The Electricity Systems Inspection Case Study for Electrical Substations in Thailand

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ABSTRACT

This research focuses on electricity system inspection for electrical substation. The research objectives are to study the problems or devices deteriorations occurred in electrical substation and to suggest the solutions. Finally, these bring suitable prevention. Four electrical substations in Thailand are observed. There are two types of systems including gas insulation substations (GIS) and air insulation substations (AIS). The four electrical substations include two systems of 69 kV, a system of 115 kV and a system of 230 kV substations. All observed substations are responded by Metropolitan Electricity Authority (MEA) hence, they are located in Bangkok and perimeter. The investigated devices consist of transformers, switch gears, capacitor banks and battery backups. There are four senior engineers as inspectors. They are separated into two teams; each of two persons. Diagnoses are obtained by four senior engineer's discussion. The inspection consists of physical and technical checking. For physical checking, it is outside investigating feather seeing. For technical checking, the instruments are needed. There are test oil maker, thermo scan, earth ground tester, voltage meter and capacitance meter. The data of four substations are gotten for 2 years. For inspection results, it is found that the most device deterioration or damaged occur in transformer about 60% of all. The next are switch gear, capacitor bank and battery backup at about 20%, 15% and 5% respectively. The transformer deteriorations consist of oil leakage, oil level gauge defective, phase protection damage, and control set damage respectively. The switch gear deteriorations are such as high humidity in SF_6, hydraulic pump leakage, damper seal CB leakage and finally counter damage respectively. Deteriorations of capacitor bank include oxide on junction, battery cell damage and finally capacity reduced. Finally, deteriorations of battery backup are timer damage and capacitor damage.

1. INTRODUCTION

Firstly, human find energy source for survive. Human used with food, solar and fire until the 1820 the age of the energy transition started [1]. This age, the fossil energy is transferred to another source for example steam engine. The fossil energy has been more consumed continuously [2][3][4]. This is corresponding with amount of world people is increasing about the rate of 1.16% between 2005 and 2010 [5]. Not only that but also energy sources are used for spread of industries [6]. Presently energy form is mostly in the electrical energy from because this form is easy to transfer to another energy form for example heat, wine, and light [7]. In 1832, the first world electricity generator was created by Michael Faraday [8]. In 1879, Thomas Edison invented electrical lamp successfully [9]. After that electricity has become much important running the world [10]. According to [11][12], it is found that the electrical energy consumption directly effects on countries development. Eventually, electrical energy becomes an important factor of human life.

By the way, the world electrical energy was consumed increasingly [13]. The world electricity consumption during 2000-2015 increased from 13,173 TWH to 20,568 TWH about 56% [14]. According to [15], Thailand, electricity generation of Thailand, it is found that the quantity increased 22% in ten years during 2008-2018. It is investigated that increasing rate is high clearly and it intends high up continuously. Refer to PDP [16] (Power Development Plan 2015-2036), Thailand, electrical power demand would be 70335 MW in 2036. On the other hand, the generating capacity is 37612 MW which data on December 2014. The gap is high distant at 32723 MW or about 87%. That means electricity power plant would be built more. Moreover, electrical substation and related devices would be more requited also.

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Considering electricity consumption over a period of 20 years (2002-2020) [17], it is found that sector of industry is the most consumption at approximately 46%. The next are commercial and public services, and residential sectors with shares 32% and 22% respectively. It is investigated that these sectors is the index of country development. They intend increase gradually. The electricity demand grows continuously also [4]. Therefore, the electricity generation process is very important factor for driving country. The example in [18], electricity station is blackout Malaysia, 1996, the period is 16 hours which this damage economic and business not less than 41 M$ (US. dollar). The cause was occurred by problem generation system disconnected from system. According to [19] the blackout in Thailand 2013 because of lighting in wire system, on 14 June, the blackout phenomenon for 2 hours occurred in southern Thailand covering 14 provinces. This damaged economic and business approximately not less than 300 M$ [20]. If the system well stability, the loss may be less than one. The well electricity system should be steadily and stability because if the trouble occurs, it brings a large loss. Especially, in the case of blackout, such is our dependency that our comfort, security, communication systems, transport, health, food supply, businesses and social equity systems strain when electricity supplies are interrupted [21][22][23]. According to [23], number of power outages recorded in different parts of world, it shows that the number of outages recorded in Asia was more than other area around the world. The average time taken during each outage was 4-6.5 hours which much longer than the other areas expect Latin America and Caribbean (The average is 8 hours). Fig. 1 shows the causes of power outages around the world.

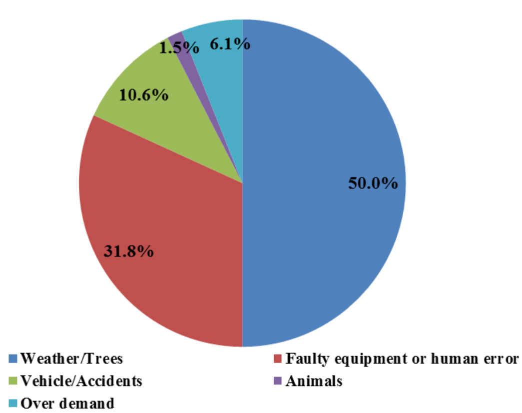


Fig. 1. Causes of blackouts since 2011 to 2019 [24].

From Fig. 1, the most cause is occurred by weather/three at about 50.0%. This case cannot stop it but protection and warning systems should be installed order to solve immediately. The next cause is faulty equipment or human error at about 31.8%. This brings power outages problem and the accident. Moreover, the electricity faulty is no safety, it brings the dangerous; fire accident, or people die by electricity [24][25]. Severally, the power outage occur from unstable system which caused by neglect checking and maintenance.

The electricity system is becoming important thing so engineer should always have checking and maintenance [7]. Especially, big system for example factory, big building and so on, the devices is complex and need checking precisely. The electrical substation is the point of distribution system which high voltage from transmission line is step down to low voltage. And after that it is distributed to all loads; house, factory, building etc. To the electrical energy is distributed continuously, the system should be inspected by professional which corresponding with standard [26][27][28]. The safety system is the good system which effect on stable of system also. Moreover, safety systems protect accident; fire or damage, breakdown production. Hence, it is seen that the safety is more needed and it should be checked always.

Presently, the factory and business building are more expand continuously [29] so substation is constructed more. Electrical substation systems consist of 69kV, 115kV and 230kV [7]. The system includes transformer, switch gear, capacitor bank and battery backup. According [30][31], the electrical system be need inspected. However, substation responded by Metropolitans Electricity Authority (MEA), Thailand, it is still power outage which one important problem occurred by faulty of equipment [32]. According to [33], the in high voltage wiring problem analysis, it is found that the most cause is deterioration in equipment. MEA and PEA also are inspected all system especially substation. Always, they need the new member, they lack of experience. Moreover, some information or point which should be focus may be neglected. The important thing is the technician should be known that problem and the solving.

Therefore, this research presents inspection for electrical substation system. The four substations are observed. The objectives of this research are to study the problems which may be occurred in electrical substation and introduce the prevent ways.

2. METHODOLOGIES

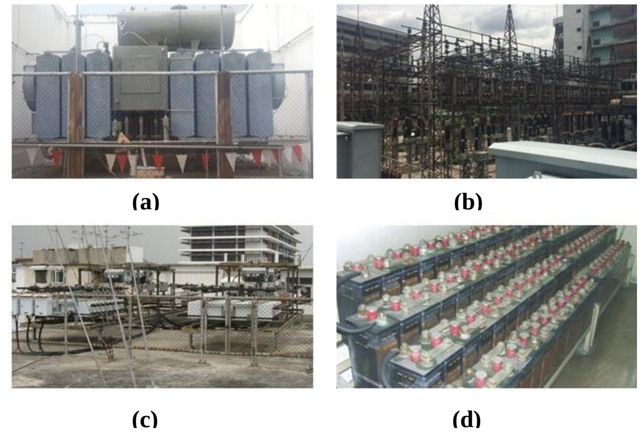
The research is inspected in four electrical substations. The inspected sectors consist of transformer, switch gear, capacitor bank and battery backup. The inspecting is performed by four senior engineers who do diagnosis together. The standard instruments are calibrated before implement. The check instruments include test oil maker, thermo scan, earth ground tester, infrared tester, capacitance meter and voltmeter. The research period in this paper is done for two years. All data is present on the term of statistic.

2.1 Observed Four Substations

There are four electrical substations which were chosen for inspection. There are two types; GIS (Gas insulation substation) and AIS (Air insulation substation). Their voltage system levels consist of three voltage levels including 69 kV, 115 kV and 230 kV electrical substations. All four locations are electrical substations of middle regional Thailand only. The first two substations are 69 kV voltage levels substation. They are GIS substations types. Both of them use SF_6 as insulator which insulation value is more than air so GIS substation's installation area is less than AIS's. They are installed in close area, in the building. One is place in 0.40 acre in area while other one is in about 0.28 acre in area. The other two substations are AIS substations. They consist of 115 and 230 kV voltage level substations. The 115 kV AIS substation is placed in area of 1.98 acre while 230 kV AIS substation is installed in area of 3.95 acre. The AIS substation used air as insulator and heat transfer. Both of them are near street so many vehicles run always, it makes the dust. Moreover there are many bird stay in night. They are flat area so they are risk of thunder. In the case of maintenance, generally, the routine maintenance is performed following MEA standard. However, some deterioration still be found. Therefore, the research studies the damage or deterioration in electrical substation under general running condition with general routine maintenance. The results show the problem or deterioration which found and still neglect.

2.2 Inspected Sectors of Electrical substation

The inspected sectors in electrical substations include four sectors; transformer, switch gear, capacitor bank and battery backup which are shown in Fig. 2. For checking the problem and deterioration of each sector of electrical substations, there are two checks; physical inspection and technical inspection. Physical inspection is general outside of equipment which investigated by visual. The inquisition depends on senior engineers. Technical inspection is the test using instrument. In the sector of transformer, the checking lists include oil insulation, ground, high voltage bushing, low voltage bushing, silica gel, rubber seal, rubber gasket, transformer tank, oil gauge, phase protection and control set. In the sector of switch gear, the checking lists include SF_6 humidity, partial discharge, pressure gauge, pressure gas, hydraulic pump, CB damper seal and finally counter. In case of capacitor bank, the checking lists include physical check, connection, the capacitance value and timer. In the sector of battery backup, the checking lists include physical check, battery capacity and connection.



(a) Transformer **(b) Switch Gear**

(c) Capacitor Bank **(d) Battery Backup**

Fig. 2. Inspected Sectors of Electrical substations.

2.3 Instrument Testers

The instrument testers consist of 9 types for technical checking; test oil maker, thermo scan, earth ground tester, infrared tester, capacitance meter, volt meter, SF_6 analyzer, micro ohm meter and transformer test. Fig. 3 shows all 9 instruments. 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 discussed in the meeting order to form the same steps of measurement by four senior engineers. The instruments would be measured 10 times for each device. The average value is calculated. Each substation is inspected 2 times by two teams; each team consists of 2 senior engineers. All values of measurement are compared and confirmed the right results.

Table 1. The Lists of Instrument Testers

Instruments	*Testing*	*System*
Test oil maker	Dielectric strength	Oil transformer
Thermo scan	Heat, Discharge	High voltage transformer
Earth ground tester	Ground	Ground of Transformer
Infrared tester	Heat	Connection of system
Capacitance meter	Capacitance	Capacitor bank
Multi meter	Battery capacity	Battery backup
SF_6 analyzer	SF_6 gas insulation	Switch gear
Micro ohm meter	CB resistance	Switch gear
Transformer test	Electrical value	Transformer

(a) Test Oil Maker **(b) Thermo Scan**
(c) Earth Ground Tester **(d) SF_6 analyzer**
(e) Capacitance meter **(f) Micro ohm meter**
(g) Transformer test **(h) Infrared Tester**
(i) Multi meter

Fig. 3. Instrument Testers.

2.4 Test Procedure

This research focuses on inspection of electrical substations case study in four substations; two AIS and two GIS substations. The results of diagnosis are obtained by four inspectors as senior engineers. All inspectors have 10 years' experience in the field of electrical system inspection. They are grouped into two teams. Each team would inspect in the same area and after that all results would be discussed in the meeting order to consider the results together. The process steps are shown in Fig. 4. To start, four inspectors would survey in area and then they have meeting to specify the forms of inspection together. After that each team inspect in the same area. Finally, the results of each team would be discussed in meeting together.

There are 2 checking types including physical and technical inspections. The instrument are selected the same. The checking steps are planed together. Finally, the summary of inspection is found out. The risks and equipment deteriorations are the answer. The ways to improved are suggest.

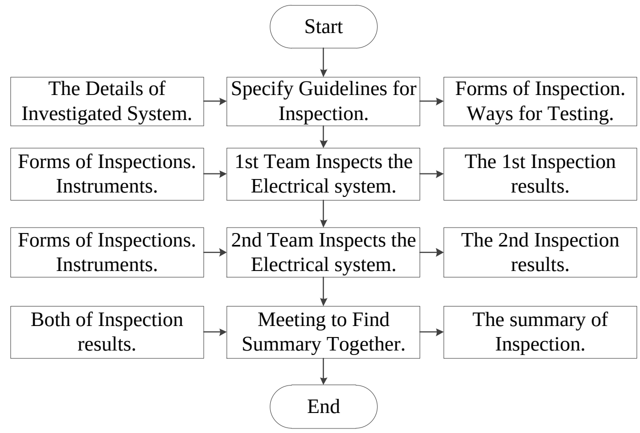


Fig. 4. Steps of Inspection.

3. RESULTS AND DISCUSSIONS

3.1 Substation

From the inspection of electrical substation in four stations, percent of damages and deteriorations are shown in Fig. 5 which it considers only number found deterioration. Overview, the most damage or deterioration is in transformers approximately 60%. The next deterioration occurs in switch gear about 20%. The third deterioration is battery backup at 15% and the final found deterioration is in capacitor bank about 5%.

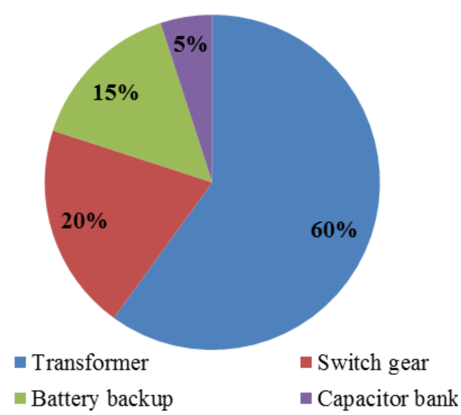


Fig. 5. Inspection of Overall Substations.

In this research, the systems consist of AIS and GIS substations therefore transformers are installed both of outdoor and indoor places. The majority of deterioration occurs in the AIS substation which their transformers place outdoor. The 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 in switch gear. Switch gear consists of the main open/close circuit devices. The devices are move to close or open circuit so it probably sparks and arcs occurred. Therefore, arc quenching and movement devices always deteriorate. On the other hand, both battery and capacitor are two last deteriorations. Mostly, they are damage by lift time. Therefore the system should focus carefully the first is transformer and the next are switch gear, battery backup and capacitor bank.

3.2 Transformer

As the inspection of four electrical substations, although, the substations are performed monthly and yearly routine maintenance, it is still found that there are deteriorations occurred in transformers. There are four deteriorations as shown in Fig. 6. The results show that deteriorations consist of oil leakage, oil level gauge defective, phase protects damage, and control set damage. The most problem and deterioration is oil leakage about 60%. The second deterioration is oil level gauge defective approximately 18%. The next two problems are phase protection damage and control set damage at about 12% and 10% respectively. Some deterioration in transformers are shown in Fig. 7. For problem of oil leakage, the oil in transformer is used as insulator and heat transfer. The problem of oil leakage is caused by rubber seal deterioration. Transformer which have high electrical load period, the heat is also high. Then, oil is hot especially if the electrical load over 80% of rate. The rubber seal of transformer, which sinks below hot oil in the long time, is probably deteriorated before suitable life time. Therefore, the load of transformer should not more than 80% of rate. If oil leakage occurs, it effects on heat transfer. The transformer is higher up rapidly probably over heat and defective. Therefore, it should be done maintenance immediately.

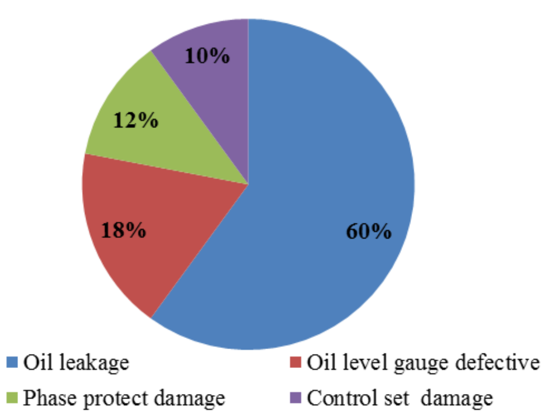
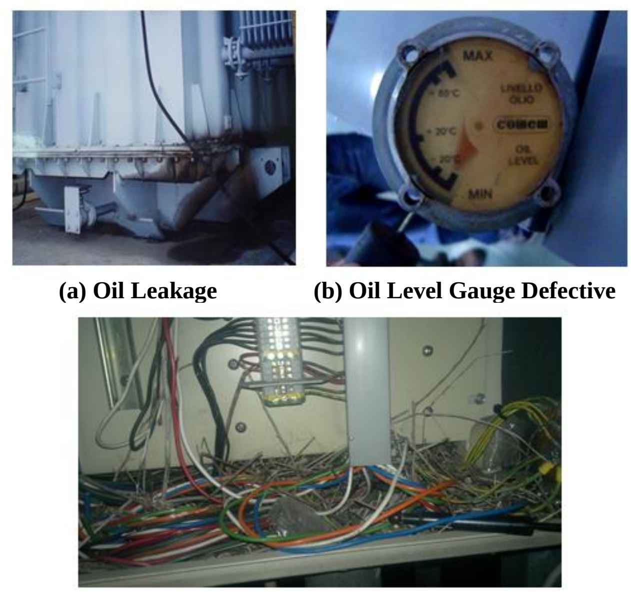


Fig. 6. Inspection of Transformers.

Because cost of new transformer is large more expensive than maintenance cost, the problem should be solved instantaneously. In the case of oil level gauge defective, generally the gauge is defective by life time. The gauge is important for routine checking. It should be calibrated for measuring precisely. If this gauge defective, the value of oil level is not the right check. Therefore the oil may be leakage, and then the insulation and heat transfer are not enough. This case probably breakdown and over heat in transformer. In the case of phase protection and control set damage is found the less. However, it is the most important because it protects the loss and damage in the case of emergency or accident. If the protection and control is not run in the case of faults, not only transformer is damaged but other equipment also.



(a) Oil Leakage **(b) Oil Level Gauge Defective**

(c) Control Set Damage

Fig. 7. Deteriorations of Transformer.

3.3 Switch Gear

In this section the deteriorations in switch gear of four electrical substations are inspected. Although they are done routine maintenance, they are still found deteriorations including high humidity in SF_6, hydraulic pump leakage, damper seal CB leakage and finally counter damage. The inspection of four electrical substations in switch gear is shown in Fig. 8. It is found that the most found deterioration switch gears are high humidity of SF_6 about 50%. The second deterioration is hydraulic pump leakage at about 25%. The next is CB damper seal leakage approximately 15%. Finally, counter damage is the last about 10%. By the way SF_6 insulation gas, it is used to quench the arc in circuit breaker of switch gear. If the gas is high humidity, the SF_6 gas insulator is low characteristic of insulation and arc quenching. Therefore, in the case of open or close circuit by breaker, the arc occur high harsh arc. These effects on the fire or blast in switch gear. This brings the breakdown in system and damage in equipment. Moreover this probably brings blackout around the area. For hydraulic pump, it is used to be force for drive breaker open/close circuit. The force is occurred by oil pressure. Therefore, in the case of leakage, the force is less depending on the oil, then it cannot drive breaker. This is problem because the electrical system is not close and open anytime it needed. It should be changed immediately. For CB (Circuit Breaker) damper leakage, it occurs from oil is leakage so the pressure to force breaker close/open is less. While the force of hydraulic sends to breaker, the leakage CB damper is not send the force to close or open circuit. The CB is harsh vibrated. This CB is damaged. The hydraulic and CB damper leakage are shown in Fig. 9. In the case of counter, it is used to count the number of close and open circuit breaker. Generally, the breaker should not often open and close because the arc would damage it. So, the number of close and open is limited for maintenance. If the counter damage, it is not sure the time to maintenance.

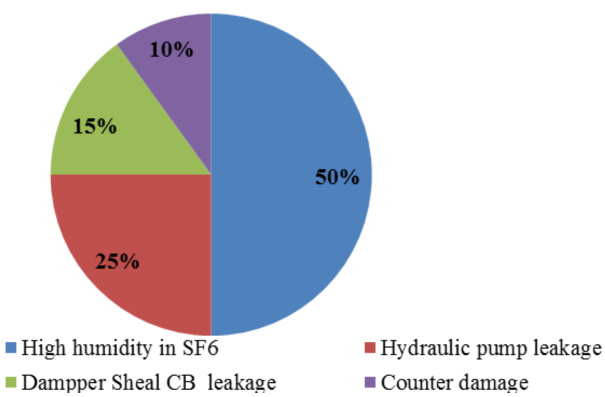
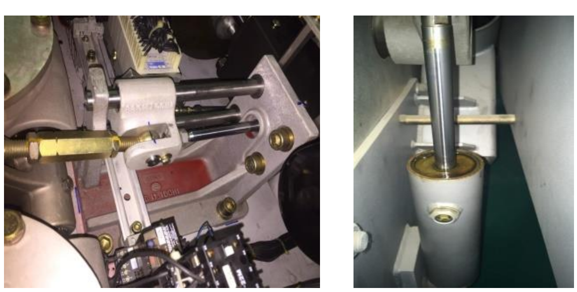


Fig. 8. Inspection of Switch Gear.



(a) Hydraulic pump leakage (b) CB damper leakage

Fig. 9. Deteriorations of Switch Gear.

3.4 Battery Backup

In this section the deteriorations in battery backup of four electrical substations are inspected. Although they are done routine maintenance, they are still found deteriorations including oxide on junction, battery cell damage and finally capacity reduced. The inspection of four electrical substations in battery backup is shown in Fig. 10. It is found that the most deteriorations or risk are two behaviors including oxide on junction and battery capacity reduced at the same about 40%. Finally, one is battery cell damage at about 20%. The battery in substation is used to energy storage in the case of power outages. The conserved energy is important on stability of system especially emergency case. When they are not used in the long time, they may be neglected to maintenance. From inspection, it found that the oxide occur on terminal as shown in Fig. 11. This problem causes on the efficiency directly of battery. The oxide effect on conductance condition of connector is lower. So the current distribute is low also. If they are neglected, battery life time is shorter than it should be. They should be clean in routine. The capacity of battery reduces because of lake of maintenance and maybe it occurs by life time. Generally, battery life time is about 3-6 years. Battery should be not used still loss out energy storage. This causes on life time also. The terminals of battery are cleaned in the routine. The place of installation should be dry which avoid high humidity.

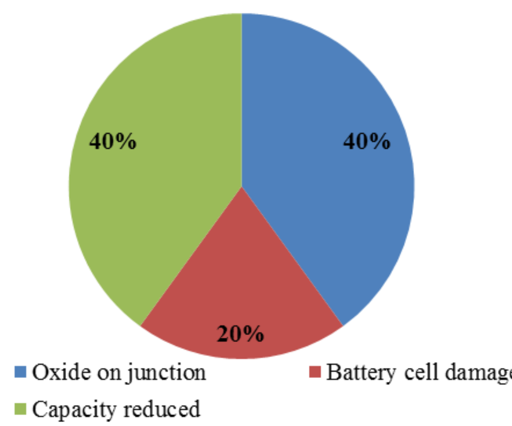


Fig. 10. Inspection of Battery Backup.

Fig. 11. Oxide on junction of Battery Backup.

3.5 Capacitor Bank

Although they are done routine maintenance, the deteriorations in capacitor bank are still found as shown in Fig. 12. It consists of timer damage and capacitor damage at about 77% and 23% respectively. The capacitor bank uses to improve power quality. The line is inductance and resistance load so the electricity occur drop voltage in the long power transmission line. So capacitor bank help improve voltage level up. Moreover, it is still power factor correction also. In the case of timer, it is installed to time checking of capacitor discharge when technician and engineer would to maintenance. Generally, capacitor still has electric charge although it is not connected the power line. If the people touch it without discharge, the large electric charge flow pass to the body which the people is dangerous probably die. So this timer is very important for maintenance. It helps tell the suitable time to start maintenance. In the case of capacitor damage, it should be changed immediately. Because this problem effects on power quality of system for example the voltage drop at the end line which lower than the requited load. And the power factor of system is low also which it effect on the loss is high.

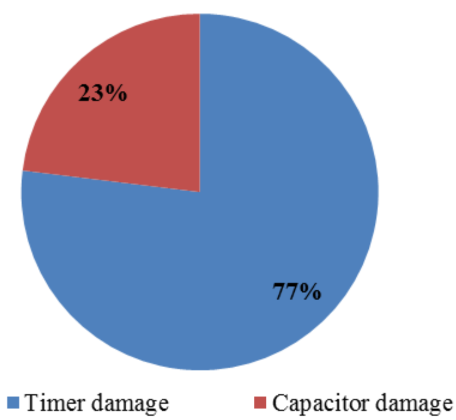


Fig. 12. Inspection of Capacitor Bank.

4. CONCLUSION

From experimental results, it can be summarized as following.

1. Considering the risks and equipment deterioration in electrical substations from four substations with routine maintenance, the research reveals that the most occurs in transformer at 60%. The second is in switch gear approximately 20%. The next is battery backup at 15% and the final is capacitor bank at 5%.

2. The most risks and equipment deteriorations which found in transformer with routine maintenance is oil leakage about 60%. The second is oil level gauge defective approximately 18%. The next equipment deterioration is phase protect damage about 12% and finally, control set damage is the last at about 10%.

3. The most risks and equipment deteriorations which found in switch gear with routine maintenance is high humidity in SF_6 at 50%. The second deterioration is hydraulic pump leakage approximately 25%. The next is CB damper seal leakage about 15%. The final deterioration is counter damage about 10%.

4. The most risks and equipment deteriorations which found in battery backup with routine maintenance are oxide on junction and battery capacity reduced at each of 40%. The final is battery cell damage at 20%.

5. The most risks and equipment deteriorations which found in capacitor bank with routine maintenance is timer damage at about 77%. The rest one is capacitor damage approximately 23%.

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