Human Injuries Risk Assessment of Medium Voltage Electrocution using Bow Tie Model in Fuzzy Environment
(Case Study: Golestan Province Electricity Distribution Company)

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ABSTRACT
Individuals involved in development, repair and maintenance activities of power transmission and distribution are at high risk of electrocution. The purpose of this research is to calculate the human injuries risk of medium voltage electrocution accidents using Bow Tie model in fuzzy environment. Therefore, existing evidences and documents was investigated, and accident causes was determined using the FTA technique. Then, their outcomes were identified by using ETA and William Fine method, and Bow Tie diagrams were drawn based on the results. After that, because of inadequate data, the fuzzy logic was used to calculate the probability of the root causes and outcomes of the accident. The probability of the middle causes and top event was also calculated by probabilistic equations. The results showed that in terms of frequency, medium voltage electrocution accident with probability of 2.2E-4 is one of the significant accidents in the electricity distribution activities, as well as the outcome of "permanent total disability or death of one person" and "with no injury", are the maximum and minimum outcome of the mentioned accident with the probability of 2.1E-6 and 1.29E-10, respectively. These outcomes with the risk of 1.05E-8 and 1.29E-10 are also considered as highest and lowest risk, respectively. "Permanent total disability or death of one person" is the most important outcome of medium voltage electrocution accident, in terms of both frequency and risk. "Lack of installing earth system" and "absence of double insulation" are the most important root causes of accidents. Finally, the results of this research can facilitate financial and human resources planning, and also, the use of Bow Tie in the fuzzy environment can resolve risk assessment problem greatly in the uncertainty and lack of inadequate data.

Key words: Power Distribution, Medium Voltage Electrocution, Risk, Fuzzy Bow Tie, Human Injuries

LIST OF ABBREVIATIONS
Event Tree Analysis (ETA)
Fault Tree Analysis (FTA)
Failure Mode and Effect Analysis (FMEA)
Analytic Hierarchy Process (AHP)
Direct Current (DC)
Occupational Safety and Health Administration (OSHA)
Business, Innovation and Skills (BIS)
Fuzzy Fault Tree Analysis (FFTA)
Fuzzy Event Tree Analysis (FETA)
Lighting & Power Substation (LPS)
Rectifier Substation (RS)
Energy Trace and Barrier Analysis (ET&BA)

INTRODUCTION
People involved in development activities and maintenance of transmission and distribution lines are at increased risk of electrocution [1]. In the decade from 1999 to 2009, contact with overhead power lines is the biggest cause of death from electrocution and 42% of deaths in America happened by contact with transmission and distribution overhead power lines [2]. Unwanted contact with transmission and distribution lines can cause death or injury of workers [3], and economic costs for employers, including lost time, malfunction of equipment, replacement of workers, lack of energy sales, duplication and wastes production, training, supervision, medical costs, compensation, higher insurance premiums, decreased productivity, administrative and other costs [4,5,6,7]. Application of control measures can reduce the risk of accidents or control their outcome. Due to constraints of the resource, we

need to apply the effectiveness management on them. Systematic approach to hazard identification and risk assessment are the key elements to effective management systems, in order to create necessary information to help in decision making on imposed risk reduction actions [8].

For a more detailed understanding of the characteristics of distribution of electrical energy and electrocution accidents, studies related to electrocution agents and human outcome were conducted. Also, calculation and reduction of accident risks were done and has been given below.

The sixth main reason of occupational mortality in the United States of America is electricity, which has led 4.7% of whole occupational mortality in 1992 to 2002 and the reason of 99.1 percent of these is electrocution [2]. Human injuries due to electricity appear in different forms depending on the condition of the occurring accident [9]. Burning, electrocution, electrical shock, overheating and awful sound of arc, fire and explosion are some consequences of electricity that mainly are due to electrocution and the arc. Electrocution happens when the injured person is exposed to lethal amounts of electrical energy [10]. From another point, electricity affects body of living creatures especially humans. It has immediate effect on the nervous system. There are also stimulation of muscles, burns, internal tissue damage, and internal burns, among others. [11]. Intensity of injuries due to electrocution depends on some factors such as current path in the body, amperage, duration of current passing through the body, voltage amplitude, etc [12]. In case of electrocution, it is very difficult to reduce the severity of injuries and effective action cannot be done in this regard [13]. But it is possible to reduce exposure to electrical current and the electrocution effectively.

Risk is calculated with combination of probability of occurrence of an accident and the severity of its undesirable outcome [14]. Severity of accident outcomes is a function of its costs. The undesirable outcomes generally lead to creation of direct costs (clear) including compensation of insurance, treatment costs and also indirect costs (hidden) including lost time, repair costs and replacement costs of injured workers [15] that finally lead to delay of the project and reduction of production efficiency. In 2001, a safety model with fuzzy approach was presented in order to make a decision in the stage of conceptual designing for effective designing variables on marine safety [16]. In 2008, an analytical hierarchy process (AHP) and fuzzy logic-based model was presented for quantitative risk assessment of Beijing's Olympics building project with participation of classified experts [17]. In 2014, evaluation of fire risk and calculation of its costs in DC trains and rectifiers of Tehran's metro were done and it was concluded that managers in decision making should compare the required investment in the safety field with the amount of profit resulting from improvement of risk [18]. In 2015, risk of activities of Iran's petrochemical industry was ranked and effectiveness of control measures done by using FMEA method. Forty eight risks were identified in the welding process and the highest value was related to welding in heights. Control measures reduced risk of all activities, and also, results were used in the mentioned industry in order to prioritize activities for applying control measures and calculate their effectiveness [19].

According to the Occupational Safety and Health Administration (OSHA) regulations, workers should comply with guidelines set by the employer and laws related to their job safety. Also, employers are responsible for providing appropriate workforce, safe workplace [20], personal protection and necessary training. The employer should know that hazard identification is the first step to identify clear and hidden hazards that may exist or be created with the workers' behaviors [21]. Most dangers in distribution activities are due to unsafe facilities, unsafe installation, unsafe environment and unsafe behaviors [22]. After identification of the hazards, suitable techniques are used to reduce risk and their outcomes are controlling occurrence probability, reduction of outcome severity and exposure amount. These improvements are mainly conducted using safety measures and methods (installation of earthing system, cut off electricity of lines), and also using electrical safety equipment (personal protective equipment, barriers, etc.) [9]. OSHA suggests safety measures such as insulating conductor, creating guard in the electricity sector, earthing conductors and equipment, and using fuse in feeders, among others.

Regulatory bodies provide standards and encourage use of techniques to reduce hazards, and although employers are forced to comply with them, they generally refuse to comply with the law or try to comply with the law with least investment in the field of safety [23]. The probability of complying with laws is lower in small and medium companies because they are worried that following these laws reduces their benefits [24] while the Department for Business, Innovation and Skills (BIS) in the report of 2008 has known that following safety and health laws lead to improvement of economic operation of small and medium organizations [25]. Also, in a report that has been prepared by the Health and Safety Executive of England, investment to prevent injuries has resulted in increased economic benefits [26].

The fuzzy theory was founded by Zadeh in 1968 in order to overcome problems due to uncertainty and ambiguities about the probabilities of root causes [27]. In this technique, which is based on expert opinions after aggregation of their opinions, it is necessary that the result of Fuzzy Inference becomes defuzzy. Making defuzzy means extraction of a numerical value from the fuzzy set. In order to change a fuzzy number to an accurate value, there are many different methods such as center of gravity, bisector, average of maximum values, the largest maximum, smallest maximum, and scoring method to left and right of fuzzy number [28]. The center of gravity method is one of the most usable of these methods [29]. About determination of experts and their selection, Miller sought opinion of at least 5–9 experts in determining fuzzy numbers [30]. Whenever the number of experts is higher, better results will be obtained. If the number of experts is 30, it is considered as excellent [31]. Nowadays, FFTA is widely being used to evaluate efficiency of activities, predict reliability, longevity, and safety of complex systems, including nuclear reactors, aerospace, petrochemical industry, oil and gas, and other mechanical and electrical systems [32]. The method of Bow Tie was used based on FTA and ETA in 2005 to manage risk of a new marine terminal of chemicals in Iceland and it was specified that this technique produces beneficial results to manage risk and reduce or control hazards [33]. In 2010, the profitability and capability of this method was ascertained. It was approved for semi-quantitative risk assessment of occupational accidents at a large shipyard in Portugal [34]. In 2013, fuzzy logic was announced as a hopeful method to evaluate reliability of chemical processes. The mathematical models based on fuzzy logic have made it possible to identify the used safety barriers to prevent occurrence of accident and reduce its effects [35]. In that year, the comparative evaluation of fire risk was done in Tehran's metro by methods of ETA, FTA and Bow Tie and the economic damage due to occurrence of fire was determined in posts of RS and LPS and DC trains based on the defined scenarios. With this method, it was possible to determine combination of defects that can lead to a special event [36]. In 2015, the safety risk of electricity distribution process was evaluated by the improved method of ET&BA and ranked with models of Topsis and Vikor in the fuzzy environment. The results showed that aerial medium and low voltage network have the highest degree of risk among other transmission and distribution networks [37]. So, investigation of the accidents is very important. In the current research, the existing gap in calculating risk of human injuries of electrocution accidents has been assessed in medium voltage network in the power industry and the mentioned risk has been calculated by using Bow Tie in a fuzzy environment based on methods of Fuzzy FTA and Fuzzy ETA.

Evaluation of statistics of the last 5 years in Electricity Distribution Company of Golestan province shows that accidents of the electricity industry can be divided into 5 major parts of low voltage electrocution, medium voltage electrocution, falling objects, fall by humans and accidents from the arc.

MATERIALS AND METHODS

The methods of FTA and ETA and guideline of the executive method of identifying safety hazards, environmental and risk evaluation were used to identify middle and root causes of medium voltage electrocution and human injuries due to this [38].

Based on that guideline, human injuries can be divided into 6 classes that include: 1- without injury 2- slight injury (normal operation) 3- slight injury (stopping of operation for less than 3 days) 4- minor permanent injury (long-term stopping of operation) 5- permanent general disability or death of a person and 6- multiple mortalities. Bow Tie diagram of the accident was drawn from the results of previous measures. The Microsoft Visio software was used to draw the diagrams. Also, the outcome was inserted in the diagram with binary logic (occurrence or non-occurrence). Then, according to this issue, that risk results from multiplication of occurrence probability and severity [39], and probability of occurrence of outcome. These were calculated from the conditional equation 1 with the assumption that they were independent.

$$P(\text{Outcome})=P(\text{Accident})\times P(\text{Outcome}/\text{Accident}) \quad (1)$$

Owing to lack of documentary information of past accidents, especially the root causes of their occurrence, fuzzy logic was used to calculate occurrence probability of accident and occurrence probability of outcome. In this research, 42 fuzzy variables have been defined that include 36 variables with topic of occurrence probability of root causes and 6 variables with topic of occurrence probability of human injuries.

Twenty seven experts of the distribution company who are working in different functions and levels of the organization were selected and their weights were calculated by using the specified indexes in Table 1 [40] and the results are shown in Table 2.

Their fuzzy opinions about occurrence probability of root causes and outcome of the accident were collected by using separate questionnaires. The middle and root causes from FTA were inserted in the related questionnaire to increase accuracy of the expert opinions. Each expert selected one of the options from very low, low, medium, high and very high as his opinion about the amount of occurrence probability of each one of the 42 fuzzy variables. Then, the equation (2) [41], which is based on opinions trapezoidal fuzzy number used from triangular membership functions of linguistic variables, (Table 3, and Fig. 1) was compared with the expert opinions. [42]

Table 1: Experts' scoring index

Number	Situation	Category	Score
1	Job Title	Manager–Assistant	4
		Specialist–Chairman	3
		Supervisor, technician	2
		Electrician	1
2	Experience (year)	more than 30	4
		20-30	3
		10-20	2
		5-10	1
3	Education	PhD	5
		MSc	4
		Diploma	3
		With A technical degree	2
		Less than Diploma	1
4	Age (year)	more than 50	4
		50-40	3
		40-30	2
		Less than 30	1

Table 2: Experts' score

Expert NO.	Expert Score	Expert Weight
Expert 1	13	4.74E-02
Expert 2	11	4.01E-02
Expert 3	12	4.38E-02
Expert 4	14	5.11E-02
Expert 5	12	4.38E-02
Expert 6	8	2.92E-02
Expert 7	9	3.28E-02
Expert 8	8	2.92E-02
Expert 9	11	4.01E-02
Expert 10	10	3.65E-02
Expert 11	8	2.92E-02
Expert 12	10	3.65E-02
Expert 13	14	5.11E-02
Expert 14	8	2.92E-02
Expert 15	5	1.82E-02
Expert 16	7	2.55E-02
Expert 17	10	3.65E-02
Expert 18	10	3.65E-02
Expert 19	10	3.65E-02
Expert 20	13	4.74E-02
Expert 21	13	4.74E-02
Expert 22	9	3.28E-02
Expert 23	9	3.28E-02
Expert 24	9	3.28E-02
Expert 25	12	4.38E-02
Expert 26	9	3.28E-02
Expert 27	10	3.65E-02

$$\mathbf{M_i=\sum W_iA_{ij} \qquad (i=1,2,3,\ldots,m)} \qquad (2)$$

M_i is aggregation of experts' opinions, W_i is weight of i-th expert and j is number of same -weight and same -opinion experts.

Table 3: Triangular membership function of fuzzy numbers

Weight of Linguistic Variable					
Variable Description		a_1	a_2	a_3	a_4
VL	Very Low	0	0	0.1	0.2
L	Low	0.1	0.3	0.3	0.4
M	Medium	0.3	0.3	0.5	0.7
H	High	0.6	0.8	0.8	0.9
VH	Very High	0.8	0.9	1	1

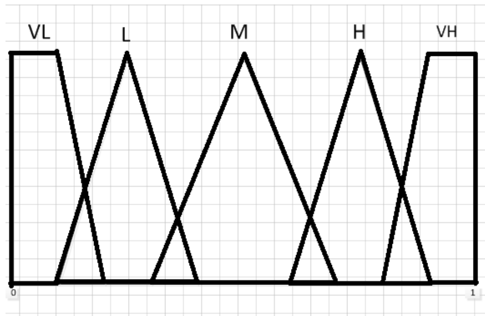

Fig.1: Linguistic terms used by Experts

Then, the fuzzy numbers from aggregation of expert opinions became defuzzy using equation (3) (the center of gravity model) and calculations of changing possibility into probability were done using equations (4) and (5) [43 and 44].

$$DE=\tfrac{1}{3}\times\frac{((a_4+a_3)^2-(a_4\times a_3)+(a_1\times a_2)-(a_1+a_2)^2)}{(a_4+a_3-a_2-a_1)} \qquad (3)$$

In the above equation, the coefficients of a_1 to a_4 are trapezoidal fuzzy numbers that have been provided in Table 3.

$$\mathbf{K=[(1-DE)\times DE^{-1}]^{0.3}\times 2.301} \qquad (4)$$

$$\mathbf{Probability=10^{-k}} \qquad (5)$$

The occurrence probability of the middle and the top event with logical combination of occurrence probability of root causes were calculated using probabilistic equations (6) intersection of probability and (7) union of probabilities. In continue, the occurrence probability of middle causes and the top event with logical combination of occurrence probability of root causes were calculated by using probabilistic equations (6) intersection of probability and (7) union of probabilities.

$$\mathbf{P(A\cap B\cap C)=P(A)\times P(B)\times P(C)} \qquad \mathbf{(6)}$$

$$\mathbf{P(A\cup B\cup C)=P(A)+P(B)+P(C)-} \qquad \mathbf{(7)}$$
$$\mathbf{P(A)\times P(B)-P(A)\times P(C)-P(B)\times P(C)+}$$
$$\mathbf{P(A)\times P(B)\times P(C)}$$

In all above stages, the calculations were conducted by definition of abbreviations for Linguistic variables (Fig. 1) and using formulators' facilities in Excel software.

Finally, by using values of severity of human injuries which have been mentioned in the "Procedures to identify safety hazards, environmental aspects and risk assessment" [38], based on tables of William Fine, risk of human injuries due to medium voltage electrocution accident was calculated by multiplying severity in their occurrence probability [45].

RESULTS

In this research, many expert opinions about occurrence probability of root causes of medium voltage electrocution accident and its outcome were collected. Forty two questions were raised from 27 experts and 1134 opinions about subject of the research were collected.

Fig. 2 shows results of FTA and ETA analyses and Table 4 shows results of fuzzy calculation of occurrence probability of root causes and probable calculation of occurrence probability of middle causes and top event.

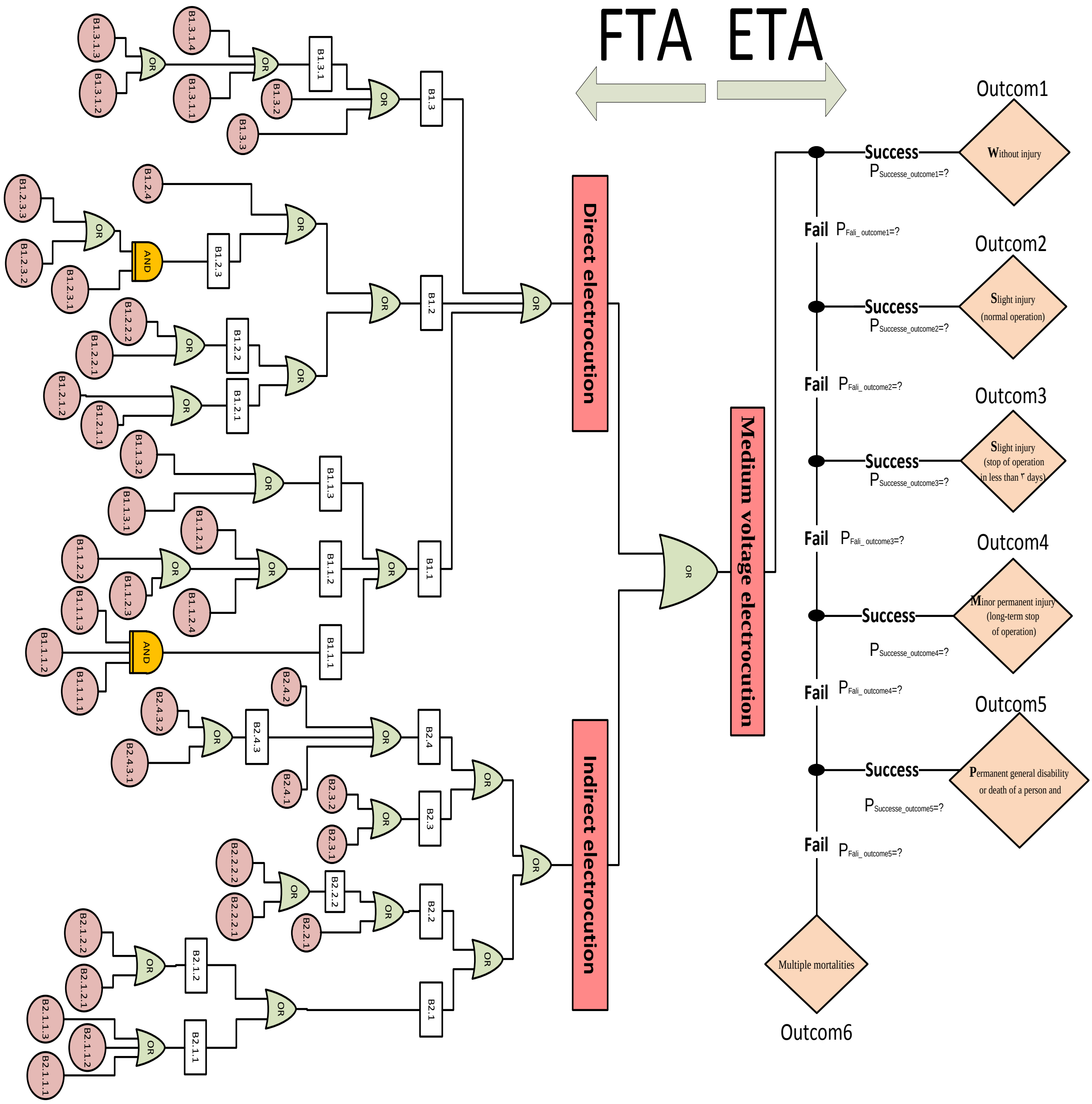

Fig. 2: Bow Tie diagram of electrocution accident in medium voltage network

Table 4: Results of FTA and calculation of occurrence probability of root and middle causes and main electrocution accident of medium voltage

Probability of Root Causes		Root Causes	Probability of middle causes level 3		Middle causes level 3	Probability of middle causes level 2		Middle causes level 2	Probability of middle causes level 1	Middle causes level 1	Probability of top event	Top event
3.80E-04	B1.1.1.1	Lack of attention to adjacent networks	4.69E-10	B1.1.1	Human error	5.62E-03	B1.1	Unwanted contact with a live network	1.93E-02	Direct electrocution B1	2.22E-02	Medium voltage electrocution B
2.76E-03	B1.1.1 .2	Non-use of PPE & GPE										
4.47E-04	B1.1.1.3	The use of inappropriate tools										
5.20E-04	B1.1.2 .1	Live wire theft	4.29E-03	B1.1.2	Entering to electric power lines right of ways							
2.87E-04	B1.1.2.2	Boom Cranes Contact with a Live wire										
1.66E-03	B1.1.2.3	Scaffolding contact with a live wire										
1.83E-03	B1.1.2.4	Contact metal objects electrified wire										
1.05E-03	B1.1.3.1	Failure to observe right of way	1.33E-03	B1.1.3	The availability of electricity network equipment							
2.83E-04	B1.1.3.2	Openness door of public distribution panels										
6.05E-03	B1.2.1.1	No install the earth	6.38E-03	B1.2.1	Human error	8.35E-03	B1.2	Energized network unwanted				
3.33E-04	B1.2.1.2	Wrong cuting off circuit										
1.72E-03	B1.2.2.1	No install the earth	1.83E-03	B1.2.2	Induction voltage in parallel or intersecting lines							
1.08E-04	B1.2.2.2	Failure to observe the permitted distance lines										
5.76E-04	B1.2.3.1	No install the earth	1.65E-07	B1.2.3	Return voltage							
8.96E-05	B1.2.3.2	Voltage return of street lightings										
1.96E-04	B1.2.3.3	Voltage return of Customers										
1.52E-04	B1.2.4	Contact with adjacent conductors										
9.12E-04	B1.3.1.1	Wrong cuting off circuit	3.09E-03	B1.3.1	Human error	5.49E-03	B1.3	Do not cut off the electricity				
1.06E-03	B1.3.1.2	Lack of familiarity with network topology										
1.12E-03	B1.3.1.3	Starting a hurry and forgot to cut off circuit										
9.13E-04	B1.3.2	damaged electricity disconector equipment										
1.50E-03	B1.3.3	Short circuited electricity disconector equipment										
2.31E-05	B2.1.1.1	Escape wire on insulators and contact with pole	1.93E-04	B2.1.1	Connection of live conductor with pole	2.77E-04	B2.1	Contact with wet live pole	2.89E-03	Indirect electrocution B2		
9.96E-05	B2.1.1.2	Unwanted contact with conductor of adjacent circuits										
7.05E-05	B2.1.1.3	Tearing wires and falling on electrical pole										
4.87E-05	B2.1.2.1	Leakage of insulators	8.43E-05	B2.1.2	Energizing pole with etryeh							
3.55E-05	B2.1.2.2	Broken Insulators										
2.01E-04	B2.2.1	Connection of live conductor with panel body				1.50E-03	B2.2	Contact with body of live panels				
7.33E-04	B2.2.2.1	No install the protection earth	1.30E-03	B2.2.2	Lack of protection layer							
5.72E-04	B2.2.2.2	The absence of extra double insulation										
5.42E-05	B2.3.1	Leakage of insulators				9.99E-05	B2.3	Energized Etryh				
4.57E-05	B2.3.2	Broken Insulators										
4.69E-05	B2.4.1	Unwanted contact with conductor of adjacent circuits				1.01E-03	B2.4	Contact with pole of streets lamps				
1.48E-04	B2.4.2	Connection of live conductor with metallic body of street lighting lamps										
4.71E-04	B2.4.3.1	No install the protection earth	8.19E-04	B2.4.3	Lack of protection layer							
3.49E-04	B2.4.3.2	The absence of extra double insulation										

The main event is presented in the first column of Table 4 and the second column shows the probability calculated for it. Pillars of the third to tenth contained information about the causes between levels 1 and 3 with the code assigned and the likelihood of their occurrence; and finally the root causes of the accident, the code assigned to each cause and the likelihood of their occurrence are presented in columns 11 to 13.

DISCUSSION

In the current research, human injuries caused by medium voltage electrocution accident were evaluated and for this purpose, 36 root causes were

identified by fault tree analysis. The injuries were classified into six groups and it was specified that the highest risk was related to "permanent general disability and death of one person" and lowest was related to accidents that has passed without injury.
In 2013, Albert *et al.*, evaluated and ranked human outcome of all accidents in projects of transmission and distribution lines [1].
The results, based on economic quantification of indexes, showed that injuries in terms of ranking risk are as follows: injuries that require first aid, injuries that need medical attention, injuries that lead to missed working hours and finally injuries that lead to death. As it is observed, low severity injuries (first aids and receiving medical attention) have higher risk compared with high severity injuries (missing work hours and mortality).
In the above research, documents of costs of previous accidents were evaluated by using statistical methods and total risk of human outcome caused by accidents in transmission and distribution projects were calculated. This was done so that the risk cannot be calculated in an ambiguous manner. In the current research, a method had been presented to calculate risk based on the fault tree analysis (FTA) and fuzzy logic. This created the possibility of calculating risk in conditions of ambiguity and lack of information from previous accidents.
Therefore, different results were obtained. But results of Albert's research are consistent with the results of Hallowell's research in 2010 which says that classification of risk can be put into two categories of low level (all outcomes with ignorable injury to outcomes that need first aid) and high level (damages with medium injury to injuries that lead to death). It specified that risk of injuries with high severity is more than risk of injuries with low severity and it is necessary that injuries with high severity be considered more in planning because the level of the identified risk is approximately 5-fold of the tolerable risk level [46].
In 2015, Rahmani S. *et al.*, ranked safety risks of electricity distribution activities by classifying activities into 9 groups. The results showed that with the method of Fuzzy Vikor, the medium and low voltage aerial distribution lines with rank 8, Fuzzy Topsis aerial low voltage lines with rank 9 and aerial medium voltage lines with rank 8 among 9 other groups have higher risk [37].
In the above research, just the comparative ranking of risk has been done based on integrated outcome of all accidents on human, environment, equipment and assets. However, values of risk have not been evaluated for the nine groups and accidents were not evaluated separately.

CONCLUSION

The content in Table 4 shows that several factors affect the occurrence probability with varied effects.

Some of these factors are lack of attention and failure to conduct operation (wrong cutting circuit, connecting wrong circuit, paying no attention to adjacent networks, rushing to do the work, etc), non-use of personal protective equipment and collective protective equipment (double insulation, insulated gloves, earthing system, etc.), failure to comply with guidelines and standard methods, lack of experience and knowledge deficiency (lack of knowledge on network topology, lack of familiarity with standard methods of conducting activities, etc).

Also, the results show that similar root causes can interfere in differenct activities with different occurrence probability.
In Table 5, it is clearly observed that indirect electrocution caused by unwanted contact with electricity can be controlled by using personal and collective protective equipment. But not using the above tools with occurrence probability of 7.7E-5 is the most probable root cause of accident and not installing the earthing system leads to unwanted risk of shock from the network in different ways with occurrence probability of 4.3E-5. This is in the next rank. In Table 5 and Fig. 3, ranking of risks of human injuries caused by medium voltage electrocution and their occurrence probability have been provided. These results show that minor injuries have lower risk and serious injuries have higher risk.

Table 5: Risk of human injuries of medium voltage electrocution

event	Outcome	Outcome Probability	Outcome Severity	Risk Number
Medium voltage electrocution	Permanent general disability or death of a person	2.1E-4	50	1.05E-2
	Minor permanent injury (long-term stopping of operation)	9.7E-5	25	2.42E-3
	Multiple mortalities	2.4E-5	100	2.4E-3
	Slight injury (stopping of operation for less than 3 days)	1.5E-5	15	2.25E-4
	Slight injury (normal operation)	3.3E-6	5	1.7E-5
	Without injury	1.3E-6	1	1.3E-6

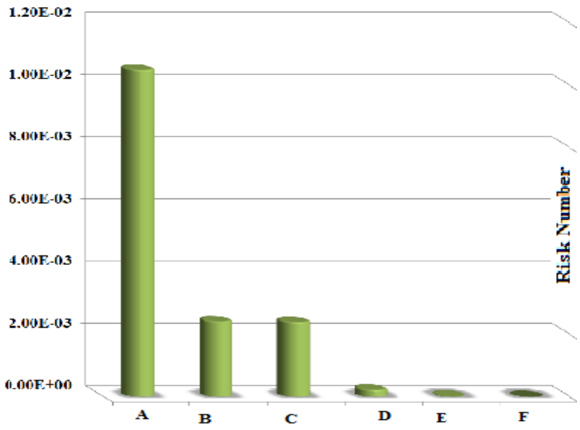

Fig. 3: Risk of human injuries of medium voltage electrocution, A:Permanent general disability or death of a person, B: Monor permanent injury (long- term stopping of operation, C: multiple moralities, D: Sligh injury (stoppong of operation for less than 3 days, E: Slight injury (normal operation, F: Without injury

Result of the current research (Table 5 and Fig. 3) shows that medium voltage electrocution accident with occurrence probability of 2.2E-6 is one of the noticeable accidents in the electricity distribution industry.

Outcome of "permanent general disability or death of one person" with risk of 1.05E-8 and "without injury" with risk of 1.3E-10 are the most risky and the least risky outcomes of medium voltage electrocution. The above results with occurrence probability of 2.1E-6 and 1.3E-10 respectively are the most repeated and least repeated outcomes caused by the above accident. The results show that serious injuries have higher risk and minor risks have lower risk.

According to the results obtained, before incurring cost and conducting control measures, the effect of the accident and its outcome can be evaluated and the best scenario chosen by prioritization of different scenarios. For example, the effect of using personal and group protective equipment and effectiveness of installing earthing system to tackle risk of human injuries etc. can be calculated simply by this method. Cognitive attention to systematic separation of barriers, human error and technical defects in Fault Tree analysis can give useful results for more accurate identification of factors that cause accidents.

Also, it is possible that the 5-option fuzzy questionnaires may not collect expert opinion optimally and don't guarantee accuracy of results. So, for future researches, attention to systematic separation of root causes and using fuzzy questionnaires with more options (7, 9 or even 11 levels) are suggested.

ETHICAL ISSUES

All ethical issues have been respected completely by the authors.

CONFLIC OF INTEREST

There is no conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors had equal role in different stages of this research and writing the paper.

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