Safety Inspection of Electrical Systems Case Study in Paper and Animal Food Factories

Surin Charoenchit[1,2,*] and Chaiyapon Thongchaisuratkrul[1,2]

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ABSTRACT

The research focuses on electrical safety inspection of factories to investigate the problem of a safety system to plan and prepare maintenance process. The two types of factories including paper and animal food factories are observed. Four factories located in Thailand, 2 paper factories, and 2 animal food factories were case studies. The total electrical load of the first paper factory is 18,450 kVA with 10 transformers. Another paper factory consists of 9 transformers also. Its total load is 13,450 kVA. On the other hand, the first animal food factory just includes an 800 kVA transformer. And another animal food factory is a 1000 kVA transformer. Investigated systems are such as transformer, main distribution board (MDB), ground and electrical wire systems. There are four senior engineers for diagnosing together. The tools are as test oil maker, thermo scan, earth clamp tester, earth ground tester, infrared tester, and outlet tester. The results show that amount of problems cases are found the most in a transformer at 53% of all inspection and the next is in main distribution board (MDB) at about 29%. Moreover, the following case is in wiring and ground system at 14% and 4% respectively. The problems occurring in the transformer include low oil insulation, deteriorated silica gel, a broken box of silica gel, a damaged rubber shield, and a damaged rubber gasket. The problems case found in main distribution board is such as more dust, terminal loose, the nut of air circuit breaker loose and air circuit breaker heat. For the ground system, the problem cases consist of broken ground injection, high resistance ground value, and heat ground wire. In wire system, the electrical is damaged because of broken insulation, overload wire, and loose injunction and by animal.

1. INTRODUCTION

In the past, the factory is a small factory. The manufacturing is small size. Engine is not applied. The product is made by hand [1]. The first industrial revolution occurred in 1750 that lasted to sometime between 1820 and 1840. During this period, technologies were transformed into machinery [2]. Many machines were applied for human life [3]. Steam turbine machineries were developed for industries [4]. Still a day, age of 4.0 industries, the advance sciences and technologies have continuously developed the industrialization around the world [5]. Electrical machines have become the most machines used in industrial factory instead of conventional machines since second industrial revolution [6]. Beside it can run the same well that it is better with environment also [7]. Electrical machines still have been widespread in industrial factories. Intelligent technologies; smart factory, cyber physical systems, intelligent robotics are more used so electricity consumption is increased [8]. Also, Thailand, a country in Asia, where become a base area of factory which it has been rapidly developed [9][10]. It is found that the industrial factory is more spread in many regions of Thailand. The industrial manufacturing has grown up continuously [11]. That means the electrical energy source is highly needed. Nowadays electrical system is very important especially in factory.

According to [12], world electricity consumption during 2000-2015 increased from 13,173 TWh to 20,568 TWh about 56% especially in Asia countries group. According to statistic electricity generation of Thailand, it is found that the quantity increased 22% in ten years during 2008-2018 [13]. Furthermore, according to Thailand Power Development Plan 2015-2036 [14], it can be summarized that in 2036, the total capacity would be 70,335 MW comprising existing capacity of 37,612 MW (as of December 2014). The gap is high about 87%. It means that the electricity consumption is increased. Amount of electricity consumption over 20 years (2002-2020)

[1]*King Mongkut's University of Technology North Bangkok, Thailand.*
[2]*Department of Teacher Training in Electrical Engineering, 1518, Wongsawang, Bangsue, Bangkok 10800, Thailand*.
**Corresponding author:* Surin Charoenchit; E-mail: surinkmuttnb1234@gmail.com.

presented in [15], the electricity consumption is the most in the sector of industry approximately 46%. The next are commercial and public services, and residential sectors with shares 32% and 22% respectively. According to [16], it shows the electricity demand grows continuously. Therefore, the electrical system is the need of industry. It is known well that electricity is more benefit. However, it is dangerous, if the system is lack of safety system [17]. Therefore, the safety system becomes more important especially in large system as factory, big building and so on.

According to [18][19][20], the electrical system is installed following as standard. Moreover, it should be inspected by professional such as engineer. The standard is provided because of safety and efficient usability [21]. A good electrical safety is more important because we could not apparently realize that, the risk of accident whenever occurs. Accident is an unexpected event causing loss of life or bodily injury and loss of property [22]. According to Safety, Health and Working Environment Act 2011, employers need provide safety-working conditions for employees, and the employer must be responsible for all operating cost [23]. The research in [24], the accident in factory occurs by many causes. According to [25], the most accident in factory of Thailand during 2001-2016 is fire because of short circuit inside the factory about highly 66%. Considering the accident by fail electrical system [26], it found that the most risk rating occurs in breaker and following indoor wire for low voltage equipment, while high voltage equipment; transformer is the most occurring accident. The damage of electrical accident injure directly on life of worker as shown in [27]. Moreover, the electrical accident yet damages the property as shown in [28]. The effects of electrical accident always are explained by iceberg theory as presented in [29]. By iceberg theory, the damages can be classified into two types; direct losses and indirect losses. Direct losses mean the directly expense cost for the injured person which include medical fees, compensation, funeral sup. Indirect losses are other expenses excluding the direct costs for each victim. The indirect losses such as for example the Loss of working time, Cost of repairing of the damaged machinery and equipment, and Wages of the injured workers paid by the factories despite the inability to work [30][31][32].

The well electrical system safety prevents effectively accident. Moreover, it effects on stable of system. It also reduces breakdown product. Hence, the safety is more needed [16][17]. To safety on works and property, electrical system should be always inspected. In 2018, there is about 50% of factory and building not passes inspection because the system is not standard so it showed not safety [33]. Therefore, these factories and building is not approved for electricity distributing by electricity seller standard MEA (Metropolitans Electricity Authority) and PEA (Provincial Electricity Authority) following in [19]. That means they do not run the process. They effects on export product to abroad and income to the country too. Although, there are technicians for checking the electrical system in factory, sometime may be not enough because they lack of experience and sometime are neglected. The important thing is the technician should really know problems, solutions and suitable maintenance plan.

Therefore, this research presents inspection of electrical safety case study in four factories. The four locations are observed such as two paper factories and two food animal factories. The objectives of this research include study the problems which may be occurred in electrical system and suggest the prevent ways.

2. METHODOLOGIES

The research was conducted on electrical systems of four factories. The inspected sectors consist of transformer, main distribution board (MDB), ground system and electrical wire system. The inspection of deterioration was inquisition by four senior engineers who decided together. The standard instruments were calibrated before experimental testing. The tools and instruments included transformer test oil maker, thermo scan, earth clamp tester, earth ground tester, infrared tester and outlet tester.

Inspected Four Factories Locations

The research focuses on inspection of electrical safety system in factory. Therefore, four factories were surveyed. The demand load transformers are shown in Fig. 1. The installed transformers of four locations are shown in figure 1. There are two types of factory; 2 paper factories and 2 food animal factories.

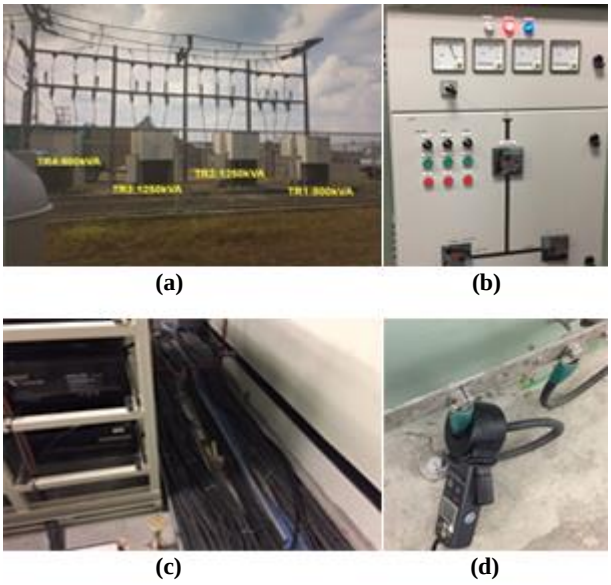
(a) **(b)**

(c) **(d)**

(a) 18450 kVA Transformer of 1st Paper Factory
(b) 13450 kVA Transformer of 2nd Paper Factory
(c) 800 kVA Transformer of 1st Food Animal Factory
(d) 1000 kVA Transformer of 2nd Food Animal Factory

Fig. 1: Inspected Four Factories Locations.

The first factory located on Prachin Buri Province is paper factory which total load transformer capacity is about 18,450 kVA. There are ten transformers which of installation is shown in Fig. 1(a). Second factory located in Samut Prakan Province is paper factory which total load transformer capacity is about 13,450 kVA. There are nine transformers whom installation is shown in Fig. 1(b).The third factory is animal food factory. Its electrical load is about 800 kVA. There is just one transformer whom installation is shown in Fig. 1(c). This factory locates on Chachoengsao Province. The forth factory is animal food factory which its electrical load transformer is about 1,000 kVA. It is just only one transformer which of installation is shown in Fig. 1(d). This factory locates on Bangkok.



(a) **Transformers**
(b) **Main Distribution Board (MDB)**
(c) **Wire System**
(d) **Ground System**

Fig. 2: Inspected Sectors of Electrical System

Inspected Sectors of Electrical System

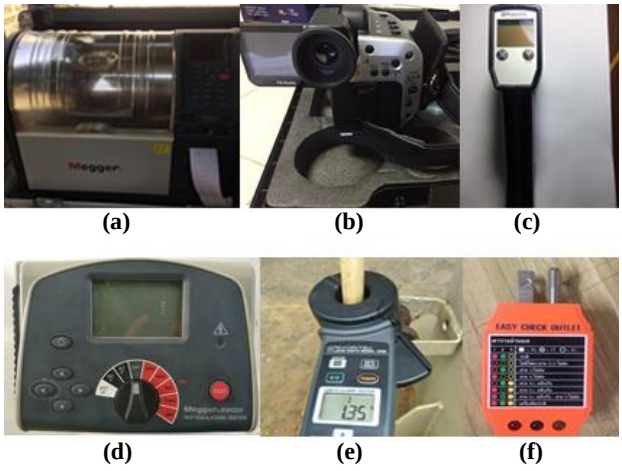
In electrical system of factory, there are inspected four sectors which consist of transformer, main distribution board, ground and electrical wire. For checking the safety system on electrical system, there are physical checking and technical checking. Physical inspection is general outside of equipment which investigated by visual. The inquisition depends on senior engineers. Technical inspection is the test using instrument. The checking of transformers include oil insulation, high voltage bushing, low voltage bushing, silica gel, rubber shield, rubber gasket, transformer tank. For main distribution broad (MDB), the checking lists include physical box, circuit breaker, bus bar, junction, wire, installation safety distance, thermo scan and lighting. The checking of ground systems include physical ground wire, ground value, ground junction, wire size and ground rod. The checking lists of electrical wire include physical wire, type and size, thermo scan, junction and installation.

Test Instrument

The instrument testers are shown in Fig. 3. They were used checking in the part of technical inspections consisted of 6 types; test oil maker, thermo scan, earth clamp tester, earth ground tester, infrared tester and outlet tester. The details of instruments testers are shown in Table 1. All testers were calibrated with standard meter before they are measured in this research. All instruments were discussion in the same steps by four senior engineers to form the same way of measurement.

Table 1: The Lists of Instrument Tester

Instruments	Testing	System
test oil maker	Dielectric	Oil transformer
thermo scan	Heat	Transformer
earth clamp tester	Ground	Ground of Transformer
earth ground tester	Ground	Ground of MDB
infrared tester	Heat	CB, bus bar, wire



(a) Test Oil Maker **(b) Thermo Scan**
(c) Infrared Tester **(d) Earth Ground Tester**
(e) Earth Clamp Tester **(f) Outlet Tester**

Fig. 3: Instrument Testers.

Test Procedure

This research focuses on inspection of electrical safety of electrical systems in four factories. In order to confirm the diagnosis the right, there are four inspectors as senior engineers. They are divided into two teams. Each team consists of two senior engineers who have at least 10 years' experience. Each team would inspect in the same area and

after that all results would be discussed in the meeting together. The summary of meeting is an answer of research. The process steps are shown in Fig. 4.

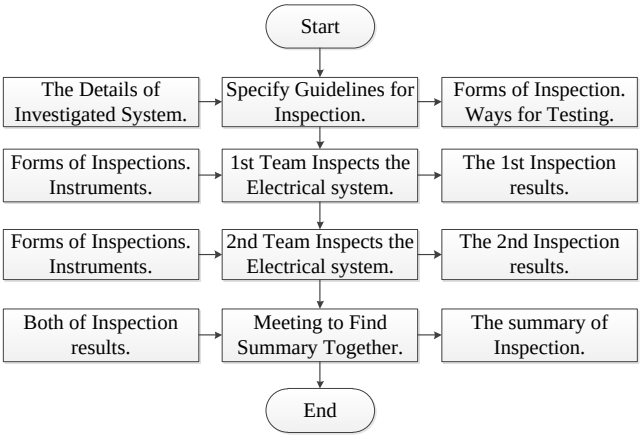


Fig. 4: Steps of Inspection

The checking process starts with specify the way of inspection together. By process, the form and instrument are selected. Then schedules are set. Both of teams would check in the same factory. After two teams finished, all results are brought to discuss together. Finally, the summary of inspection is found out. The risks and equipment deteriorations is the answer. The ways to improved are suggest.

3. RESULTS AND DISCUSSIONS

From the inspection of electrical systems in four factories, amount of damages and deteriorations are shown in Fig. 5. Overall, the most damage or deterioration is in transformers about 53%. The second deterioration is in main distribution board (MDB) approximately 29%. The next is wire system at 14% and the final deterioration is in ground system about 4%. Transformers are outdoor equipment which majority devices are affected by environment; solar, rain, wind storm and so on. Therefore, devices are risk to deteriorate. Transformer should always be checked and done maintenance to prevent probably damage. The cost of transformer is expensive while maintenance cost is much cheaper than a new transformer replacing cost. The second equipment deteriorations are found in main distribution board (MDB). Although, MDB is inside close room, this electrical device is as pass all more electrical energy. Moreover, there are injunction between main wire and branch circuit. Therefore, they are heat and in long term the nuts or injunctions are loose. These bring probably accident from heating. Also, wire system is used a long time, the loose of injunctions are occurred by heating. But the wire system's injunction is less than MDB's, so the risks or problems are less than one also. On the other hand, ground system is the last because it is the least affected by environment. Therefore, deterioration of electrical system can be sort by amount as following transformer, MDB, wire and ground respectively.

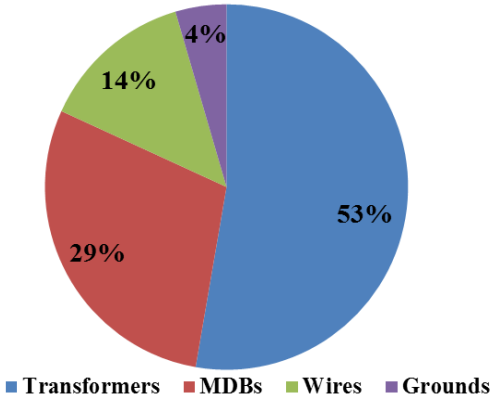


Fig. 5: Inspection of Electrical System in Factories.

Transformer

Based on the electrical safety inspection, it is found that there were equipment deteriorations in transformer among four factories. The lists of risk deteriorations are found as shows in Table 2. The 1st paper factory found fully deteriorations as lists of deterioration (as Table 2).The 2nd paper factory is different. They are not appeared silica gel box broken. While, both of animal factories are not found rust on transformer tanks, silica gel box broken and high voltage bushing broken. According to technicians factory responses, both of animal food factories is just a transformer so it is easy on observation and maintenance. While both of paper factories have many transformers so, although, the problems are found, there are so difficult to maintenance because sometime amount of deteriorations is not more. From Fig. 6, it is noted that the frequent deteriorations are less dielectric of oil, silica gel deteriorated, rubber shield deteriorated and rubber gasket deteriorated about each of 17%. The next are transformer tank occurring rust, transformer tank oil leak and high voltage bushing broken approximately each of 9%. The final deterioration is silica gel box broken at 4%. By the way, it is found that they are classified into two types; frequent deteriorations and infrequent deteriorations. For frequent deteriorations, they include less dielectric of oil, silica gel deteriorated, rubber shield deteriorated and rubber gasket deteriorated. On the other hand, infrequent deteriorations consist of transformer tank oil leak, transformer tank occurring rust, silica gel box broken and high voltage bushing broken.

Table 2: Inspection of Transformers

The List	F1	F2	F3	F4
Transformer tank occurring rust	✓	✓		
Transformer tank oil leak	✓	✓	✓	✓
Less dielectric of oil	✓	✓	✓	✓
Silica gel deteriorated	✓	✓	✓	✓
Silica gel box broken	✓			
Rubber shield deteriorated	✓	✓	✓	✓
Rubber gasket deteriorated	✓	✓	✓	✓
High voltage bushing broken	✓	✓		

Note: F1 is 1st paper factory with 18,450 kVA transformers.
F2 is 2nd paper factory with 13,450 kVA transformers.
F3 is 1st animal food factory with 800kVA transformer.
F4 is 2nd animal food factory with 1000kVA transformer.

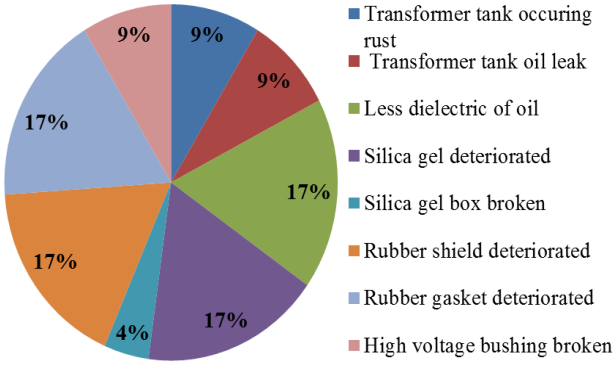


Fig.6. Inspection of Transformers

(a) Rubber Gasket Deteriorated (b) Less Dielectric of Oil
(c) Rubber Shield Deteriorated (d) Silica Gel Deteriorated

Fig. 7: Deteriorations in Transformers.

From the results, the frequent deteriorations would be usually checked and done maintenance. The plans of these cases are routine. Budget and material should be prepared. The examples of deteriorations show in Fig. 7.

Main Distribution Board

Table 3 shows results of inspection in four factories. It is found that there were four deteriorations. The factory found the fully four deteriorations is 2nd animal food factory. The deteriorations occurred in all four factories are more dust and terminal loose. The case of circuit (CB) heat is found the less which not appears 1st-3rd factories. The four deteriorations are the causes of electrical energy loss which waste an energy cost without benefit. Moreover, they are the causes of fire accident because the loss generally brings the heat. Therefore, heat accumulation in the long time is probably the cause of fire. In the case of more dust, this case it blocks the flow heat dissipation. Then, heat accumulation is higher continuously. It is the loss and fire accident also.

Table 3: Inspection of MDBs

The List	F1	F2	F3	F4
More dust	✓	✓	✓	✓
Nut of CB loose		✓	✓	✓
Terminal loose	✓	✓	✓	✓
Case of CB heat				✓

From Fig. 8, it is found that the majority of deteriorations in main distribution board include more dust and terminal loose about each of 34%. The next is nut of circuit breaker (CB) loose approximately 25%. And the final deterioration is case of circuit breaker (CB) heat at 8%. Therefore, they are also classified into two types; frequent deteriorations and infrequent deteriorations. They are more dust, nut of CB loose and terminal loose as frequent deteriorations. While, infrequent deterioration is case of CB heat.

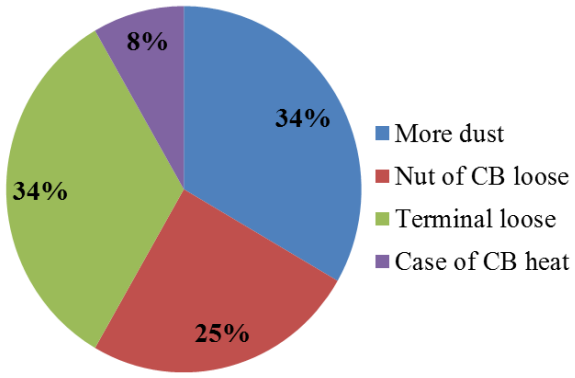
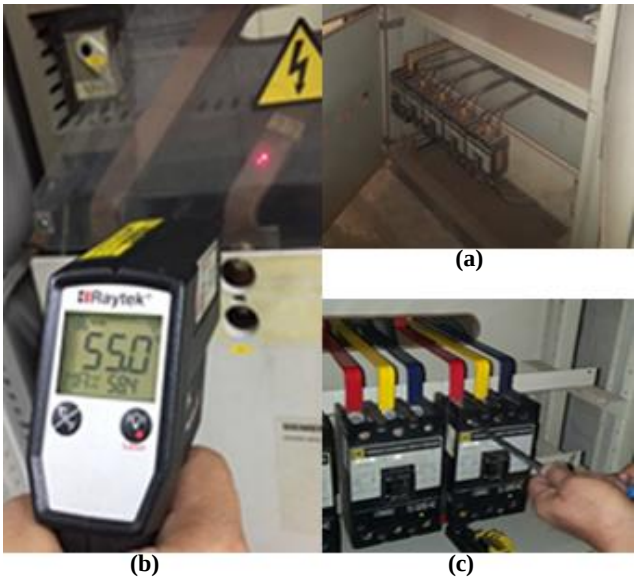


Fig. 8: Inspection of Main Distribution Boards.

However, all deteriorations of main distribution board are maintained by technicians of factory because the tools and equipment are not complex. Moreover, the cost of tools is lower than in the case of transformer. The checking and maintenance are usually done as routine at least 3-6 months a time. The examples of deteriorations and checking are shown in Fig. 7.



(a) More Dust **(b) Heat Checking**
(c) Nut of CB Loose

Fig. 9: Deteriorations in Main Distribution Boards.

Ground system

Table 4 shows the lists of electrical ground inspection in four factories. Overall, the first paper factory was found all types of deteriorations for the lists in Table 4; ground injection broken, less ground value and ground wire heat. Second paper factory was found less ground value and ground wire heat. While, 1st animal food factory not appeared any deteriorations. Second animal food factory found the risk occur high resistance ground value and ground wire heat. The majority of deteriorations were found in both of paper factories because of large system when compare with another two animal food factories. However, the problem in ground is the least. The Fig. 10 shows the rate deterioration in ground system. It is found that the most deterioration of ground is less ground value approximately 60%. The next is ground wire heat at 35%. Moreover, the final deterioration is ground broken about 5%. Also, the types of deteriorations in ground system can be classified into two groups; frequent deterioration and infrequent deterioration. Frequent deteriorations consist of less ground value and ground wire heat. Infrequent deterioration is such ground injection broken.

Table 4: Inspection of Ground Systems

The List	F1	F2	F3	**F4**
Ground injection broken	✓			
Less ground value	✓	✓		✓
Ground wire heat	✓	✓		✓

Fig. 11 shows some example of deterioration in ground system. The ground system is much important on safety system because it prevent the harm on people. Generally, according the standard installation [19], the ground resistance has to be lower than 5 Ω. But Fig. 11(b) the resistance is 13.89 Ω which is high. That means the ground value is low. If the leak current occurs in the system, leak current is inconvenience pass to ground. Probably, the current flows in to people who work at that area. These risks probably injury or dead on people life. The solution to increase ground value is ground rod adding in the ground system. It helps increase the current area flow convenience and the resistance of ground is reduced.

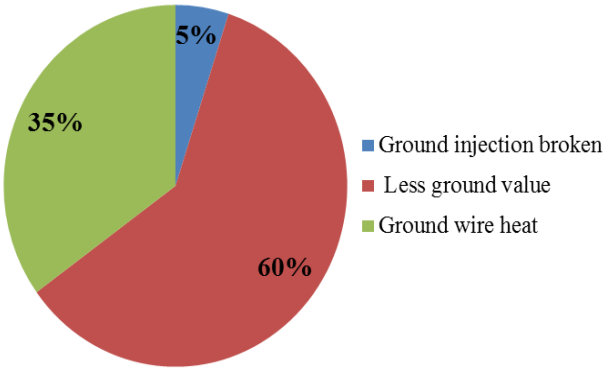


Fig. 10: Inspection of Ground Systems.

In the case of ground wire heat, it causes an effect on ground resistance is high up because heat in metal conductor has effect on resistance increasing. Therefore, leak current is difficult flowing to ground and current may be danger worker. Considering the reason why ground wire

heat, the cause occur unbalance in three phase electrical system. Unbalance electrical system, some current would flow in ground wire which sometime is higher than the current rate of ground wire. Generally, ground wire is lower than power line wire. Therefore, the heat occurs because of overload. The solution is balance load performance. Finally, ground broken is the least occurring. The cause is overshoot probably by lightning impulse surge or over voltage switching. The very much current run to ground until ground wire damage. For this case, leak current difficultly flows to ground. Probably, the leak current injures people, if people touch it. The solution replaces a new ground wire. Although, deteriorations of ground system occurs less, technicians should check them in the routine.

(a) **(b)**

(a) Ground Injection Broken **(b) Less Ground Value**

Fig. 11: Deteriorations in Ground

Electrical Wire

Table 5 shows the results of inspection in electrical wire system. The amount of deteriorations types were mostly found in both of animal food factories. While, both paper factories found also wire insulation broken only. It is investigate that the wire damaged by animal (Rat) found in both animal food factories. Second animal food factory found fully types of deteriorations.

Table 5: Inspection of Electrical Wire

The List	F1	F2	F3	F4
Less than required load			✓	✓
Heat in wire				✓
Insulation broken	✓	✓	✓	✓
Wire injunction loose			✓	✓
Damaged by animal			✓	✓

From Fig. 7, it is found that the most found deteriorations of electrical wire are wire insulation broken approximately 34%. The next are wire less than required load and wire injunction loose approximately each of 22%. Finally, they are heat in wire and wire damaged by animal about each of 11%. From the investigation, it is found that the majority of problems caused by leak of maintenance and checking. First of all, the electrical wire is match with requited loads. But in a period, factory plan expend, so amount of load is increased while, size of electrical wire is not changed. Therefore, the wire is loaded higher until near the maximum rate or overload. These caused wire heat. Considering another wire path (Wire way and Tube), it is found that some space is less. Then space of air flow is less. Heat dissipation is difficult. Heat is high up. Then, insulation is deteriorated and damaged. Moreover, the heat in system causes the wire injunction loose also because of metal expansion and restraint. If the injection loosed the heat is occurred also. These causes usually risk a fire accident. In the case of wire damaged by animal, majority of cause is rat. They bid a wire, then wire leak current so, it is fault in electrical system. This causes danger on people on area. Not only the accident but it is loss of energy also. Therefore, maintenance should be done always.

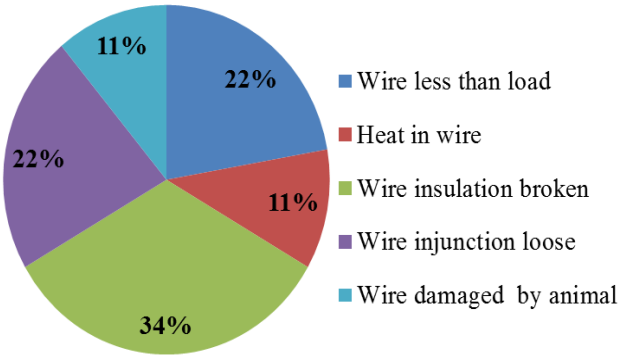


Fig.12. Inspection of Electrical Wire

From all found deteriorations in wire system, there are types of deteriorations; frequent deteriorations and infrequent deteriorations. Frequent deteriorations, they include wire insulation broken, wire injunction loose and less than required load. For infrequent deteriorations, they consist of heat in wire and wire damaged by animal. Therefore, technicians of factory should focus in the point. The frequent deteriorations should realize and do routine check.

(a) **(b)**

(a) Insulation broken **(b) Damaged by Animal**

Fig. 13: Deteriorations in Wire Systems

From the research, it is recommended that technicians should do maintenance. Frequent deterioration should be focus and plan the budget for checking and maintenance about 3-6 month a time. While infrequent deterioration should be done maintenance about 8-12 month a time.

4. CONCLUSION

All results above can conclude as follows.

1. Considering the risks or equipment deterioration in the electrical system in four factories, the findings reveal that the most occur in transformer about 53% and the next is main distribution board (MDB) about 29%. The deterioration of wiring is about 14% and the ground system is quite less at 4%.

2. The risks and equipment deteriorations which found in transformer include less dielectric of oil insulation, silica gel deteriorated, rubber shield and gasket broke about each of 17%. The next is rust on transformer tank, oil leak of transformer tank and bushing broken approximately each of 9%. Finally, it is silica gel the last at 4%.

3. The risks and equipment deteriorations in the main distribution board are more dust and terminal loose about each of 34%. The next is the nut of air circuit breaker loses approximately 25%. The last is heat on the case of air circuit breaker about 8%.

4. The risks and deteriorations of ground systems are found. It is found the most deterioration of ground is less ground value approximately 60%.

The next is ground wire heat at 35%. Moreover, the final deterioration is ground broken about 5%.

5. For risk and deterioration, it is found that the most found deteriorations of electrical wire are wire insulation broken approximately 34%.

The next is wireless than required load and wire injunction loses approximately each of 22%. Finally, they are heated in wire and wire damaged by an animal about each of 11%.

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