we calculate the incompatibility index as follows:

$$CI = \frac{\lambda max - n}{n-1} \quad (4)$$

Eighth step: By dividing the value of the inconsistency index by the random index, we calculate the inconsistency ration[11].

$$CR = \frac{CI}{RI} \quad (5)$$

Random index or RI is a fixed value and its value depends on the number of criteria. The table of its values is as follows:

Table 2. Randomness index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Note that the value of the inconsistency rate must be greater than 0.1, in this case the determined criteria are logically compatible.[24,25]

The flowchart of the Analytical Hierarchy Process (AHP) is as follows:

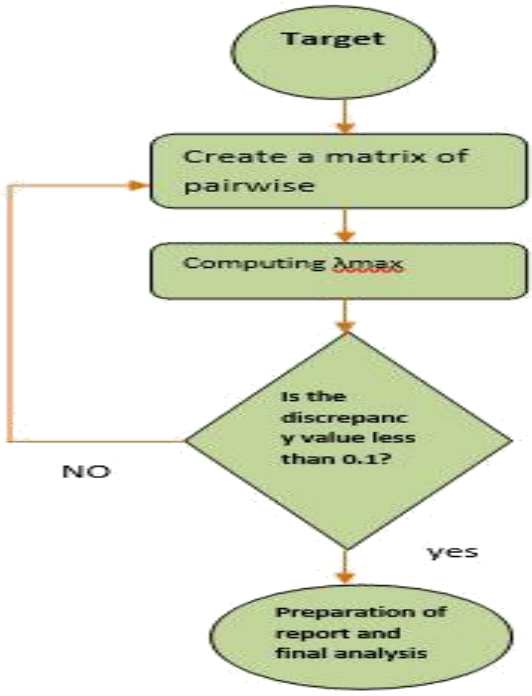

Fig.5. AHP process flowchart

3. Results

According to the table below, we evaluate the risk of four incidents that occurred in the power distribution company of Chaharmahal and Bakhtiari province using the Tribod-Beta and AHP methods.

Table3. Frequent events

Sickness period / death	Corrective actions	Consequences	cause of the accident
sick days 20	Enclosing the work environment - using a helmet	Breaking the person's head and neck	Falling objects on a person
death of the person	Covering the power grid - complying with the legal distance between the lifting boom and the power grid	Passing electric current through a person's hand and heart	Low pressure electrocution
death of the person	Harnessing the electric pole with a crane-repairing the pit of the electric pole base	The base falls on the person	Falling with a concrete base
45 sick days	Disconnecting the public electricity distribution and measurement board - using medium pressure gloves (class 01)	Creating a severe arch and burning the face	Entering the area of the electrical panel

- Description of the incident on 2019/10/08

After going to work, the person was injured in the head and neck area. While carrying out the modification and optimization of the electricity distribution network, without safety equipment, the mentioned person entered the area of the operation of Simban forces and by releasing the aluminum wire from the insulator, he caused injury to the head and neck of the mentioned person. The Tribod-Beta diagram of this incident is as follows.

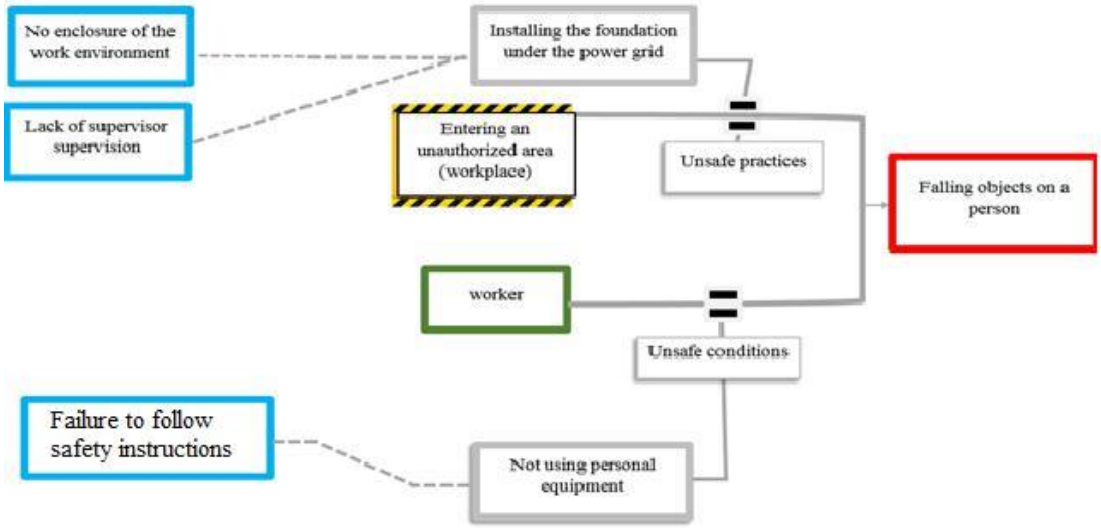

Fig.6. Tripod-beta accident diagram2019/10/08

- Description of the incident on 2021/12/05:

The mentioned person was sent to the workplace with a lift truck to repair the network and replace the lamp. Unfortunately, while working on the network, the mentioned person did not observe the legal distance between the boom and the power grid, and also his colleague, who was responsible for guiding the boom on the ground, negligently did not notice what happened and caused a severe electric shock. It led to the death of the mentioned person. The tribod-beta diagram is as above.

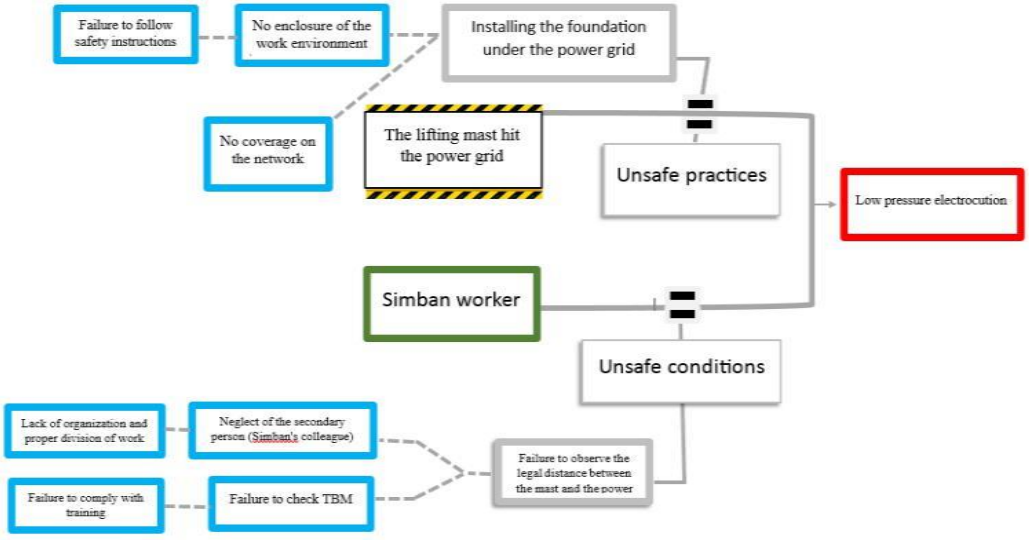

Fig.7. Tripod- beta accident diagram2021/12/05

The Simban force was sent to the work place along with their colleagues to move the electricity distribution network. The mentioned person has climbed the pole without considering the principles of work safety to remove the power grid. Due to the excavation of the place where the pole was installed by the highway department, the pole in question lost its strength and when the mentioned person climbed, the pole came out of the hole and caused the person to fall and die.

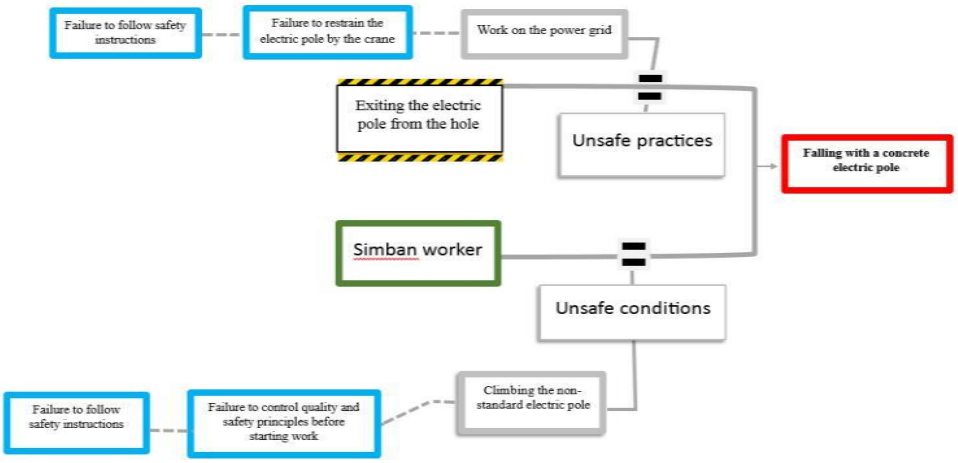

Fig.8. Tripod- beta accident 2022/07/12

- Description of the incident 2023/02/19:

The lighting force is sent to the place to improve the lighting network of the city. Without paying attention to the principles of safety and not using personal safety equipment, the said person cut off the fuse switch inside the lighting panel, and while his hand hit the electric ingots of the panel, he encountered a severe arc of the panel, which unfortunately caused electrocution and burns to his hand. And he was sent to the hospital with the coordination of the emergency center.

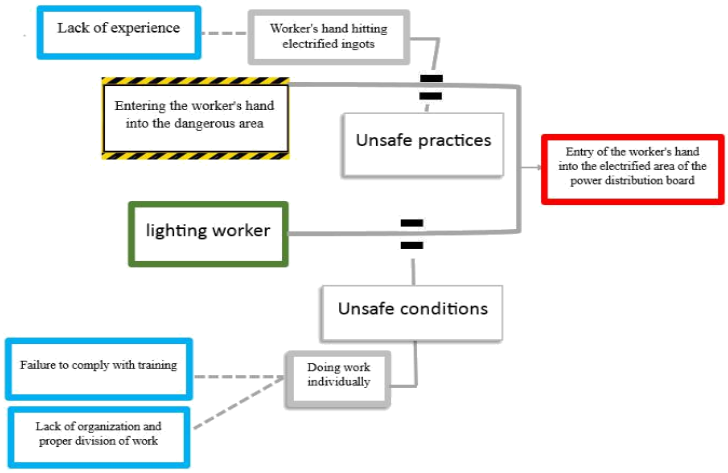

Fig.9 Tripod- beta accident 2023/02/19

According to the trees of the above accidents, non-observance of safety instructions with a frequency of 50% is the most common cause of accidents in the category of unsafe conditions, and in the category of unsafe practices, all three options have caused accidents with the same frequency.

Table 4. The frequency of incidents

The root causes of accidents in unsafe conditions	grace Frequency	The root causes of accidents in unsafe practices	Grace Frequency
Failure to follow safety instructions	%50	Failure to comply with training	%66.6
No enclosure of the work environment	%25	Lack of organization and proper division of work	%66.6
Lack of supervisor supervision	%25	Non-observance of personal safety principles	%66.6
Lack of experience	%25	-	-

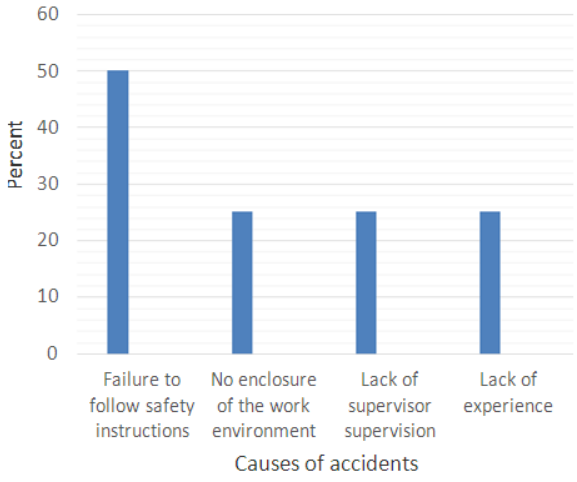

Fig.10. Diagram of causes of accidents in unsafe conditions

Fig.11. Diagram of causes of accidents in unsafe practices

Considering the importance of the subject and the absence of personal tastes in the analysis of accidents, we use the AHP method to analyze the causes of accidents and by giving weight to each of the defined criteria, we choose the main cause. To analyze an AHP method, we do the following:

In the first step, by defining a high-level goal, we specify criteria and sub-criteria to form a hierarchical structure. Hierarchical structure with the aim of analyzing the cause of the accident in the electricity distribution company of Chaharmahal and Bakhtiari province is as follows:

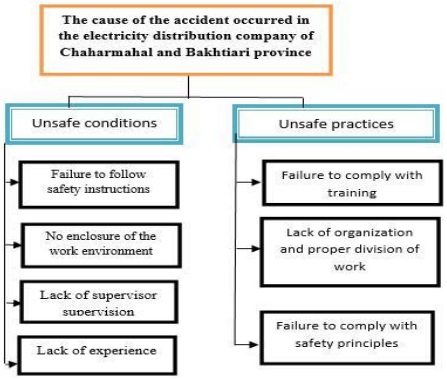

Fig.12. Hierarchical structure

In the second step, we form a pairwise comparison matrix for the criteria and sub-criteria of unsafe actions:

Table 5. Pairwise comparison matrix in unsafe practices

Failure to comply with training	Lack of Organization and proper division of work	Failure to comply with safety principles	
1.8	2.25	1	Failure to comply with safety principles
0.8	1	0.44	Lack of organization and proper division of work
1	1.25	0.55	Failure to comply with training

In the third step, we will calculate the criterion weight and compatibility rate as follows:

Table 6. Criterion weight matrix and compatibility vector in unsafe practices

Compatibility vector	Weighted Criteria	
2.96	0.5	Failure to comply with safety principles
3.11	0.22	Lack of organization and proper division of work
3.037	0.27	Failure to comply with training

$$\lambda max = \frac{2.96+3.11+3.037}{3} = 3.03$$

$$CI = \frac{3.036-3}{2} = 0.018$$

$$CR = \frac{0.018}{0.58} = 0.031$$

According to the criterion weight obtained, it can be said that non-compliance with safety principles with a criterion weight of 0.5 is the first priority, non-compliance with training with a criterion weight of 0.27 is the second priority, lack of organization and proper division of work with a criterion weight of 0.22 is the last priority. have dedicated themselves. Also, according to the obtained compatibility rate (CR=0.03<0.1), it can be said that the selected criteria are logically compatible. The fourth step: We form a pairwise comparison matrix for the criteria and sub-criteria of unsafe conditions as follows:

Table 7. Pairwise comparison matrix in unsafe conditions

Lack of experience	Failure to follow safety instructions	Lack of supervisor supervision	No enclosure of the work environment	
0.5000	0.6861	0.6002	0.6289	No enclosure of the work environment
0.2143	0.0858	0.1200	0.1251	Lack of supervisor supervision
0.2143	0.1715	0.2401	0.1572	Failure to follow safety instructions
0.0714	0.0572	0.0400	0.0898	Lack of experience

In the fifth step, we will calculate the criterion weight and compatibility rate as follows:

Table 8. Criterion weight matrix and compatibility vector in unsafe conditions

Weighted Criteria	Compatibility vector	
0.603	4.1762	No enclosure of the work environment
0.1365	4.0225	Lack of supervisor supervision
0.1958	4.1553	Failure to follow safety instructions
0.0646	4.0488	Lack of experience

$$\lambda max = \frac{4.176+4.0225+4.1553+4.0488}{4} = 4.1007$$

$$CI = \frac{4.1007-4}{2} = 0.03355$$

$$CR = \frac{0.03355}{0.90} = 0.0372$$

According to the above calculations, failure to comply with safety instructions with a criterion weight of 0.1958 in the first priority, lack of supervisor supervision with a criterion weight of 0.1365 in the second priority, lack of enclosure of the work environment with a criterion weight of 0.603 in the third priority and lack of sufficient experience with a criterion weight of 0.0464 in the last priority has assigned Also, according to the obtained compatibility rate (CR=0.0372<0.1), it can be said that the selected criteria are logically compatible.

Offers in order to prevent the repetition of the mentioned incidents, we suggest corrective measures for each of the incidents as follows:

A. Corrective measures for the incident dated 2019/10/08

- Enclosing the work environment
- Passing and browsing in the safe area
- Checking personal safety equipment
- Employing a health and safety expert during work
- Using a lift to replace electric wires

B. Corrective measures for the incident dated 2021/12/05

- Covering the low voltage power grid
- Doing work in groups
- Employing a lift operator
- Using personal equipment, especially class 01 gloves
- Shutting down the low pressure network for repairs
- Use of earth in weak pressure network

C. Corrective measures for the incident dated 2022/07/12

- Filling the TBM form before work
- Testing the strength of the electric pole before climbing
- Controlling the electric pole by the crane while climbing

-Using a lifting device to remove the electricity distribution network

D. Corrective measures for the incident dated 2023/02/19

- Separate the lighting board from the power distribution board
- Use of safety equipment (face shield - class 01 gloves)
- Doing work in groups
- Using the automatic switch in the lighting panel
- Using covered ingots

- Disconnecting the feeders with the cardi fuse key
- Fulfilling the requirements of the TBM form

4. Conclusion

In this research, the risk assessment of four frequent accidents in the electricity distribution company of Chaharmahal and Bakhtiari province was done using the Tribod Beta-AHP method. The obtained frequency percentage can be said that non-observance of safety principles with 50% frequency is the highest risk. Also, by giving weight to each of these causes, we came to the conclusion that non-compliance with safety principles has the highest criterion weight. In the end, by using the suggested solutions, we have prevented the recurrence of these incidents.

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The Impact of Artificial Intelligence on Project Management (a case Study of Human Resource Management)

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Abstract

It could be easily understood that most project managers have had problems in human resource management and in supplying physical resources. These managers have mostly dealt with artificial intelligence technologies and have considered it to be useful and utilized it in their daily activities. But when it is time to make vital decisions in projects, the project managers rely on the precision of their learning and their outlooks regarding the selection of the decisions. The introduction of artificial intelligence in professional and academic world of project management and the proposal of several resolutions based on using software could foster different tasks which were previously very time consuming and costly such as communication, supervision processes, data collection, data analysis, and many other variables. Furthermore, the exploitation of artificial intelligence technology in human resource management has had many challenges and advantages. The present study has tried to recognize the advantages of using artificial intelligence in human resource management. Artificial intelligence could easily be applied in all human resource processes. Currently, it is mostly used in recruitment processes, resume assessment, chatbots, and interviews. Many mega-corporations such as Microsoft, Google, and Uniliver have been using this technology in their companies during some recent years in order to apply and develop it.

Keywords: artificial intelligence, human resource management, advantages, managers

1. Introduction:

Using artificial intelligence in human resource management may be called the most astonishing event among recruitment scholars in the year 2018. The selection of artificial intelligence in human resource management can be called “a new era in human resources” in a way that artificial intelligence alters the usual and daily tasks carried out by human beings to change the recruitment business. Artificial intelligence can help us in enhancement of human resource processes such as recruitment, services compensation, training, and developing the staff, decision making prediction, staff’s exit prediction, and many others in an organization. The enhancement of human resource management efficiency through the use of artificial intelligence has been changed into an important process in developing the future human resource management trends (Jia and et al., 2018).

Some of the capabilities of artificial intelligence for human resource management are as follows:

1) Automated performance of repeated tasks and saving time and the appropriation of time for more strategic works
2) Video analysis of the applicants and recognition of their face states, stress, topic awareness, body language, and effective communication capability through deep

learning techniques and finally the selection of the best applicants for recruitment

3) Designing a supportive smart decision making system, using neural network techniques to create a just system for the assessment of wages and salary (Jia and et al., 2018).

Therefore, regarding the importance, utilization trend, and the development of artificial intelligence inhuman resource management in many organizations and the international companies, we have tried through the present research to review the documentations and utilize digital human resource management to investigate about advantages of using artificial intelligence in different processes of human resources using data based human resources, advantages and tools in artificial intelligence in human resources. The results of the present study can help us in recognizing the outstanding advantages of utilizing this technology in Iranian organizations and companies.

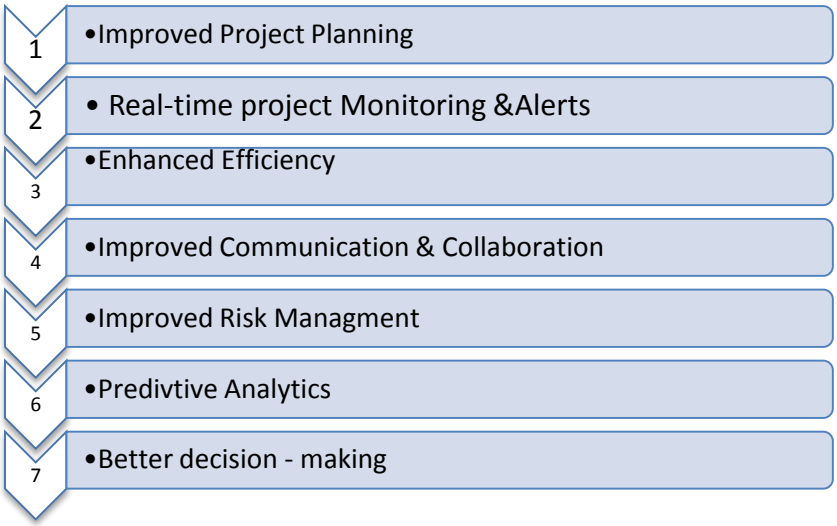

Fig.1. Benefits of Artificial Intelligence in Project mangement

In this study we have dealt with a complete review of the application of artificial intelligence in recruitment, training, services compensation, future staff behavior prediction, talent management, and performance assessment.

2. Human resource management in team management using artificial intelligence:

To guarantee high throughput and output for each work team, the project manager should make sure that the appropriate training and merit development have been guaranteed for project team. This can be achieved through preparing online classes, couching sessions or instructions, or even in service training (Project Management Institute, 2017).

Communication is another important factor that should be included in team management because it lets the project manager to follow team development, to present in time and outstanding feedback, and also he can make sure that the team members get all required emotional and technical supports and cultivate their sacrifice (Project Management Institute, 2017). The inclusion of team members in decision making sessions and during team making activities can enhance relationships.

Fig.2. Systematization of artificial intelligence and project management

The creation of appropriate work environment to increase the satisfaction and performance of the staff and applying the required changes in the team are highly important in projects. The project managers can present the challenges and opportunities, feedback and in time support when required, and recognize and reward for good performance (Project Management Institute, 2017).

The study carried out by Thamhain (2004) showed that the appropriation of challenging professional tasks and the presentation of proper support for project teams increase their commitment and reduces communication obstacles and fight dangers and enhance the overall project team performance. Also the project manager should assess the development and quality of the works during team management because it provides an understanding of the weak points and strengths of a team or a member of a certain team.

3. Research Method:

The present study is a documentary review of the research carried out in the field regarding the advantages of using artificial intelligence in human resource printed in international journals. Based on the major goal in the present research which deals with the identification of the advantages of artificial intelligence in human resource management, the studies carried out since 2017 and included in different databases were investigated (Wiley, Sage, Science Web, Google scholar, digital human resource (HR), Artificial Intelligence (AI) and human resource (HR)).

4. Findings:

Artificial intelligence exists everywhere. It includes smart and driverless vehicles to communication bots that talk with customers without the customers being informed that they are not talking with a human being (Gicopolos, 2019). Tom Stechora, the vice for talent recognition and individuals' analysis in IBM Company has explained artificial intelligence as: "it is a facilitator that helps us to present appropriate talent in time and achieve personality" (Gonul and Ginzig, 2018). From among the subcategories of artificial intelligence we can refer to machine learning, deep learning, natural language processing, and neural networks each of which can help us in some of human resource processes. According to the studies carried out in the field, 76 percent of organizations believe that artificial intelligence

has had a considerable effect on workforce absorption and this has resulted in artificial intelligence being considered as a necessary tool in human resource (Permanat and Choly, 2020). The use of artificial intelligence in human resource is different from what is done in reality. This technology helps human beings to understand staff instead of controlling them. This technology can lead to higher yields and greater satisfaction of the staff and reduces their job leave (Gicopolos, 2019).

4.1. Absorption of talented staff

Increasing yield and carrying out activities rapidly and with high quality are among the major advantages of artificial intelligence in human resource (Hug, 2019). Some other advantages of using artificial intelligence in human resource management include: increasing job commitment of the staff, reduction of bias in decision makings, staff exit rate prediction, the achievement of precise results in works (Yawalkar, 2019). Through the use of technologies based on artificial intelligence we can collect data required very fast and adjust ourselves with the organization's requirements and propose appropriate suggestions based on the data (Jiang and et al., 2019). Artificial intelligence presents two outputs for the organization: the decisions and the solutions based on the rich data received (Wan Crug, 2018). It should be noted that artificial intelligence would present its highest capability when ethical and humane issues are observed and supervised. Still human beings make the final decisions (Gulliford and Dickson, 2019).

In table 1, some of the advantages of artificial intelligence in human resource management have been presented:

Table 1: Advantages of artificial intelligence in human resource management (Oracle Company, 2019)

Resource finding	- Finding the best recruitment applicants using machine learning algorithms and the adjustment of conditions for the job and the applicant - Suggestion of the best jobs to applicants looking for a job - Prediction of applicant's performance based on the data
Screening and interview	- The applicants are able to change the interview time and get interviewed in an appropriate time. Also they are able to share information, writings and whatever they need. - It helps managers to avoid forgetting the interview time and have access to the applicants' data. Also it helps them adjust their questions based on the data related to the previous applicants.
Selection	- It helps managers to compare the job applicants with those who are currently working in the organization and to make the best decision. Artificial intelligence does not make the final decision. - Artificial intelligence techniques help managers to predict the probability of acceptance, rejection, and ongoing job opportunities by the job applicants.
Acquaintance and skill achievement	- Deletion of manual human resource processes such receipt of documents, presentation of information and organizational policies and the data gained from the documents investigated. - The digital assistant for a newly employed individual in the form of a 24 hour assistant - The supply and presentation of required training to an individual to increase yield

4.2. Artificial intelligence in recruitment:

The recruitment process has encountered lots of changes throughout the history. Until 1990s, the traditional recruitment methods were used in organizations which required spending lots of time and money. In this era the organizations broadcasted in newspapers to absorb personnel or tried to absorb work forces through the friends of organizations' staff. From mid 1990s on the process of recruitment took another form which is literally called digital recruitment. The digital recruitment has gone through two stages up to now and is located in third stage as follows:

Digital recruitment 1: This stage was started in mid 1990s along with the use of internet. In this period, organizations used websites such as Monster to broadcast recruitment advertisements to absorb new staff. These ads in websites had some advantages both for the employers and the applicants. For example, the employers could broadcast their ads more rapidly and with lower costs and could receive many resumes. Also the applicants could refer to websites to select the best job positions appropriate for themselves.

Digital recruitment 2: This stage started 10 years after Digital recruitment 1**.** There were two major characteristics attributed to this period: first, different jobs could be proposed using the same environment and it led to the emergence of indeed. Through such instruments the applicants could see all job opportunities without physical presence and through searching different websites and the employers could have access to the appropriate workforce. The second characteristic of this period is the advent and use of social media. The social media called Linkdin was created in this stage and in year 2003.

Social media let individuals to communicate with each other and create new opportunities through sharing their interests, styles, job opportunities, and many other things. This period started in 2010 and ended in 2015.

Digital recruitment 3: The major characteristic of this period is the use of artificial intelligence in recruitment process which is greatly noticed from the year 2015 onwards (Black and Wan H., 2020).

Artificial intelligence can screen a great deal of resumes related to recruit applicants. This activity compared to the traditional method used by human beings could screen the applications in shorter time periods and more effectively. The use of this method could minimize the probable errors such as the deletion of talented applicants. For example, to employ 74 persons for the position of civil engineer in the ministry of labors in Malaysia, 17000 resumes were sent by the applicants and the artificial intelligence selected only 2575 applicants to be invited for the interview. Imagine how much time was needed to evaluate this amount of resumes using the traditional and manual methods (Wan and Roshidi, 2019). Paradox Start Up Company has produced a chat bot called Olivia and presents some information for the recruitmentof applicants regarding the needed jobs, skills, and the interview times (Palmo, 2019).

Based on one of the applicant recognition tools using artificial intelligence, the recruitment ads and the resumes are adjusted and a report is prepared to give the employers.

Chat bots (communication bots) can create a novel experience for the organization, specifically for new staffs. The new staff carry out the tasks required in their first working week through the use of artificial intelligence. Also they could learn about who to be connected with through it. Furthermore, they receive new data through chat bots and report their problems with the related authorities. Moreover, the approval of their off times and getting knowledge about

performance assessment indexes could be carried out through this method (EY Institution, 2018).

Also chat bots can be used to teach the staffs who are not native and don't know the language of the organization.

Chat bots are computer programs that communicate with people through Natural Language Processing (NLP) and can work all 7 days of the week and 24 hours a day. Some of the advantages of chat bots are as follows:

1) Communication with recruitment applicants and answering common questions
2) Rapid responses to the applicants and access to their data
3) The recognition and isolation of qualified applicants from among others
4) Companies can create databases comprised of data related to the applicants and communicate with them in proper times and propose jobs to them.
5) They can inform the applicants about whether they are accepted or rejected through the recruitment process
6) They can adjust interview times for the applicants (Navaz and Gomez, 2019).

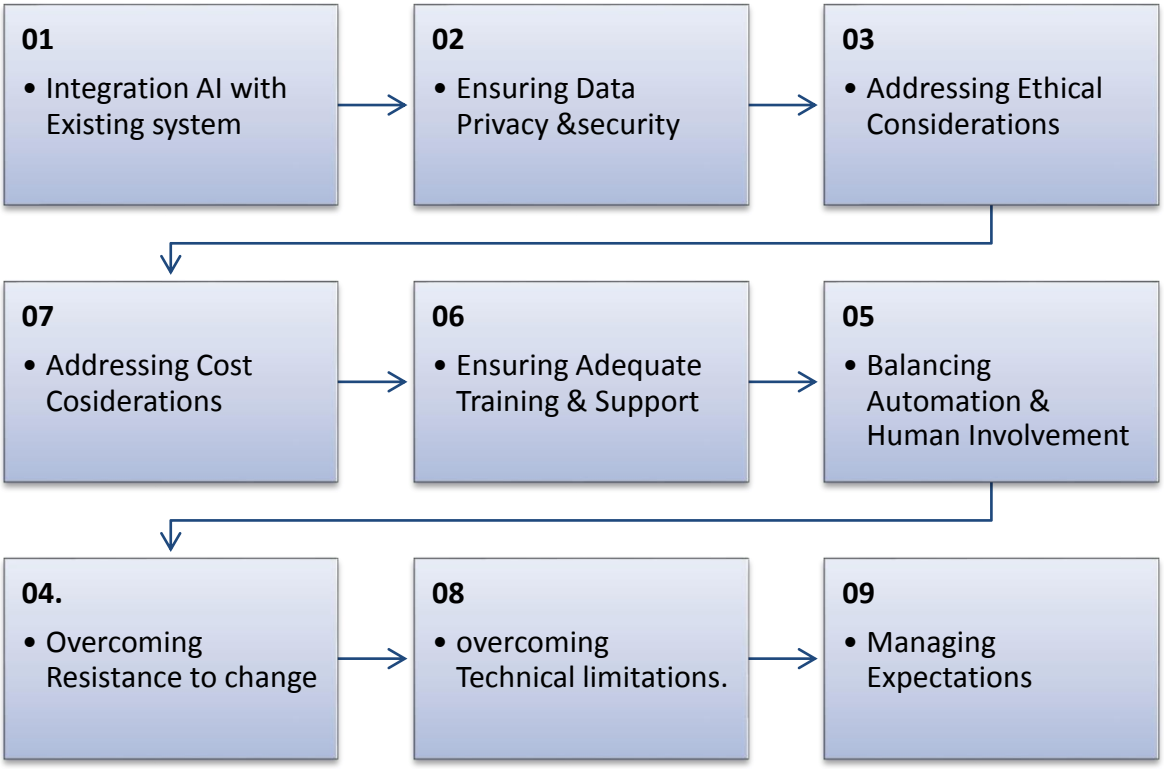

Fig.3. Challenges of AI in Project Management – authors

4.3. Using artificial intelligence in performance assessment:

Artificial intelligence can help the organization in creating a system to present feedback. Artificial intelligence can identify measureable goals for each staff, foster the process of receiving their viewpoints permanently. Also the staff can record all their suggestions, criticisms, and worries in an online view recording system

and this can lead to be able to predict the amount of commitment to the job on the part of the staff in current and future times and their performances through analyzing the data in this system (George and Runny Thomas, 2019).

Through the use of artificial intelligence technologies, we can record and investigate about individuals' daily performance unlike the traditional performance assessment which usually was done annually (Navaz and Gomez, 2019).

On the whole, it can be claimed that the application of artificial intelligence in staff performance management could have the following advantages:

1) the data utilized in performance assessment are collected from different resources
2) staffs' performance is assessed when needed and without any delays
3) psychological biases are deleted
4) gender discrimination is reduced (Hashmi and Baig, 2020).

One of the trustable platforms in management is Synergita which is used to assess staffs' performance such as their performance assessment to create more cooperation of the staffs and to improve efficiency and yield at work place.

4.4. Artificial intelligence in talent management:

Human assets play a vital role in gaining permanent competitive merits in any organization. Thus, the absorption of talented workforces is known as the most important process in human resource management. Organizations know about this issue that a considerable amount of their competitive merits depend on the presence of talented individuals in the organization (Kolcareni and Ch., 2019).

Employing qualified and talented individuals in sensitive job positions and important posts in organizations seems a necessary task. The organizations manage the talents to select talented individuals for vital positions in the organization and try to pave the way through it to achieve organizational goals. Artificial intelligence technology helps the organization to choose the best individuals from among the applicants. It also excludes a number of individuals to focus on more talented applicants (Abdoldaim and Aldawalimi, 2020).

4.5. Artificial intelligence in human resource training:

Organizations permanently seek for staffs who accomplish their responsibilities in the highest possible level and consider up to date training programs to achieve this. Also the staff are required to enhance their knowledge and skills to do their duties better.Artificial intelligence recognizes the needs of staff and the organization using its techniques and helps the staff through designing job routes, individualization of training, and using digital facilities and helps the organization to achieve its goals and to preserve consistency in competitive routes (Permanat and Choly, 2020). Artificial intelligence algorithms can help the organization in programming training courses. This technology uses its recorded data to plan the courses based on individual differences of the staff including generation, cultural educational, environmental, and enthusiasm differences (Palmo, 2020). Artificial intelligence can plan and administer appropriate training programs for new staff (Metsa and Gualmaji, 2019).

Artificial intelligence technology can help the organization using its techniques along with training instructors and even it uses a potentiality to present appropriate training for the staff in the form of a personal instructor (Jiang and et al., 2019).

Artificial intelligence identifies a certain level of training for each of the personnel through investigating about the daily learning capabilities

of the individuals and it utilizes the feedback on the part of the individuals towards the presented training to adjust the speed and type of training and the specific person. If a person shows a negative feedback due to the high speed of the training context presented or avoids giving feedback, artificial intelligence recognizes it and tries to change the type of training. Another advantage of artificial intelligence in training refers to the access of managers to results of training the staff in an online and on spot format. Also the staff can identify their goal of attending a certain training program and get help from artificial intelligence to have access to the appropriate training program. The teachers of artificial intelligence can guide the individuals all the time (Jia and et al., 2018).

4.6. Artificial intelligence in prediction:

Artificial intelligence can study the recorded data to recognize the current algorithms along with prediction of future behavior of the staffs. Thus, when a climax or collapse of the algorithm is recognized, the authorities could act appropriately to alleviate the problems (Iqbal, 2018). The previous and current data of the organization can be analyzed using modelling, machine learning, and artificial intelligence and based on it we can predict the future. Organizations' managers can predict the staffs' behavior through data analysis and this can result in staffs' performance optimization and finally there would be a better return of capital in the organization (Ghoddos Mohammad, 2019).

4.7. Artificial intelligence in services consumption:

Services consumption is known as one of the most important processes in human resource management and it has a vital role in job satisfaction and belongingness of the staffs to the organization. Artificial intelligence recognizes the patterns and predicts staffs' performance in different parts to design different models of staffs' service consumption. Artificial intelligence in service consumption can lead to justice in wages and rewards. Through the use of artificial intelligence, the human biases in payments to the staffs are alleviated and artificial intelligence acts based on current and previous outcomes of staffs' performances (Hashmi and Baig, 2020).

Conclusion

Some advantages of artificial intelligence are quality enhancement and training individualization. Since a great deal of in service training programs of the staff in organizations is carried out without considering the needs of the staffs, and this leads to unwanted effects, the use of artificial intelligence can reduce this weakness to a great extent. Artificial intelligence helps the organization to hold different training programs based on the requirements of the organization and the needs of the staff throughout the whole 24 hours a day. Also findings in this research showed that training through artificial intelligence can increase the quality and effect of training programs to a great extent. Another issue stressed as a result of doing the present study refers to decision making based on the data and different algorithms. Artificial intelligencecan reduce conceptual decision making and psychological biases and result in increasing the precision in decision making by the organizations' managers. Additionally, due to the capability of artificial intelligence in prediction based on the data, the organizational managers are able to present more comprehensive viewpoints about the future for the organization and for the staffs. Fairness in payments, performance assessment, and recruitment are among other important advantages attributed to artificial intelligencein human resource management. Of course, it should be emphasized that artificial intelligence

will cause some certain challenges which we should consider along with the advantages of such a technology. The findings in this research showed that artificial intelligence has had the highest amount of usage in recruitment process in organizations up to now.

It could be predicted that artificial intelligence will be considered more seriously in future by big organizations, specifically those organizations that propose information technology services and strategies required in human resource management.

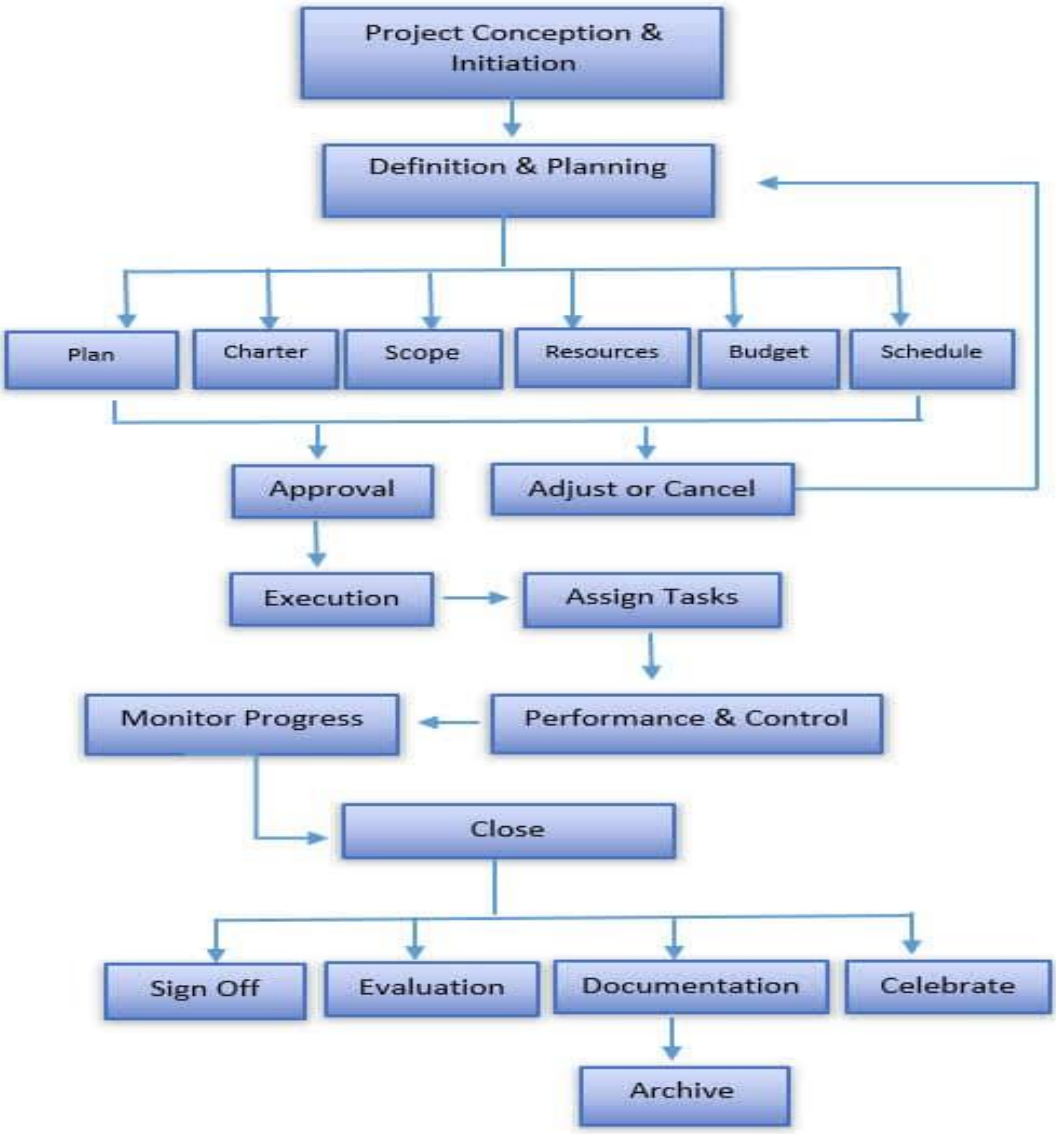

Fig.4. Project Management Process Flow Chart

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Mathematical Calculation of ${}^{14}_{6}C$ Radioactivity lifetime in Archeology

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Abstract

The radiocarbon dating method of ${}^{14}_{6}C$ is one of the newest methods in archeology. Knowing and applying this method is possible by using the methods of natural sciences in general and mathematical sciences in particular. The use of radiocarbon dating method has been expanded in recent years in Iran in archaeological excavations and often, citing this method, findings and works related to them are dated absolutely (Mofidi Nasrabadi, 2018: 23-41). Therefore, this study has been done by describing and determining the radioactive equations used in calculating the age of ${}^{14}_{6}C$. ${}^{14}_{6}C$ is one of the isotopes of carbon, a radioactive substance and the result of interactions with ${}^{14}_{6}N$. Living organisms absorb some ${}^{14}_{6}C$ in their food cycle, and when they die, the absorption of radioisotopes stops, and the absorbed ${}^{14}_{6}C$ gradually decreases according to the half-life of radioactive carbon with the physical characteristic, i.e., the rate of transformation (the numerical interpretation of the derivative). This physical law is expressed in the form of a mathematical equations, and two basic and dynamic mathematical tools are used, i.e. differential and integral, and With the help of ${}^{14}_{6}C$ properties, the activity equation (exponential function) is obtained, which is used in the calculation of ${}^{14}_{6}C$ dating.

Keywords: ${}^{14}_{6}C$ dating, radiocarbon, mathematics in archaeology, radioactivity equations, radioisotope.

1. Introduction:

Mathematics emerged in ancient times depending on the needs of life and gradually became a system of various knowledge. Mathematics, like other sciences, is a reflection of the laws of nature and is used as a powerful tool to understand nature. But since mathematics is too abstract and subjective, its new fields are not accessible to those who are not specialized in work. Since ancient times, this abstract feature of mathematics has given rise to subjectivist ideas about its lack of connection with nature. Today, despite its abstract and subjective nature, the immeasurable extent of its application has been shown to everyone. In this regard, in archaeology, the successful crystallization of the idea of applying other sciences, especially mathematics, can be seen from the developments of the beginning of the 20th century in the collection and processing of data in archaeological research. By accepting the rate of use of mathematics by other sciences, in the ranking of this use, it can be seen that archeology is at the bottom of the table. A look at the history of archeology and possibly the traditional thinking in the application of modern archeology is indicative of this fact.

The first real application of mathematics in archaeological research should be found in the revolutionary discovery of radiocarbon annuity by Professor Libby and his colleagues in 1947. This article is a plan of how to apply and explain the mathematical model and function used in the calculations of the annuity of (6^14)C. By examining the theoretical principles of the exponential function, (6^14)C radioactivity, along with the examination of its cycle and transformation or activity equations, the necessary model and pattern used in annuity of (6^14)C are determined..

2. Radioactivity

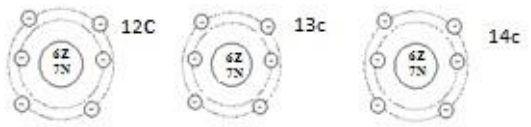
Radiocarbon dating is the most famous and well-known absolute dating method for determining the age of organic materials and materials containing carbon. This method was presented by Libby and his colleagues in 1947 AD (Libby, W.F. et al., 1974, pp931-936). Libby was able to measure this substance in methane gas in the mines of the Baltimore Islands in the United States with complex enrichment methods. slow. Two years later, Libby and Anderson used this method to date ancient Egyptian objects whose ages were known, and the results were in very good agreement with known dates (Arnold, J.R and W.F. Libby, 1949, pp678-680).) Currently, there are various methods for dating carbon 14. The method invented by Libby has gradually evolved over the years and is now used in many laboratories around the world. This method requires large amounts of samples (from grams to kilograms) and the testing process may take several months, but at the same time, this method is very accurate. Mass Spectrometry) have been invented which is widely used in various research fields. Analysis using this method requires a small amount of sample. Of course, each of the methods and equipment used in carbon 14 analysis have their own advantages and complications. Carbon 14 dating has a special place in archeology researches in Iran. Iranian and foreign archaeological research teams used to send many samples to carbon 14 dating laboratories in Iran and abroad for dating. The first carbon 14 dating of Iranian samples belongs to Hasanlu region, which was done at the University of Pennsylvania (Ralph, E.K, 1959). The results of the dating of different samples from the ancient areas of Iran are published in different magazines such as (Bovington, R.H. et al, 1979, pp, 195-195), and other specialized magazines of archeology and archeology (Amirlu, 1366: 51-74).

In the conversation about the universe, two things are mentioned, matter and energy. These two quantities can be transformed into each other and exist in various forms to form all the visible and invisible objects of the universe. Matter is characterized by one of its characteristics, mass, which is made of tiny particles or atoms. The smallest component of a simple element is an atom, which is not found in free form, and the smallest component of a compound substance is a molecule, which is found in free form. The molecules of the substances that make up the compounds around us are made of the combination of atoms. Atom is the smallest constituent particle of matter that has the chemical properties of matter. All atoms are made up of two distinguishable regions. The central area of the atom, called the nucleus, with a radius of about 10^{-15} meters, contains protons with a positive electric charge and neutrons without an electric charge. The outer region of the atom and around the nucleus contains electrons with a negative electrical charge with a radius of about 10^{-10} meters. In a neutral atom, the number of electrons orbiting the nucleus is equal to the number of protons in that atom. These electrons exist in orbits around the nucleus and in separate groups. The number of protons is represented by Z and it is called atomic number. The atomic number is different for different elements and is used to indicate a special type of atom. The number of neutrons is represented by N and it is called neutron number. The total number of protons and neutrons in the nucleus of an atom is called the mass number of that atom and is denoted by A; that's mean:

$A = N + Z$

The number of electrons of each element and their arrangement around the nucleus indicate the chemical properties of each element. The number of neutrons in an atomic nucleus does not play a role in chemical processes, but it plays a decisive role in nuclear reactions. The number of neutrons of an element is not always the same. Nuclei that have the same number of protons but different numbers of neutrons are called isotopes. Isotopes of an element are atoms that have the same number of positive charges in the nucleus and the same number of electrons, but the number of neutrons in their nucleus is different. To distinguish between isotopes of an element, the mass number is written in the upper part of its name. For example, an atom with chemical symbol X is represented by An atom like ${}_{6}^{14}C$ represents the carbon isotope. Z may be removed because all atoms of a chemical element have the same Z. For example, carbon isotopes can be written as ${}^{12}C$, ${}^{14}C$, ${}^{13}C$, etc. Most of the elements have several isotopes and because the electronic structure of the isotopes is the same, their chemical reactions are also similar. Isotopes differ from each other in terms of atomic mass.

Carbon element with atomic number 6 has 3 isotopes, (${}_{6}^{14}C$ with 6 protons and 8 neutrons), (${}_{6}^{12}C$ with 6 protons and 6 neutrons) and (${}_{6}^{13}C$ with 6 protons and 7 neutrons) are isotopes of carbon element. ${}^{14}C$ is the heaviest isotope of carbon and has an unstable nucleus.



Isotopes of carbon with the same number of protons and different nuotrons

French scientist Henri Bequrel first used the concept of radioactivity. Radioactivity is the spontaneous emission of particles or electromagnetic waves from the nucleus of an atom. In fact, decay is a phenomenon during which an unstable atom emits its excess energy. Among the carbon isotopes, ${}^{14}C$ is a radioactive substance due to the instability of its nucleus and has a specific half-life. Half-life is the time required to reduce any radioactive isotope to half of its initial value, and it is a measure of the rate of conversion of that radioactive isotope into another isotope, and it is an invariable property for every isotope. The basis of ${}^{14}C$ annuity is the radioactivity of ${}^{14}C$.

3. Transformation or Activity Equations

Derivation is one of the most effective methods in mathematics that is used to solve various problems. In radioactive studies, the first studies have shown that each radioisotope (unstable nuclei) is known by the characteristics of its transformation rate (the numerical interpretation of the derivative). It is proved that the ratio of atoms being transformed is proportional to N number of atoms available for transformation. so;

$$\frac{dN}{dt} = -\lambda N \qquad (1)$$

The negative sign indicates that the number of atoms decreases with time. The activity ratio or transformation activity of unstable nuclei is called radioation activity and it is displayed in terms of transformation per time unit. Actives are expressed in terms of the number of collapses that occur in a certain time interval. It represents the fraction of atoms that are transformed per unit of time. This coefficient is called transformation coefficient or decay constant. If the relationship (1) is written as;

$$\frac{dN}{N} = -\lambda dt \qquad (2)$$

Then we get;

$$\int \frac{dN}{N} = \int -\lambda dt$$

$$\ln(N) = -\lambda t + c$$

where ln is the natural logarithm function and c is a constant value. If at time t = 0 we represent the number of N atoms with N_0 (the number of first unstable nuclei), then;

c = ln(N_0)

After placing we get;

$$\ln N - \ln N_0 = -\lambda t$$

and finally;

$$N = N_0 e^{-\lambda t} \quad (3)$$

It is an exponential equation and it is a general formula for the transformation of radioactive substances. In (3), N0 is the number of atoms available at the time t = 0 and N is the number of remaining atoms Fig(1).

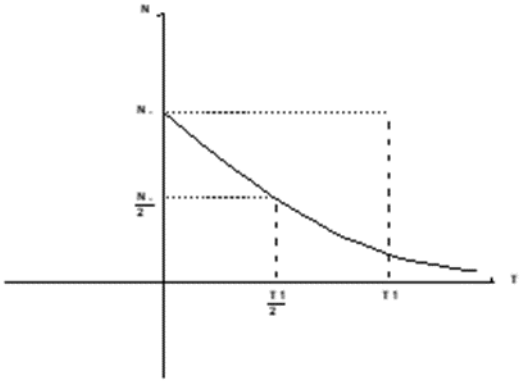


Fig1: Change in the number of radioactive nuclei with time

The number of transformed atoms after time t can be easily obtained;

$$N' = N_0 - N \quad (4)$$

(the number of transformed nuclei)

By placing (3) in (4), we will have;

$$N' = N_0 - N_0 e^{-\lambda t} = N_0(1 - e^{-\lambda t}) \quad (5)$$

That is, the number of transformed atoms of a radioactive substance also follows an exponential function Fig(2).

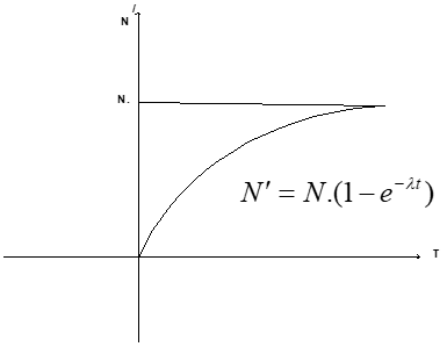


Fig2.:Variation of the number of transformed nuclei with time t

In practice, relative activity R (the number given by the counter) is usually used instead of absolute activity, so it can be written;

$$R = R_0 e^{-\lambda t} \quad (6)$$

where R_0 is the relative number of atoms present at time t = 0. With the explanations given and the obtained equations, in the simplest case, the general equation of the relative radioactive transformation can be written as follows;

(future)= $e^{-\lambda t}$(present).

4. ^{14}C radioactive carbon cycle

The bombardment of Earth by cosmic rays produces a steady source of neutrons in the atmosphere. These neutrons react with nitrogen in the atmosphere and produce radioactive ^{14}C. ^{14}C atoms, which are formed in the upper layers of the atmosphere, form carbon dioxide (CO_2) by interacting with air oxygen. Radioactive carbon dioxide remains in the atmosphere for a long time and mixes with normal carbon dioxide (consisting of ^{12}C and ^{13}C). Plants absorb biomolecules containing ^{14}C through photosynthesis and metabolism, and animals

absorb ^{14}C containing biomolecules through feeding, therefore radioactive activity is observed in the bodies of animals and in the trunks of plants.

Various theories and experiments show that there is a balance between the decay rate of radioactive carbon and its production rate in all organisms. In living organisms, the ratio of radioactive carbon isotope (^{14}C) to the number of non-radioactive carbon isotopes (^{12}C) is approximately 1 to 10^{12}. As a plant or animal breathes, ^{14}C remains at a constant level in its respiratory structure, but when living organisms die, absorption of the radioisotope stops and radioactive ^{14}C undergoes a decay process. As a result of this action, the activity of the radioactive substance gradually decreases, which will be proportional to the half-life of radioactive carbon. Using highly equipped devices, scientists calculated the half-life of ^{14}C to be 5730 ± 40 years. This means that for every 100 carbon atoms, only 50 atoms of ^{14}C remain after a half-life (i.e. 5730 years). The rest are converted to nitrogen (N) by emitting a beta ray. It has been proven that 1% of ^{14}C decays every 830 years, thus the natural ^{14}C that has been created since the Earth was formed has completely decayed.

Conclusion

The use of different series of samples made it possible to determine the relative age tendency of the structural periods and, to this order, control and confirm the results of stratification. The interesting issue is that radiocarbon testing for all structural periods shows an age of about 50 to 200 years older than the initial dating based on pottery and written texts.

It is also interesting to note that this is the case for data enclosures.

Another ancient site such as Tel Melian in Fars province and also some other places. It has been observed in Mesopotamia as well as in Egypt, so that in these places too, the radiocarbon method has dated the findings several decades older than the era that archaeologists estimated based on written texts and matching pottery.

In general, it can be concluded that the dating of several series of samples by radiocarbon method can be used to determine relative dating, but this method is not able to date the data in an absolute way and is often associated with several decades of error. The age obtained from the examination of carbon samples is such that they can be estimated up to 50 thousand years. However, other isotopes such as potassium or uranium are also used in estimating the lifetime of objects. These isotopes have a much longer half-life and are used to determine very old geological events that should be considered millions or billions of years old.

How will the equation of relative activity that was obtained in the general state be in the ^{14}C annihilation? As mentioned before, in living organisms, the ratio of radioactive carbon isotope (^{14}C) to the number of non-radioactive carbon isotopes (^{12}C) is approximately 1 to 10^{12}. Therefore, in the mentioned equation, it is determined at time t = 0 (the time when living organisms die) we have:

$$R0 = \frac{1}{10^{12}}$$

But how is the coefficient (decay coefficient) determined? We use the definition of half-life to determine. Because during the half-life, the activity reaches half of its original size, therefore, we put the expression $R0 = \frac{1}{10^{12}}$

in the equation $R = R_0 e^{-\lambda t}$ and take the natural logarithm from both sides and obtain;

$$t_{1/2} = \frac{0.693}{\lambda} \qquad (7)$$

Because the half-life time for radioactive ^{14}C has been determined to be 5730, by putting it in equation (7), we get;

$$\lambda = \frac{0.693}{5730} \cong 0.00012094$$

Or

$$5730 = \frac{0.693}{\lambda} \qquad (8)$$

Therefore, the transformation equation $R = R_0 e^{-\lambda t}$ for radioactive ^{14}C is obtained as follows;

$$R = \frac{1}{10^{12}} e^{-0.00012094t} \qquad (9)$$

This is the equation of relative activity of ^{14}C that is used in the calculation of ^{14}C annihilation.

For example; Suppose that the ratio of ^{14}C to ^{12}C in a newly discovered skull (by measuring the concentration of ^{14}C using an accelerating mass spectrometer (AMS)) is

$$R = \frac{1}{2}10^{-13}$$

The life of this skull in the ^{14}C dating model, according to equation (9) is equal to;

$$\frac{1}{2} \times \frac{1}{10^{13}} = \frac{1}{10^{12}} e^{-0.00012094t}$$

$$\frac{1}{20} = e^{-0.00012094t}$$

$$-\ln 20 = -0.00012094t$$

$$t = \frac{\ln 20}{0.00012094} \cong 24770 \text{ years}$$

Therefore, the radiocarbon age of the skull is approximately 24,770 years. By taking into account the conditions, the chronological age is obtained.

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Smart Frequency Control in Multi-Carrier Micro-Grid with the Presence of V2G Electric Vehicles

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Abstract

Due to the high cost of fossil fuels, concerns about environmental contamination, and the requirement to satisfy rising energy demands, renewable energy sources have recently gained a lot of attention. Since the output of renewable resources like solar and wind energy depends on meteorological factors, the energy sector faces several issues as a result of their dependability. The microgrid frequencyis managed in accordance with the peak use of the gas network. Both the distribution of electric and gas network loads are taken into account. In a multi-carrier network, the frequency is adjusted in a nonlinear manner. On the other hand, the rising trend in production and the use of electric cars has increased the amount of new demands on the electrical network; if effective management is not implemented to handle these new loads, the rise in network frequency deviations might cause the network to malfunction or even collapse. In this study, the ANFIS adaptive fuzzy control approach is utilized to fine-tune the frequency of the network using vehicle-to-grid (V2G) electric cars. The wind turbine, solar panel, battery, flywheel, electric vehicle (EV), diesel generator, and multi-carrier energy hub (MCEH) systems with combined heat and power (CHP) make up the proposed micro-grid. A fuzzy controller is contrasted with the suggested approach in terms of frequency control. The simulations are carried out using MATLAB/SIMULINK software. The simulation results demonstrated that the studied microgrid's SMART controller can deliver stable output power and strong frequency control performance. In terms of effective (RMS) values and maximum frequency deviation, the suggested technique outperformed the fuzzy method.

Keywords: Electric vehicles, micro-grid, frequency control, ANFIS

1. Introduction

Grid-connected and islanding are the two primary modes in which micro-grids function. In order for a micro-grid network to function in the islanding mode, active distributed energy resources (DER) are needed. These DER include micro-generators, combined heat and power (CHP) units, photovoltaic (PV), wind or hydro turbines, and energy storage devices. The CHP unit is one of the several DER choices that is frequently employed in micro-grids [1].Utilizing electric vehicles can lower greenhouse gas emissions, according to multiple published papers [2,3]. Accordingly, it was expected that by 2020, 2030, and 2050, respectively, 35%, 51%, and 62% of all cars in the country will be electric [4]. A new load will be introduced to the system since rechargeable electric cars require power. As a result, as the usage of electric cars rises, the issue of regulating and stabilizing the frequency of power networks must also be addressed.With more electric vehicles on the road, renewable electricity dependability may rise. Electric cars can function as a controlled load or an output source when they are linked to the grid [5]. The term "vehicle-to-grid" (V2G) systems refers to a network of electric cars that may be viewed as a big storage battery with a capacity of several megawatts. By offering a quick reaction to disturbances, V2G systems may establish a backup storage source that balances power in the grid network. Network vehicles involved in load frequency management are under the control of fuzzy control [6, 7]. With a novel model of load response program, equipment planning for a multi-carrier microgrid with dependability is

described. The impact of dependability indicators on cost reduction is examined in this paper [8].Daealhaq et al. [9]presented a two-tier optimization model to determine the sales strategy in the previous day's market in the presence of a wide range of renewable wind resources. The uncertainty of wind and load sources is modeled by the Monte Carlo scenario generation method considering their interdependence and the Coppola method. The proposed model also provided a linearized model of IC load distribution to reduce the complexity of the problem.Qin et al. [10] proposed a top-of-the-line DC-DC solid-state transformer for two-way parking of photovoltaics / EV batteries with network vehicle service (V2G-PVBP). Relying on the energy storage performance of EVs, V2G-PVBP can not only meet the normal needs of electric vehicle owners but also provide load handling and load adjustment performance to the microgrid.Prusty et al. [11]introduced the optimal performance of a fuzzy controller for balancing load and power generation in an independent microgrid (S-MG) with electric vehicles (EVs). Khooban et al. [12] presented a new modified optimization algorithm for adjusting scale factors and membership functions of type 2 fuzzy PI controller (GT2FPI), which effectively reduced the frequency deviations of the MG system against load disturbances. Iqbal et al. [13] proposed a new primary frequency control via V2G capability in an industrial microgrid, which includes the convenient coordination of the charging station operator, EV collector, and EV operator .Fan et al. [14] proposed a frequency regulation method in a three-zone LFC system, in which PEVs are utilized to regulate frequency under different load disturbances. Their results showed that the proposed LFC scheme successfully suppresses frequency fluctuations in the presence of delays and provides robustness against PEV uncertainties. The simulation results obtained from MATLAB by Yan et al.[15] results proved that the use of a hybrid energy storage system (HESS) can properly stabilize the frequency of interconnected multi-zone systems. Moreover, the proposed powerful controller was quite effective.Xu et al. [16] proposed a new energy storage method based on pumped hydropower storage (PHES) for an integrated renewable energy microgrid (REMG). Also,a load frequency control (LFC) wasproposed for the under-studysystem. In this paper, the problem of optimizing LFC controllers for REMG was investigated and optimal controllers were designed for multiple regions in REMG.Ivanovaet al. [17] showed that the energy and heat generation system (CHP) has a relatively high electrical application forstrengtheningthe power production sector. Murali et al. [18] investigated the derivative-based virtual inertia simulation using the energy storage system (ESS) and its effect on power system frequency control. In this work, a new effective optimization strategy called the Opposition-Based Volleyball Premier League (OVPL) algorithm was used to optimize the essential controller and ESS parameters. Irudayaraj et al. [19]described a physics-derived atom search optimization (ASO) algorithm for adjusting the fractional-order proportional integral control (FOPID) parameters for automatic control of HPS load frequency. In this study, an attempt was made to analyze the stability of the HPS frequency using Matignon’s theorem.In a work performed by Mohanty and Panda [20], an electric vehicle and a heat pump with HPS were used to control the frequency. The operation of customer electrical appliances such as an electric vehicle (EV) and heat pump (HP) reduces the use of stand-alone energy

storage units for HPS. Lund and Kempton [21] connected electrical wires as a controllable load or source of outputto the grid.Their results showed that the reliability of renewable sources will increase by increasing the number of electric vehicles.A large number of electric vehicles in the network can be used as a huge storage battery on a scale of several MW, which is called vehicle-to-grid or V2G systems.V2G systems can create a backup storage source for balancing the power in the grid network and providing a rapid response to disruptions.Jan et al. [22]studied an independent Micro-grid includinga heating turbine system, wind turbine, photovoltaic and electric vehicle.In this research, the fuzzy PI method and adaptive droop control were used.Aliabadi et al. [23] investigateda Smart charging method for electric vehicles to control the Micro-grid frequency. In this paper, the smart charging method wasperformed based on fuzzy control. Amamra and Marco [24] provided frequency and voltage support based on a fleet of integrated V2G electric vehicles in the power network.The designed scheme was able to provide optimal regulation services as well as voltage regulation support for the grid network.In addition to providing the necessary ancillary services, issues related to EV battery failure were also investigated.Kumar and Jaladi [25] designed a battery charging station supply by using three grid sources, a photovoltaic system (PVS), and a battery energy system (BES).BES was used as a buffer with excessive energy storage under mild load conditions and its supply if required.In its infrastructure, a two-way DC / DC converter is activated by the control unit for charging and discharging.The MPPT (Maximum Power Point Tracking) technique was used to obtain suitable pulses for the DC / DC converter to achieve the maximum output power from PVS under different conditions.Annamraju and Nandiraju[26] proposed an adaptive FO-fuzzy-PID controller for LFC in a renewable permeable power system.The main part of this work is that an initial application was created to adjust simultaneously all possible parameters of the fuzzy, the FO, and PID controllers to deal with uncertainties caused by renewable sources, loads, and parametric changes. Liu et al. [27] proposed a coordinated distributed model predictive control (DMPC) for the LFC of a power system that includes inherently variable wind-power generations. Kong et al. [28] constituted a hierarchical distributed model predictive control (HDMPC) model for frequency regulation.Mainly highlights the essential problems, resource availability differences and the importance of hybrid renewable systems. In this research, the structure of electronic power converters and their performance with integrated hybrid systems have been discussed in detail. Energy management of input PV/wind sources along with battery and their respective control technologies are reviewed[29, 30].The main objective of this research work has been done for the enhanced settling point and voltage stability with the help of different maximum power point tracking (MPPT) methods. Different control techniques such as fuzzy logic controller, neural network, and particle swarm optimization are used to evaluate PV and FC through DC–DC boost converters for this enhanced settling point[31].Proposes a fuzzy logic controller (FLC) based maximum power point tracking (MPPT) approach deployed to PV panel and FC generated boost converter. PV panels must be operated at their maximum power point (MPP) to enhance efficiency and shorten the system's payback period. There are different kinds of MPPT approaches for using PV panels at that moment. Still, the FLC-based MPPT approach was chosen in this study

because it responds instantaneously to environmental changes and is unaffected sby circuit parameter changes. Similarly, this research proposes a better design strategy for FLC systems. It will improve the system reliability and stability of the response of the system.Eshetu et al. V2G electric vehicles were used as moving energy storage units.In an independent micro-grid, these mobile energy storage units can be a good solution for load frequency control (LFC).In this paper, an intelligent LFC technique based on ANFIS adaptive neural fuzzy system is used, andthe LFC controller based on ANFIS adaptive neural system is comparedto other controllers.

In the present paper, the ANFIS neural fuzzy controller is used to control an electric vehicle to regulate the frequency in multi-carrier microgrids. Therefore, two scenarios are designed for the proposed control structure. However, this work has considerable differencesfrom other works in the literature, CHP and diesel generator (DG) by the classical controller are optimized by the genetic algorithm as the main secondary frequency controller in the first scenario. In the second scenario, the V2G-equipped electric vehicle is used to perform the secondary frequency control with the proposed ANFIS controller. As well as the presence of storage devices (batteries and flywheels) as backup sources can increase the reliability of the under-study microgrid, which is not mentioned in the reference. The proposed method canshow acceptable performance in reducing frequency deviations and improving dynamic responses. It also has a more stable output power in microgrid resources. The rest of the paper is organized as follows.In section 2, the microgrid model is presented. In section 3,a briefliterature review on controller research is provided.Section 4 contained the simulation results and related discussions. Finally, the conclusions are summarized in section 5.

2. The Proposed Multi-Carrier Micro-Grid Model

As shown in Figure 1, the renewable microgrid network is composed of wind turbines, solar cells, storage facilities (flywheel and battery), diesel generators, CHP (Simultaneous generation of electricity and heat), and V2G electric vehicles as mobile storage systems. Given that the frequency is constant throughout the whole system, all loads and power output are modeled on a bus.

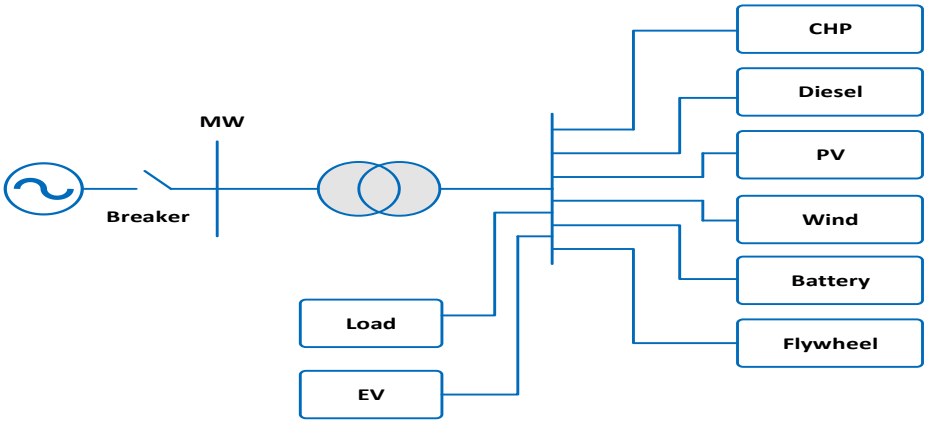


Fig.1. The layout of the isolated micro-grid

3. Model of Electric Vehicles (EVs)

The EVs system is modeled according to the work performed in reference [6]. The equivalent EV model used for LFC is illustrated in Figure 2. Details of the equivalent EV model including battery and charger based on the charging and discharging characteristics can be found in [6].

Figure 2 show that $T_e$is the time constant of EV, Δu_E is the LFC signal dispatched to EV, $\pm\mu e$ is the inverter capacity limit, and $\pm\delta e$ is the power ramp rate limit. E is the current energy of the EV battery. $E_{min}$and $E_{max}$are the minimum and maximum controllable energy of the EV battery, respectively. K_1 and K_2 arethe difference between the limited energy and current energy of the EV battery ,respectively .They can be calculated as $K1=E-E_{max}$and $K_2= E-E_{min}$.

Finally, $\Delta P_E$is the charging/discharging power. When $\Delta P_E= 0$, EV is in the idle state; when $\Delta P_E> 0$, EV is in the discharging state; and when $\Delta P_E< 0$, EV is in the charging state. The EV can be charged and discharged only within the range of $\pm\mu e$. However, if the energy of the EV exceeds the upper limit (i.e., E_{max}), the EV can only be discharged to$(-\mu e)$. Also, if the EV energy is under the lower limit (i.e., E_{min}), the EV can only be charged within the range of $(-\mu e \sim 0)$.

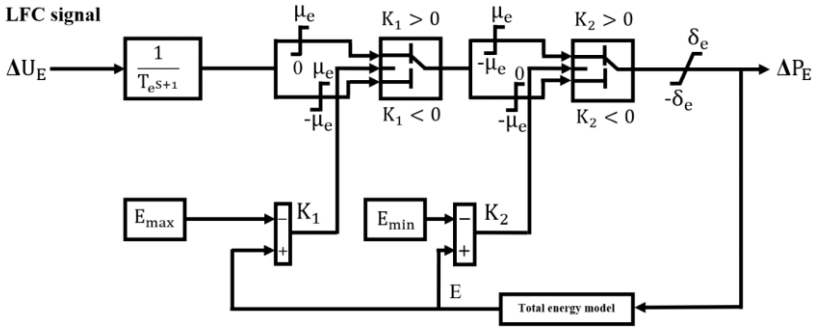


Fig.2. The equivalent EV model for controller [33]

Multi-carrier micro-grid control model

The proposed controller structure according to the parameters of Tables 2,3 in the multi-carrier microgrid is shown in Figure 3.

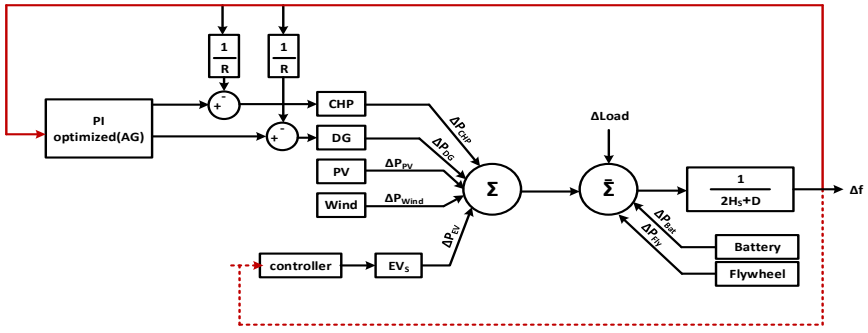


Fig.3. The control model of the micro-grid

4. The Proposed Controllers

A-fuzzy logic controller

The frequency deviations of the system and its derivatives of the two signals input and power as the output of the fuzzy system were studied. Frequency deviation is shown in the Figure of membership functions. The input and output variables in the proposed controller are shown as a set of seven language variables as follows: NB (Big negative), NM (medium negative), NS (small negative), Z (zero), PS (small positive), PM (Medium positive), and PB (Big positive). Each of the above fuzzy variables has a member of the subsets whose membership's degree varies between [-1, 1]. There are a total of 49 fuzzy rules that are considered in this scheme according to Table 1.

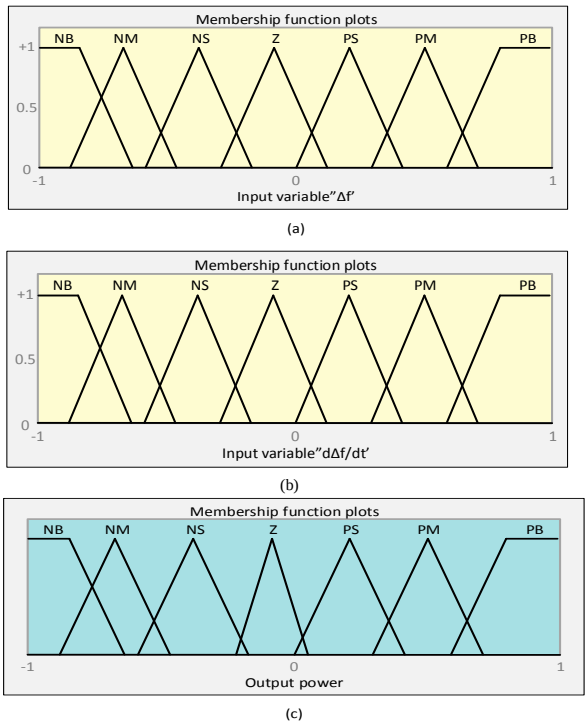


Fig.4. (a) Membership functions of Fuzzy Controller, (b) input fuzzy membership, and (c) output fuzzy membership

Table 1. Fuzzy rules of the controller

Inputs		Δf						
		NB	NM	NS	ZO	PS	PM	PB
Δf/dt	NB	PB	PB	PB	PB	PM	PS	ZO
	NM	PB	PB	PB	PM	PS	ZO	PS
	NS	PB	PB	PM	PS	ZO	NS	NM
	ZO	PB	PM	PS	ZO	NS	NM	NB
	PS	PM	PS	ZO	NS	NM	NB	NB
	PM	PS	ZO	NS	NM	NB	NB	NB
	PB	ZO	NS	NM	NB	NB	NB	NB

B-Adaptive Neuro FuzzyInterface System (ANFIS)Controller

Neuro-fuzzy techniques are developed from the fusion of ANN and Fuzzy Inference Systems (FIS). ANFIS has an advantage over both fuzzy and ANN. It combines the learning power of neural networks with knowledge representation of fuzzy logic to implement a different mode of functions.

The ANFIS is a multi-layer adaptive neural network-based fuzzy inference system. The architecture of the ANFIS systemisshowninFigure

9.Inthisstudy,thefuzzyinference systemhastwosetsofinputs(Δf,$\dot{\Delta} f$)andone output u (power).Suppose that the rule base contains two fuzzy rules including Takagi and Sugeno. For example,

Rule 1: If Δf is X1 and $\dot{\Delta} f$ is Y1,
then $u_1=p_1\Delta f+q_1\Delta f+r_1$

Rule 2: If Δf id X2 and $\dot{\Delta} f$ is Y1,
then $u_2=p_2\Delta f+q_2\Delta f+r_2$

Layer 1: This layer is an adaptive node that is known as the fuzzification layer. The parameter values of this layer change according to the error signal and generate the proper value of each membership function. Each node is denoted as I, and hasan adaptive node function, as shown:

$$o_i^1=\mu_{X_i}(\Delta f) \quad \text{for i=1,2} \qquad (1)$$

$$o_i^1=\mu_{Y_{i-2}}(\dot{\Delta} f) \quad \text{for i=3,4} \qquad (2)$$

Where Δf (or ($\dot{\Delta} f$)) is input at node I, while Xi (or Yi) is a linguistic label (fuzzy sets: Big, Small) that represents the membership functions of each node.

Layer 2: In this layer, the outputs of the first layer are multipliedby each other and forwarded to the next layer. The nodes in this layer are fixed nodes and labeled as II.

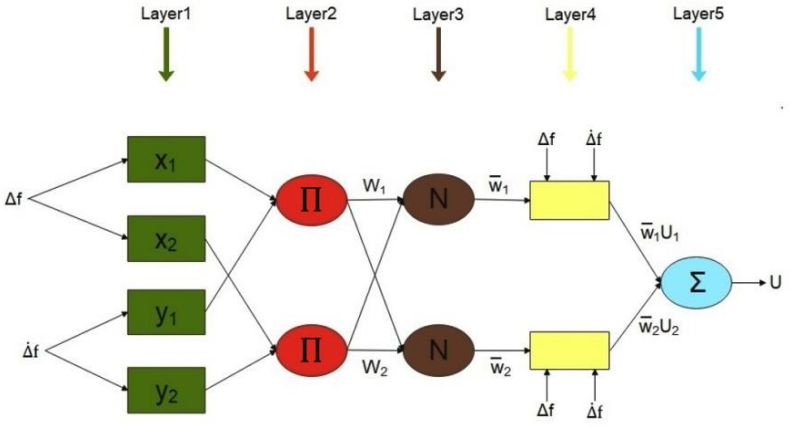


Fig.5. ANFIS network structure [27]

The output of each node is a product of all incoming signals. The output obtained from each node of this layer is given by;

$$o_i^2=w_i=\mu_{x_i}(\Delta f)\times\mu_{y_i}(\dot{\Delta} f) \text{ for i=1,2} \qquad (3)$$

This output representsa degree of activation or (firing strength W_I) of a rule.

Layer 3: This layer calculates the normalized firing strength of each rule and is labeled as N (Normalization). Each node in this layer is also fixed.The output of this layer is normalized firing strength. For i^{th} node the normalized firing strength ($\bar{w}_1$) is given by the following expression.

$$o_i^3=\bar{w}_1=\frac{w_i}{w_1+w_2} \quad \text{for i = 1,2} \qquad (4)$$

Layer 4: Each node in this layer is an adaptive node and the output obtained from this layer is given as follows:

$$o_i^4=\bar{w}_1u_i$$

$$\bar{w}_1u_i=\bar{w}_1(p_i\Delta f+q_i\dot{\Delta} f+r_i)i=1,2 \qquad (5)$$

Where $\bar{w}_1 is$ the output of the third layer and {pi, qi, ri} is the parameter set of this node. The parameter in this layer is referred to as the consequent parameter.

Layer 5: This layer is the last layer of ANFIS architecture which result in the output U and labeled as$\sum$, which computes the overall output as a summation of all incoming signals to the node which is given as

$$o_i^5 - U = \sum \bar{w}_l u_i = \frac{\sum w_i u_i}{\sum w_i} \qquad (6)$$

The ANFIS methods are applied to hybrid-learning algorithms that consist of a combination of various algorithms, the least squares methods are used to set the parameters of linear as well as gradient-descent, which is used to identify the premise parameters. ANFIS edit toolbox is used for production (ANFIS-FIS) in MATLAB software.Training and experimental data are used to train the adaptive neural fuzzy system. For more details to understandthe steps of ANFIS design,see this reference.

5. Simulation Results

To compare the proposed method and fuzzy controller, simulations were performed in five case studies in Simulink MATLAB. The performance of the proposed control scheme is evaluated by two criteria of numerical evaluation of the mean power of the frequency deviations RMS (Δf) and the maximum size of the frequency deviations (max(IΔfI)).

Table 2. Proposed micro-grid parameters [32]

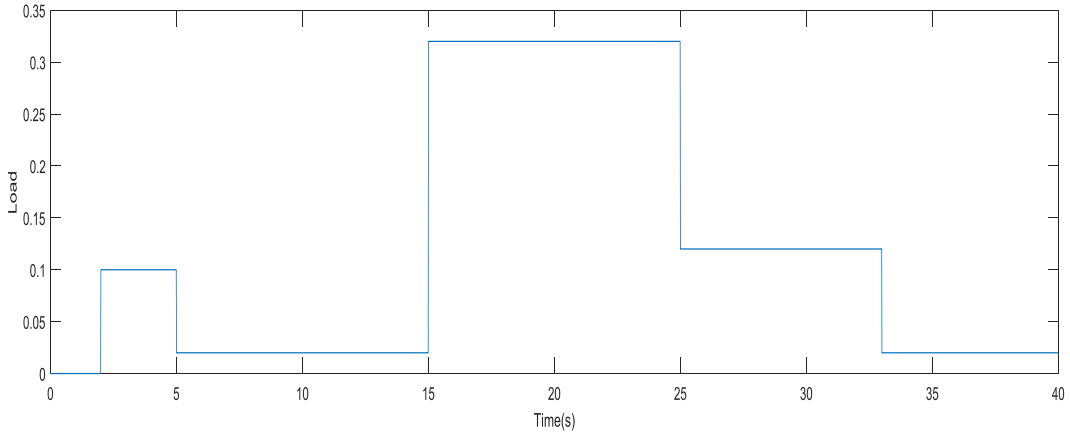
Parameters	Value	parameters	Value
D (pu/Hz)	0.015	T_g (s)	0.08
2H (pu s)	0.1667	T_t (s)	0.4
T_{Fess} (s)	0.1	$T_{t/c}$ (s)	0.004
T_{Bess} (s)	0.1	T_{IN} (s)	0.04
R (Hz/pu)	3	-	-

Table 3. Parameters of the micro-grid model [33,37,38]

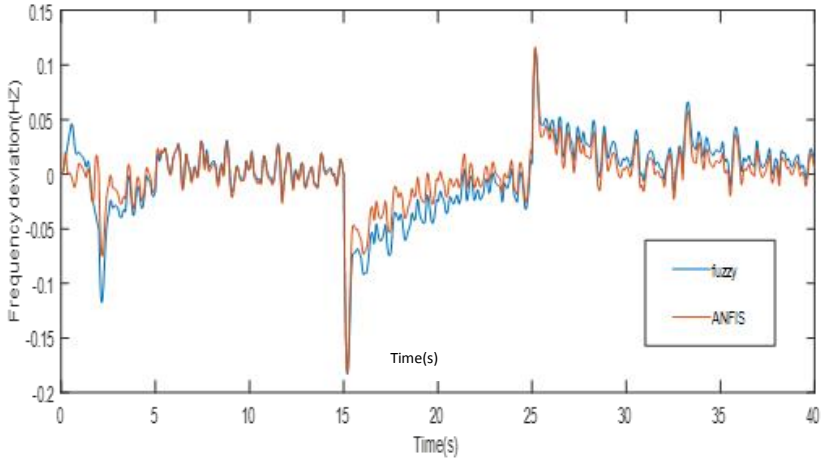
Grid component	Parameters	values
CHP	Xc	0.6 (s)
	Yc	1 (s)
	T_{CR}	0.1 (s)
	T_F	23 (s)
	C_g	1
	b_g	0.05 (s)
	T_{CD}	0.2 (s)
EV_s	T_e	1(s)
	δe	0.01(pu.MW/s)
	μ_e	0.25 (pu.MW)
	Emax	0.95(pu.MW/h)
	Emin	0.8 (pu.MW/h)
PI(optimized AG)	Proportional gain	-0.355
	Integral gain	-0.375

Study A

This study was performed to show the dynamic response of the system in the face of multistage load disturbance (ΔPL).Timeseconds (2-5-15-25-33) are applied to the microgrid according to Figure 6a, and the frequency response of the system is shown in Figure 6b. As shown in Figure 6b, when the proposed ANFIS method is used, the frequency fluctuations and deviations are decreased compared to the fuzzy controller. As a result, the proposed controller has a good performance in the frequency response. In the proposed ANFIS method, the effective (RMS) values and maximum frequency (max) deviation according to Table 5 show a decreaseof 54% and 45%, respectively, compared to the fuzzy controller. It can be concluded that the proposed method in frequency controlindicates proper performance.



(a)



(b)

Fig.6. (a) Multiple-step load disturbances, (b) MG frequency response

Study B

In this study which assumed in winter, the multi-carrier Hub (MCH) network is faced with production shortages due to a sharp drop in gas pressure, and no available CHP in the networkresults in reduced frequency. At this point, a relatively large disturbance of 0. 2 (pu) is applied to the network in 27 seconds.The results of this simulation in figure 7 show the robustness of the fuzzy and ANFIS intelligent controllers of the under-study system. Figure 7 shows that ANFIS performs better in reducing frequency deviations than fuzzy.In the proposed method, the effective (RMS) values and maximum frequency (max) deviation according to Table 5 show a decreaseof 175% and 45%, respectively, compared to the fuzzy controller.

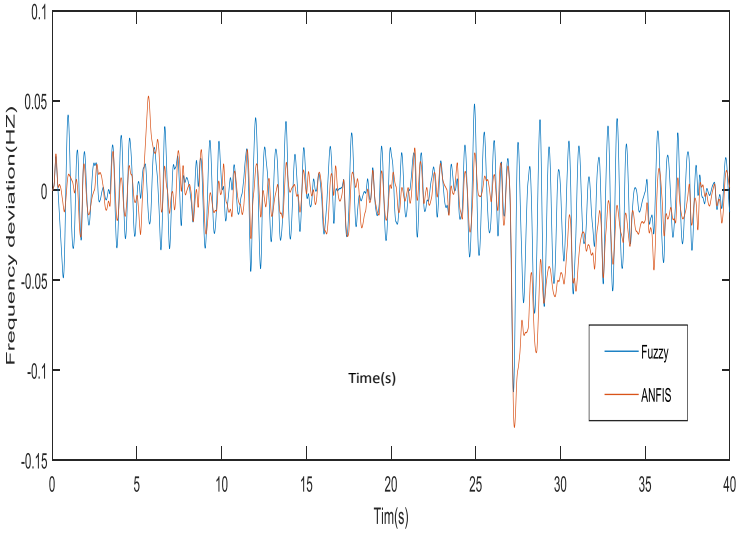


Fig.7. Frequency response of gas changes

Study C

Power system parameters change continuously over time, and this may affect the frequency response of the system. Resistance to environmental and dynamic changes is the advantage of intelligent control methods. At this stage, the main parameters of the power system include damping factor (D), inertia constant (H), drop constant (R), turbine time constant (T_t), generator time constant (T_g), battery time constant (T_{BESS}), flywheel time constant (T_{FESS}) changes to respond the frequency fluctuations according to Table 5. After applying these changes in the microgrid system, the closed-loop frequency response is shown in Figure 8.The optimal resistance of the proposed controller against the considered uncertainties was investigated. Also, the proposed method demonstrates better damping than the fuzzy one and improves the performance of the frequency system. In the proposed method, the effective (RMS) values and maximum frequency deviation(max) according to Table 5 were reduced by 50% and 62%, respectively, compared to the fuzzy controller.

Table 4. Uncertain parameters and variation range

Parameter	Variation range	Parameter	Variation range
R	+60%	T_g	+60%
D	-35%	T_{FESS}	+70%
H	-40%	T_{BESS}	+70%
T_t	+60%	-	-

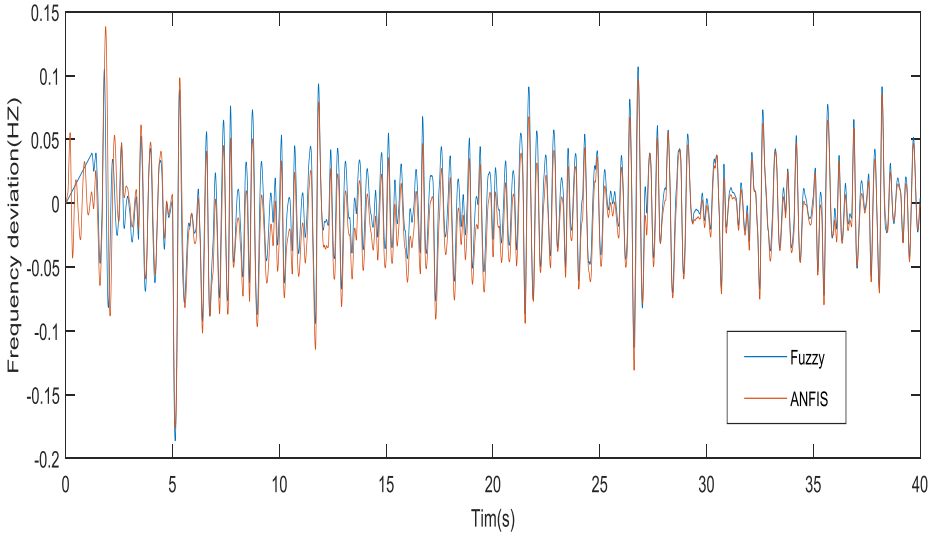


Fig.8. Frequency response according to the parameter's changes shown in table

Study D

In this study, disturbance in the photovoltaic system (PV) and wind system (wind) was managed to occur in 17 and 32 seconds, respectively. The system response to power fluctuations with and without PV system, and also withand without wind turbines are shown in Figures 9 and 10. The simulation results in Figure 11 show an ANFIS-based control method has a better performance in regulating frequency deviations and acceptable strength against perturbations than the fuzzy method. Also, in the proposed method, the effective (RMS) values and maximum frequency deviation (max) according to Table 5 were improved by 49% and 41%, respectively, compared to the fuzzy controller.

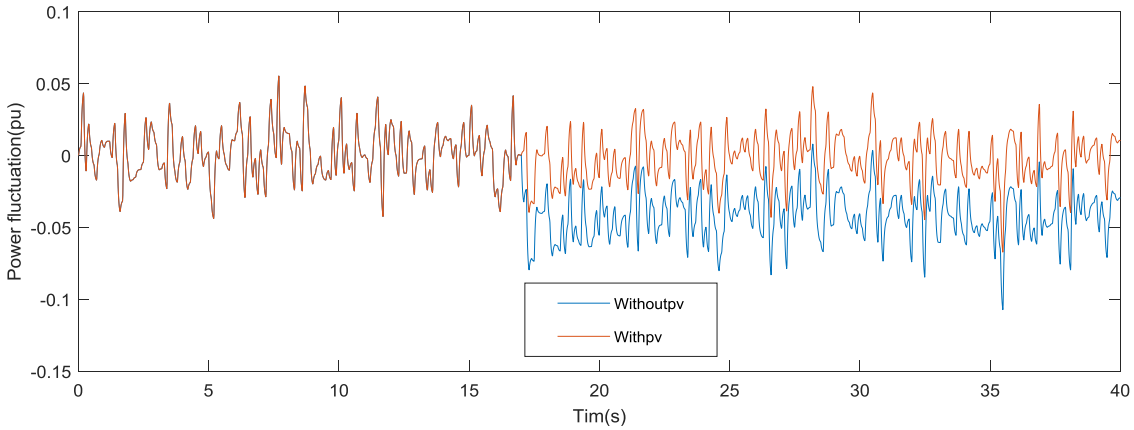


Fig.9. Output power with and without PV

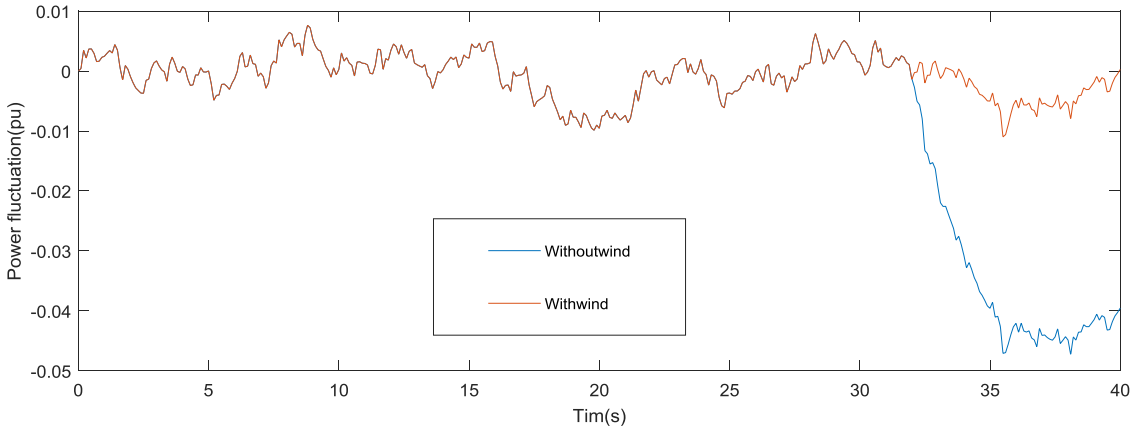


Fig.10. Output power with and without wind

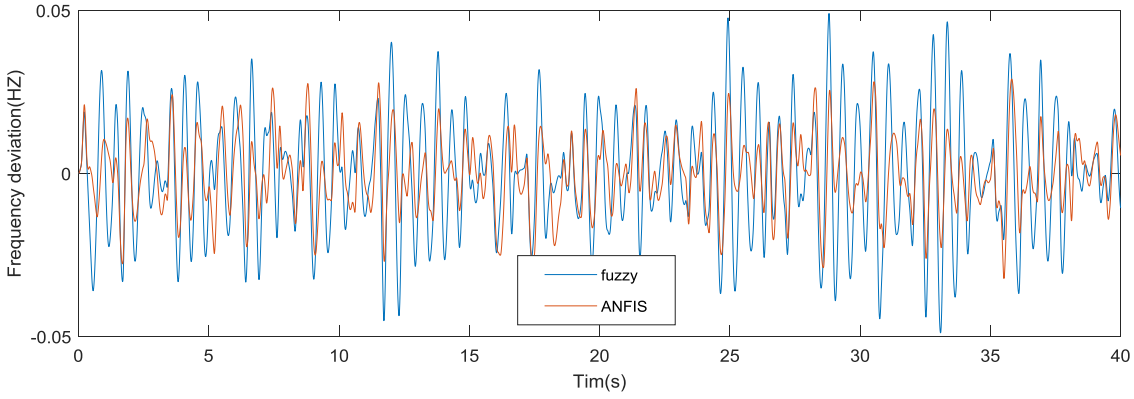
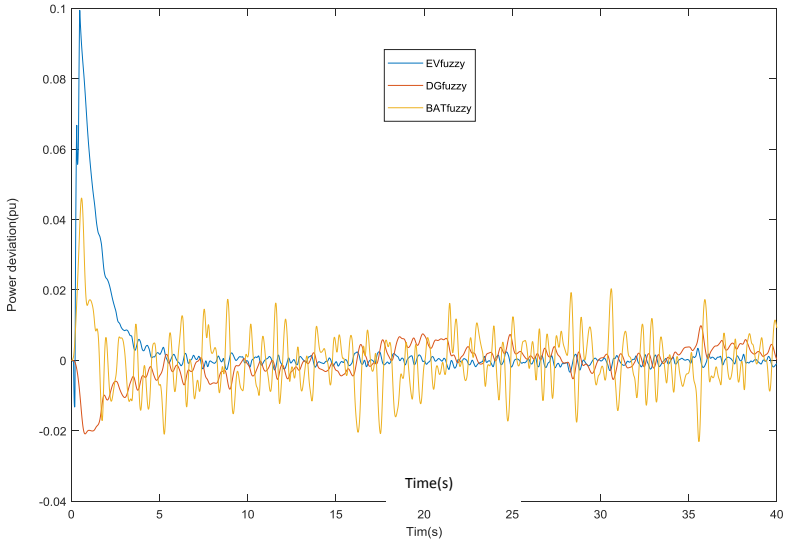


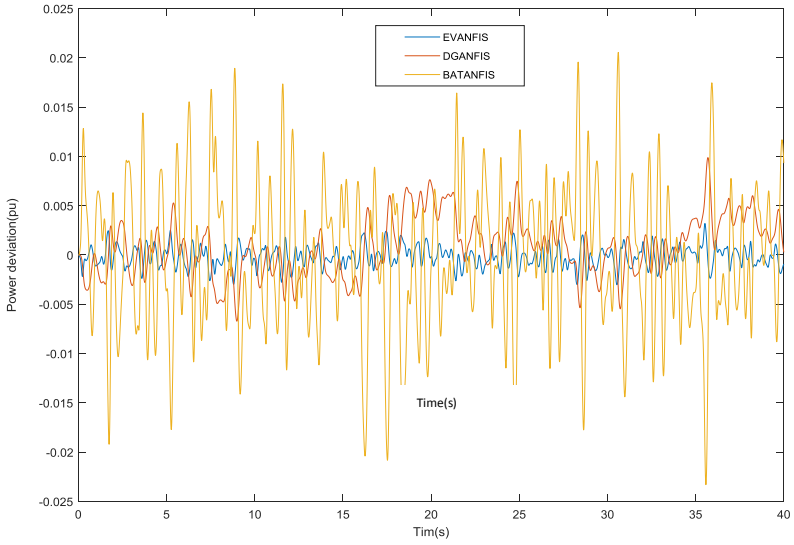
Fig.11. Comparison of the proposed ANFIS method and fuzzy controller in terms of frequency deviation

Study E

In this study, the output power results of the proposed ANFIS-based controller ina system including a battery, diesel generator (DG), and electric vehicle (EV) were compared to a fuzzy controller. The output power of the fuzzy controller and the ANFIS controller are shown in Figures 12a and 12b, respectively. The simulation results show that the ANFIS-based intelligent controller has a more stable output power than the fuzzy. As a result, the proposed method has a good performance in power stability.



(a)Fuzzy Response



(b) ANFIS Response

Fig.12. Output Power deviation (Battery-DG-EV$_s$); (A) fuzzy, (B) ANFIS

6. Summary

The performance of the proposed ANFIS controller was compared witha fuzzy controller in five scenarios. The simulation results showed that frequency adjustment is properlyconducted in the presence of uncertainties such as load changes, renewable energy sources, gas changes, changes in power system parameters, and as well as system stability interruption. The proposed method canshow good performance and significantly reduce frequency deviations. Finally, the proposed method (ANFIS) was compared with control methods in these references [23,26] to evaluate the proposed method, in which the algorithm colonial competition was usedto optimizethe fuzzy controller in [23] and the FO-fuzzy-PID controller was used in reference [26]. In the simulation, a disturbance of 0.3 pu was applied to the microgrid in 16 seconds.

Figure 13 shows the frequency deviation of the proposed method and the methods presented in these references [23,26]. The simulation results in this figure show the optimal performance of the proposed method and the above-mentionedreferences in terms of reducing frequency deviation and resistance to disturbances. Furthermore, effective (RMS) values and maximum frequency deviation (max) of the proposed method were compared with the other two reference methods according to Table 6. According to the results of the proposed method in this table, the effective values and maximum frequency deviation are decreased from [23] up to 61% and 77%, respectively, and compared to [26] are decreased up to 53% and 75%, respectively. Therefore, better performance in frequency regulation for the proposed method than the presented controllers in the literature [23,26] was observed.

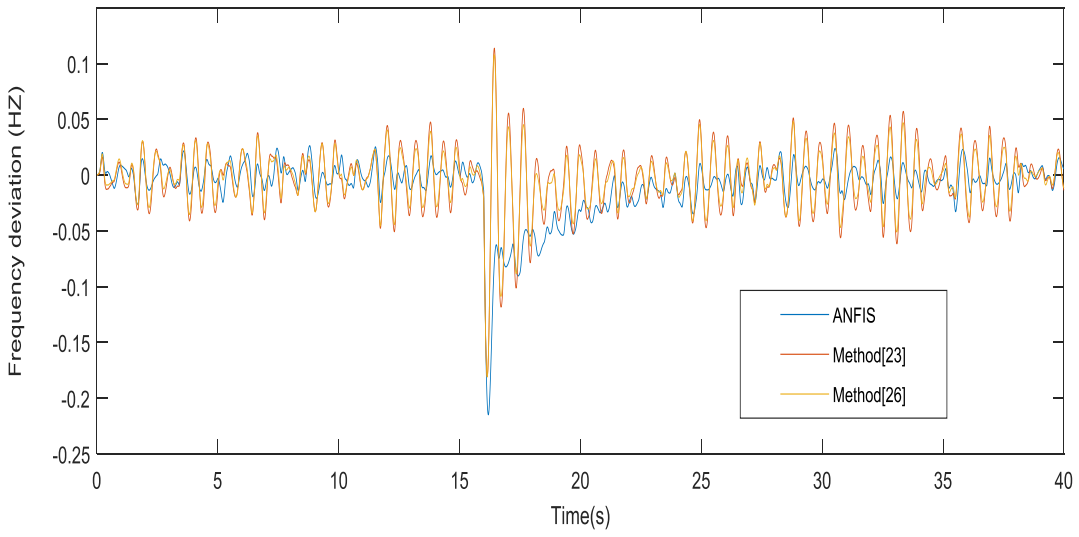


Fig.13. Frequency deviation using the proposed method and control method in [23,26].

Conclusion

This paper aimed to control the frequency in a multi-carrier microgrid. The under-study microgrid includes nonlinear factors that mimic the real-world behavior of the system. Considering that the microgrid is naturally nonlinear, traditional controllers show weak performance in this situation. Therefore, smart controllers areused due to their acceptable performance in nonlinear conditions. In the under-study multi-carrier microgrid, CHP sources and diesel generatorswere used for the secondary frequency controlling as the main sources by the classical Pi controller optimized by the genetic algorithm. The main discussion of this research is the presence of V2G electric vehicles as moving batteries controlled by the intelligent participant ANFIS Neural Fuzzy in secondary frequency as a backup power source. The performance of the proposed ANFIS controller was evaluated in 5 case studies. Also, the degree of resistance of the proposed controller to various parameters and resistance to changes were evaluated. The proposed controller against uncertainties in the simulation results showed that the proposed ANFIS intelligent controller improves system performance compared to the fuzzy intelligent controller and shows better damping performance than the fuzzy one. The proposed controller in all aspectsincluding limit, steady state error, time, andsettlement time shows better performance than other controllers.

Table 5.RMS and maximum values of frequency deviation

Study A (RMS.pu)		**Study B (RMS.pu)**		**Study D (RMS.pu)**		**Study E (RMS.pu)**	
ANFIS	fuzzy	ANFIS	Fuzzy	ANFIS	Fuzzy	ANFIS	fuzzy
0.0058	0.0126	0.0044	0.0121	0.0019	0.0038	0.0054	0.0106
Study A (max.pu)		**Study B** (max.pu)		**Study D** (max.pu**)**		**Study E** (max.pu)	
ANFIS	fuzzy	ANFIS	fuzzy	ANFIS	Fuzzy	ANFIS	fuzzy
0.1163	0.2124	0.0262	0.0480	0.1058	0.2809	0.0289	0.0490

Table 6.RMS and maximum values of frequency deviation

Reference method [26]	**Reference method[23]**	**Proposed method**
RMS(0.0115 pu)	RMS(0.0136 pu)	RMS (0.0054 pu)
max (0.1078 pu)	max (0.1138 pu)	max (0.0264 pu)

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