Development of a Safety Assessment Model of Electrical Installations using AHP

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1. Introduction

- Safety assessment model of electrical installations

- It was developed in order to assess safety degree of electrical installations managed by Korea Electrical Safety Corporation(KESCO)
- It was developed in 1998 for the first time

  → Since then, the safety assessment model of electrical installations has been used as indicators of safety degree of electrical installations managed by KESCO
- However, because the model was developed 17 years ago and it did not reflect diverse factors, such as environmental influences, there has been a limit to apply for assessment lately.

1. Introduction

- Therefore, in this research,

• An improved model was developed in the following process.

→ Firstly, theoretical background of safety assessment was analyzed.

→ Then, development procedure was explained.

→ After that, an improved safety assessment model of electrical installations was developed based on theoretical background.

→ Finally, simulation and verification of the model were conducted with sample data.

2. Theoretical Background

4M Risk Assessment Method

- According to the 4M risk assessment method of KOSHA(Korea Occupational Safety and Health Agency), risk factors of work process are classified into four major elements(Machine, Media, Man, Management).
- Examples of application of the 4M risk assessment method include laboratories as well as industrial sites.
- The 4M risk assessment method has the advantage of producing risk degree by number, so it is easy to manage risk degree.
- However, risk factors are chosen only when accident statistics are applicable or accident possibilities are predictable.

2. Theoretical Background

AHP(Analytic Hierarchy Process)

- The Analytic Hierarchy Process(AHP) developed by Thomas L. Saaty is a method for multi-criterion decision making.
- The AHP consists of a three layer hierarchical structure.
  - The top layer : the goal of decision
  - The intermediate layer : the criteria
  - The lowest level : the alternatives
- The AHP is widely used for decision making involving multiple criteria in the world today.
- Also, it has found its widest applications in multi criteria decision making in planning and resource allocation, and in conflict resolution.

2. Theoretical Background

Example of calculation of weight by AHP

- In case of determination of importance of three factors(A, B, C)
  - If we get pairwise comparison matrix below, then, weights of three factors are calculated by the following procedure.

	A	B	C
A	1	1/2	1/2
B	2	1	3
C	2	1/3	1

2. Theoretical Background

(1 step) Add each row ⇒ (2 step) Divide by addition of each row

	A	B	C
A	1	1/2	½
B	2	1	3
C	2	1/3	1
	5	1.833	4.5

	A	B	C
A	0.2	0.273	0.111
B	0.4	0.545	0.667
C	0.4	0.182	0.222

⇒ (3 step) average of each column

A(weight)	0.195
B(weight)	0.537
C(weight)	0.268

3. Safety Assessment Model of Electrical Installations

3.1 Development procedure of a safety assessment model of electrical installations

◆ Based on theoretical background, first draft of a safety assessment model was made.

↓

◆ Experts group meetings were held twice, and during the meetings assessment items were selected.

↓

◆ an AHP survey was carried out with 35 experts to determine weights of selected assessment items.

↓

◆ a safety assessment model of electrical installations was developed.

3. Safety Assessment Model of Electrical Installations

3.2 Safety Assessment Model of Electrical Installations

3.2.1 Total evaluation

- Total safety degree(S)
  $= A\times\alpha + B\times\beta \leq 100$

Objective	Item	Symbol	Weight	Evaluation
Total safety degree(S)	Electrical installations status	A	α= 0.7	$A\times\alpha$
	Electrical safety consciousness	B	β= 0.3	$B\times\beta$
Final evaluation equation				$S=A\times\alpha+B\times\beta$

3. Safety Assessment Model of Electrical Installations

3.2.2 Electrical installations status(A)

- Electrical installations status(A)
  $= (A_1 \times a_1 + A_2 \times a_2) \times E^* \leq 100$

Item(Symbol)	Sub item	Symbol	Weight	Evaluation
Electrical installations status(A)	Low voltage electrical installations safety	A_1	$a_1 = 0.67$	$A_1 \times a_1 \times E^*$
	High voltage electrical installations safety	A_2	$a_2 = 0.33$	$A_2 \times a_2 \times E^*$
Equation				$(A_1 \times a_1 + A_2 \times a_2) \times E^*$

3. Safety Assessment Model of Electrical Installations

※ environmental influence(E^*)

- $E^* = E_1 \times e_1 + E_2 \times e_2 + E_3 \times e_3 + E_4 \times e_4 \leq 1$

Item(Symbol)	Sub item	Symbol	Weight	Evaluation
Environmental influence (E*)	Period of use	E_1	$e_1 = 0.34$	$E_1 \times e_1$
	Load factor	E_2	$e_2 = 0.21$	$E_2 \times e_2$
	Area	E_3	$e_3 = 0.2$	$E_3 \times e_3$
	Types of business	E_4	$e_4 = 0.25$	$E_4 \times e_4$
Equation				$E_1 \times e_1 + E_2 \times e_2 + E_3 \times e_3 + E_4 \times e_4$

3. Safety Assessment Model of Electrical Installations

(1) Low voltage electrical installations safety(A_1)

- Low voltage electrical installations safety(A_1)

= 100−∑[{Quantity of unsuitable low voltage electrical installations /

Quantity of low voltage electrical installations} x 100 x weight] ≤ 100

3. Safety Assessment Model of Electrical Installations

Sub Item (Symbol)	Name of low voltage electrical installations	Quantity of installations	Quantity of unsuitable installations	Weight	Risk ratio [%]	Evaluation [%]
Low voltage electrical installations safety (A_1)	Entrance wiring	QL_1	QLB_1	LG_1	$(QLB_1 / QL_1) \times 100 \times LG_1$	
	Distribution Panel board	QL_2	QLB_2	LG_2	$(QLB_2 / QL_2) \times 100 \times LG_2$	
	Molded case circuit breaker	QL_3	QLB_3	LG_3	$(QLB_3 / QL_3) \times 100 \times LG_3$	
	Residual current circuit breaker	QL_4	QLB_4	LG_4	$(QLB_4 / QL_4) \times 100 \times LG_4$	
	Switch	QL_5	QLB_5	LG_5	$(QLB_5 / QL_5) \times 100 \times LG_5$	
	Wiring	QL_6	QLB_6	LG_6	$(QLB_6 / QL_6) \times 100 \times LG_6$	
	Electric motor	QL_7	QLB_7	LG_7	$(QLB_7 / QL_7) \times 100 \times LG_7$	
	Electric heater	QL_8	QLB_8	LG_8	$(QLB_8 / QL_8) \times 100 \times LG_8$	
	Capacitor	QL_9	QLB_9	LG_9	$(QLB_9 / QL_9) \times 100 \times LG_9$	
	Lighting	QL_{10}	QLB_{10}	LG_{10}	$(QLB_{10} / QL_{10}) \times 100 \times LG_{10}$	
	Electric line on the premises	QL_{11}	QLB_{11}	LG_{11}	$(QLB_{11} / QL_{11}) \times 100 \times LG_{11}$	
	Generator	QL_{12}	QLB_{12}	LG_{12}	$(QLB_{12} / QL_{12}) \times 100 \times LG_{12}$	
	Other	QL_{13}	QLB_{13}	LG_{13}	$(QLB_{13} / QL_{13}) \times 100 \times LG_{13}$	
	Total	$\sum QL_n$	$\sum QLB_n$	$\sum LG_n$	$\sum\{(QLB_n / QL_n) \times 100 \times LG_n\}$	
Equation						$100-\sum \{(QLB_n / QL_n) \times 100 \times LG_n\}$

3. Safety Assessment Model of Electrical Installations

(2) High voltage electrical installations safety(A_2)

- High voltage electrical installations safety(A_2)

= 100−∑[{Quantity of unsuitable High voltage electrical installations /

Quantity of High voltage electrical installations} x 100 x weight] ≤ 100

3. Safety Assessment Model of Electrical Installations

Sub Item (Symbol)	Name of high voltage electrical installations	Quantity of Installations	Quantity of Unsuitable installations	Weight	Risk ratio [%]	Evaluation [%]
High voltage electrical installations safety (A_2)	Overhead line, Underground line	QM_1	QMB_1	MG_1	$(QMB_1 / QM_1) \times 100 \times MG_1$	
	Switch	QM_2	QMB_2	MG_2	$(QMB_2 / QM_2) \times 100 \times MG_2$	
	Wiring	QM_3	QMB_3	MG_3	$(QMB_3 / QM_3) \times 100 \times MG_3$	
	Lightning Arrester	QM_4	QMB_4	MG_4	$(QMB_4 / QM_4) \times 100 \times MG_4$	
	Metering outfit	QM_5	QMB_5	MG_5	$(QMB_5 / QM_5) \times 100 \times MG_5$	
	Power fuse	QM_6	QMB_6	MG_6	$(QMB_6 / QM_6) \times 100 \times MG_6$	
	Transformer	QM_7	QMB_7	MG_7	$(QMB_7 / QM_7) \times 100 \times MG_7$	
	Incoming panel, distribution panel	QM_8	QMB_8	MG_8	$(QMB_8 / QM_8) \times 100 \times MG_8$	
	Relay	QM_9	QMB_9	MG_9	$(QMB_9 / QM_9) \times 100 \times MG_9$	
	Circuit breaker	QM_{10}	QMB_{10}	MG_{10}	$(QMB_{10} / QM_{10}) \times 100 \times MG_{10}$	
	Capacitor	QM_{11}	QMB_{11}	MG_{11}	$(QMB_{11} / QM_{11}) \times 100 \times MG_{11}$	
	Load	QM_{12}	QMB_{12}	MG_{12}	$(QMB_{12} / QM_{12}) \times 100 \times MG_{12}$	
	Grounding	QM_{13}	QMB_{13}	MG_{13}	$(QMB_{13} / QM_{13}) \times 100 \times MG_{13}$	
	Other	QM_{14}	QMB_{14}	MG_{14}	$(QMB_{14} / QM_{14}) \times 100 \times MG_{14}$	
	Total	$\sum QM_n$	$\sum QMB_n$	$\sum MG_n$	$\sum\{(QMB_n / QM_n) \times 100 \times MG_n\}$	
Equation						$100-\sum\{(QMB_n / QM_n) \times 100 \times MG_n\}$

3. Safety Assessment Model of Electrical Installations

3.2.3 Electrical safety consciousness(B)

- Electrical safety consciousness(B)

$$= B_1 \times b_1 + B_2 \times b_2 + B_3 \times b_3 \leq 100$$

Item(Symbol)	Sub item	Symbol	Weight	Evaluation
Electrical safety consciousness (B)	Level of effort to repair facilities *{(repaired facilities)/(unsuitable facilities)} × 100*	B_1	$b_1 = 0.47$	$B_1 \times b_1$
	Management status of protective facility *{good(100), medium(50), bad(0)}*	B_2	$b_2 = 0.3$	$B_2 \times b_2$
	Number of education to managers *{4times(100), 3times (80), 2times (60) 1time(40), 0time(0)}*	B_3	$b_3 = 0.23$	$B_3 \times b_3$
Equation				$(B_1 \times b_1 + B_2 \times b_2 + B_3 \times b_3)$

4. Simulation

Sample NO	Area in Korea	Capacity (kW)	Electrical installations status (70) A		Electrical safety consciousness (30) B			Environmental influence E*				Electrical Safety Degree S
			Low voltage electrical installations safety A_1	High voltage electrical installations safety A_2	Level of effort to repair facilities B_1	Management status of protective facility B_2	Number of education to managers B_3	Period of use E_1	Load factor(%) E_2	Area E_3	Types of business E_4	
		Weight	0.67	0.33	0.47	0.3	0.23	0.34	0.21	0.2	0.25	
1	Seoul	600	98.73	100	99.63	100	60	0.64	0.96	0.52	0.56	73.22
2	Busan	325	100	100	100	100	60	0.57	0.97	0.52	0.63	73.37
3	Daegu	300	100	100	100	100	60	0.85	0.94	0.52	0.48	76.98
4	Inchoen	300	100	100	100	66.6	60	0.86	0.93	0.52	0.09	67.27
5	Gwangju	500	100	100	100	100	60	0.88	0.96	0.54	0.56	79.66
6	Daejeon	450	100	100	100	83.3	60	0.85	0.97	0.49	0.56	76.89
7	Gyeonggi	355	99.83	100	97.99	100	60	0.88	0.96	0.49	0.63	79.84
8	Gyeonggi(northern)	900	100	88.68	98.15	66.6	60	0.89	0.94	0.56	0.56	74.65
9	Gangwon	450	99.63	100	98.26	100	60	0.89	0.93	0.49	0.09	70.18
10	Chungbuk	300	100	100	100	100	60	0.89	0.67	0.49	0.63	76.17
11	Cheonbuk	600	100	100	100	100	60	0.85	0.96	0.49	0.07	69.70
12	Gyeongnam	600	99.94	100	99.68	100	60	0.88	0.97	0.54	0.56	79.74
13	Jeju	900	100	100	100	100	60	0.9	0.96	0.52	0.56	79.85
	Average											**75.20**

5. Conclusions

Based on the application of 4M risk assessment model, experts group meetings and the AHP, safety assessment model of electrical installations has been developed. The developed model has the following characteristics.

1) An AHP survey was carried out with 35 experts to determine weights of selected assessment items.

5. Conclusions

2) Safety assessment model includes two main items(Electrical installations status, Electrical safety consciousness). Weights of each items were determined by the result of the AHP survey.

3) Sub items of electrical installations status consist of two parts(Low voltage electrical installations safety, High voltage electrical installations safety) according to environmental influence. Weights of each sub items were determined by AHP survey.

5. Conclusions

4) Sub items of Electrical safety consciousness consist of three parts(Level of effort to repair facilities, Management status of protective facilities, Number of education to managers).

◈ We hope that the developed model can be applicable to assess the degree of customer´s electrical installations more accurately.

Also, we hope that this model can be used as electrical safety index of electrical installations.

THANK YOU

MERCI - 감사합니다