

Study of Breakdown Occurrence on the 11kV Sewerage Plant Substation in UiTM Shah Alam

Muhammad Syahmi b Abd Razak
Faculty of Electrical Engineering
Universiti Teknologi MARA
40450 Shah Alam, Selangor, Malaysia
e-mail: mie_uitm7@yahoo.com

Abstract – This paper describes the characteristics of environment of 11kV outdoor distribution substation that was affected to underground cable supply. There is some visual checking and site testing to detect breakdown on the cable and calculated cost involve comparing to suggested solution. Details inspection and testing are usually perform if any tripping or fault occur. In this case, breakdown of insulation cable was studied on how it could be solve with less cost spend. First, inspection and testing was performed in order to find point of fault. Then analysis of data and information was estimated that moisture is the main cause contributes to this case of fault. The affected part was identified so that repairing work could be done. It was confirmed that gear involved in switchgear truck, interconnected bus-bar and insulation of cable was affected and will not be able to operate. Repairing work cost was studied by comparing it with the suggested solution. The suggested solution is to eliminate Sewerage Plant substation from operation supported by availability considered.

Keyword – Distribution Substation, Cable Faulty, Repairing Maintenance, Moisture

I. INTRODUCTION

In this situation Universiti Teknologi MARA was develop a facility unit which functioning as an organisation which coordinate the distribution of electric energy. Therefore, if any problem occur regarding of electrical distribution and supply in this campus, facility unit is the organization which taking responsibility [10]. One of the objectives of “Unit Projek Elehtrik Infra” is to plan an upgrading of electrical supply system and electrical fitting including substation room, transformer, switchboard and generator set. Then, in this case of study, the problems which incur by sewerage substation become one of the responsibilities of this organisation.

For distribution part, there are a few stages which become a standard voltage [3]. They are 33kV, 11kV and

0.4kV and 230V for single phase. However there are a few parts in Semenanjung Malaysia which used another standard which are 22kV and 6.6kV located in country of Johor and Perak. The supply frequency in Malaysia is 50Hz with $\pm 1\%$. For transmission part the standard voltage network which available in Malaysia are 500kV, 275kV and 132kV [6]. These level of voltage was distribute using transmission tower and commonly known as transmission line or National Grid. Both part of transmission and distribution level of voltage could be recognising in two parts which are low voltage and medium voltage [9].

The standard of substation buildings criteria used in Malaysia is usually depending on utility which is Tenaga Nasional Berhad (TNB). However, the general and basic criteria are usually the same. The next explanation is some of the consideration that should be taken when installing any level of substation. It is also focusing on the outdoor stand alone substation with high voltage room (VCB). In Malaysia, the construction of electrical substation must be approved by electric utility. Therefore, the construction plant is always following the specification supplied by utility. However, the specification is already followed the basic criteria.

Waterproofing is the important characteristics due to water could cause any problem that could cause fault and breakdown to the power electrical equipment [5]. The site of substation house should be drained effectively including floor, roof and area around it.

Sewerage substation is one of distribution substation in UiTM Shah Alam. Therefore, its incoming supply cabling is 11kV as stated. In high voltage application size of cable is really important aspect to be consider. The figure above shows cross sectional area inner surface of the cable 3 core sheath wound armoured XLPE type. This type of cable is usually having insulator type of Polyethylene (see figure 2.1) to withstand voltage a.c cable operating up till 15kV [4].

In August 2013 facility of UiTM was received a report from consumers that there is supply trip on Sewerage plant substation. The VCB isolator was isolated supply on cable

“to DATC substation (Dewan Agung Tengku Censelor)”. This case caused facility to make an observation to the site and it was observed that Sewerage substation was out of electric supply. It was observed that fault was occurred at interconnector cable connected to VCB at Sewerage Plant in UiTM Shah Alam caused of explosion. It was caused VCB which protect circuit of incoming supply from DATC building was trip. Bus bar which connect incoming cable from circuit of protection was observed change in color from silver to greenish [10]. The problem is the bus-bar will not be able to be maintaining during routine or preventive maintenance. The bus-bar supposes to be maintained in chrome colour during its entire operation. Another problem is about a breakdown cable supply observed. The figure 1 below shows the bus-bar which changed in colour and the point of fault on the incoming underground cable.

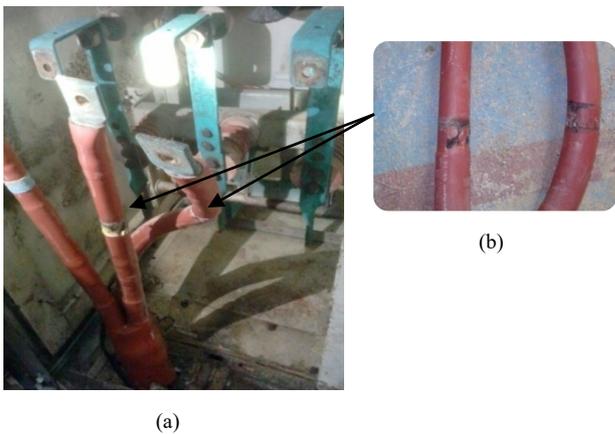


Fig 1: (a) Bus-bar shows Change in Colour. (b) Cable Fault at Phase Yellow and Blue

There are three objectives that aimed by this research which is *Study on Effect of Environment to the 11kV Sewerage Plant Substation in UiTM Shah Alam*. These objectives are organized to be as a focus on studying, finding method and discussion of result found.

The first objective is to understand the distribution system in UiTM Shah Alam. Based on the study, the system of electrical distribution is understood to identify the significant of study and method that can be used to identify the problem incur. Then, to identify the problem incur in the electrical substation become the second objectives of this project. This becomes an objective to this project because in order to search for solution, the main cause of the problem should be confirmed. To propose the solution to overcome the problem become the third objective so that this project will conclude the best solution that could be considered from the breakdown that was occurred.

II. METHODOLOGY

A. Flowchart

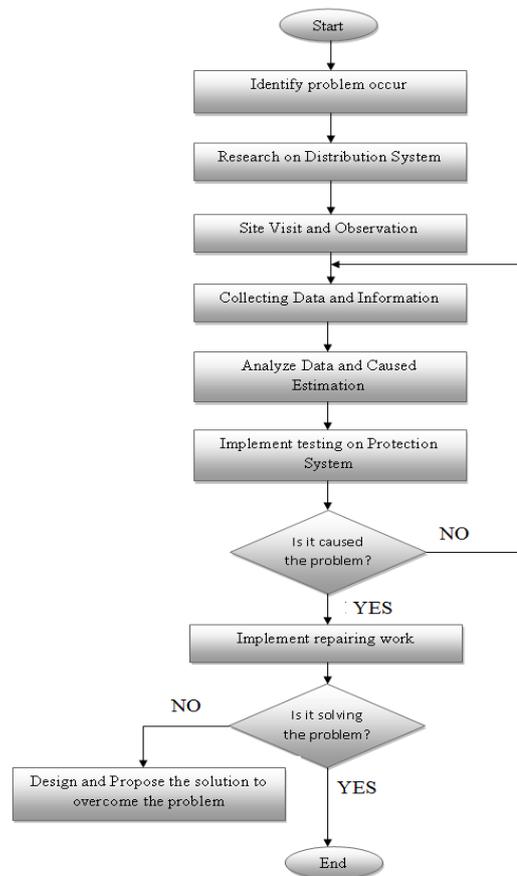


Fig 2: Research Flowchart

B. Method Considered

Identifying the problem was a first step in this study whereby there must be a problem to be solve before searching for solution. The main problem of the study is going to be discussing in this part. It is including how serious the problem could be, the incoming effect by the problem and situation of the problem.

Distribution system is the general parts that must be understand in order to identify this problem. This is because the problem occurs by the local substation was effect on the system of electrical supply. By doing some research on distribution system there are many possibilities that could be consider in this study. They are many questions such as why does the protection system VCB (to DATC) does not isolate the incoming supply before flash over happen on cable and how do the moisture effect 11 kV type XLPE (SWA) cable [10].

Site visit was done in the day of cable substitution and some observation was made to make sure there is any sign that could be associates with the assumption made. By comparing the observation and specification that should be maintain, there are many aspects which is no more comply

with the requirements. For example, the position or place of Sewerage Substation including HT room, transformer room and LV room is lower than drainage system.

In the way of completing this study, there are a few types of data and information needs. Firstly, single line diagram is analyzed to know link of supply cable from one substation to another [6]. In the way of proposing the solution, single line diagram for HT and LV room of Sewerage Plant substation is need in order to identify all the power equipment that could be affect to oxidization during operation on that site. Furthermore, to identify calculation of payback period on the proposed solution compare to the preventive cost there are some cost was gathered.

In this study, preventive solution was done in order to maintain the energy supply to the substation there are some observation and site testing that was done immediately after the fault happen. Megger Insulation Tester is used to measure the fault resistance of cable [6]. This recorded reading was analyzed to know if any fault along the cable.

The effect of environment could be control in order to prevent fault to be happening twice or more [4]. In this case, there is one solution which could be considered other than doing preventive repair. This thesis will analyze the total payback period of this solution work. The analysis will shows whether this solution is worthwhile to be proceed to the Sewerage Plant substation.

C. Solution Designed

This part will explain about the flow of method which has been used in order to present the solution suggested. Analysis was made on the payback period that could archive comparing between repairing work done. Cable sizing is perform in this analysis due to it is the biggest contribution of cost spend in this project.

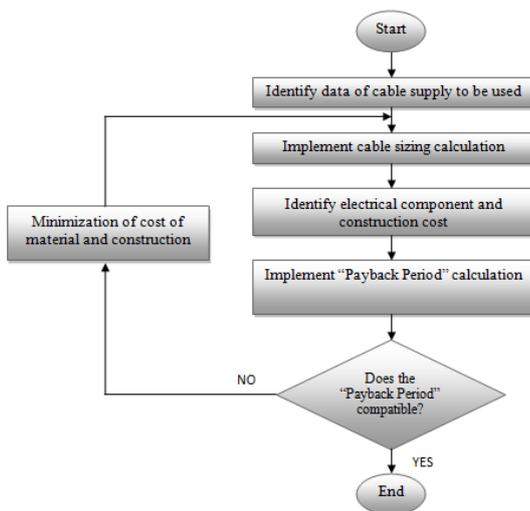


Fig 3: Solution Designed Flowchart

III. RESULTS AND DISCUSSION

A. Site Observation

Basically the result recorded from this research divided into three parts which are observation and inspection, testing and calculation. The inspection and testing work implement on site which are at Sewerage Plant Substation with the supervision of electrical engineer and qualified team. The calculation and design was made based on Malaysia Standard and available equipment in Malaysia focusing on project's payback period.

The main cause of oxidation that occur is the presence of moisture that make a direct or indirect contact with the power equipment. In this study, the moisture is developed based on the water stagnant at the around underground power cable. Figure 4.1 shows water has been pump out to doing maintenance work.



Fig 4: Underground Cable 11 kV (XLPE SWA) Immerge in Water.

For analysis part, it was perform to using comparisons, recorded data and calculation result. From the comparison assumption was made to find the situation that could lead to that failure. Then analysis was made from the recorded testing data to identify the performance of insulation on the switchgear and cable. Based on this analysis decision was made to implement repairing work.

Last part of this study is on the proposed solution that could be considered in this situation. This proposed solution design cost was compared to the repairing cost in ten years of operation. The comparison was performed on the payback period that will conclude compatibility of the proposed solution.

TABLE 1. INSPECTION ACTIVITIES ON VCB PANEL IN SEWERAGE PLANT SUBSTATION

Activities	VCB1 "To FSPU (Lama)"	VCB2 "To Local Tx (1000kVA)"	VCB3 "To DATC"	VCB4 "To Stadium UiTM"
General cleaning and inspection of external body compartment	In good condition	In good condition	In good condition	In good condition
Cleaning, tightening and inspection of truck compartment	In good condition	In good condition	In good condition	In good condition

Cleaning, tightening and inspection bus-bar compartment	In good condition	In good condition	-Dismantled -Bas-bar is oxidized	In good condition
Cleaning, tightening and inspection of cable compartment	In good condition	In good condition	-Termination of cable is oxidized	In good condition
Cleaning, tightening, lubricating and inspection of VCB truck	In good condition	In good condition	-Mechanical gear is jammed caused by oxidation	In good condition
Testing of CLOSING/OPENING mechanism on AUTO/MANUAL operation	In good condition	In good condition	Operation not smooth caused by oxidation	In good condition

In this case, study was divided into two parts which are to find cause of problem and repairing job and the second part is to suggest a solution for facility concern. In first part of analysis, a few steps were taken during the repairing work. From the first observation Sewerage Plant Substation is found was having a serious rusting problem. It is found that all physical steel body of compartment are rusty. Therefore, moisture must be presence at that environment that will create that process. Then, decision was made to proceed with further inspection on all the power equipment in HT room at that substation. The details inspection was made on VCB compartment and VCB truck including termination of cable. Based on inspection result in table 4.1 it shows that from all four panel of VCB there is one panel that was not functioning as required. The vacuum circuit breaker that functioning to isolate supply from DATC substation found 100% oxidized. After basic process of cleaning that part is found could not back to normal condition physically. The part that mention is especially on the interconnected bus-bar, termination of cable to bus-bar and mechanical part of VCB truck.

B. On Site Testing

Another condition is from quick testing for mechanical part of the VCB truck, the mechanical gear was jammed and the other mechanical part does not move smoothly. Three VCB was inspect would be as normal after process of cleaning and lubricating physically.

TABLE 2. TABULATED READING OF INSULATION TEST ON VCB1 TRUCK

Test Connection	Phase to Phase (GΩ)			Phase to Earth (GΩ)		
	R – Y Phase	R – B Phase	Y – B Phase	R – E	Y – E	B – E
Cable side	0.10	0.08	0.12	0.85	1.20	10.0
Bus-bar side	0.10	OL	0.18	1.00	0.80	1.50
Interconnected bus-bar	60.0	OL	65.0	1.20	1.20	1.10

TABLE 3. TABULATED READING OF INSULATION TEST ON VCB2 TRUCK

Test Connection	Phase to Phase (GΩ)			Phase to Earth (GΩ)		
	R – Y Phase	R – B Phase	Y – B Phase	R – E	Y – E	B – E
Cable side	0.26	0.12	0.10	0.20	OL	0.80
Bus-bar side	0.08	0.05	0.10	0.10	0.28	1.20
Interconnected bus-bar	60.0	OL	65.0	1.20	1.20	1.10

TABLE 4. TABULATED READING OF INSULATION TEST ON VCB3 TRUCK

Test Connection	Phase to Phase (GΩ)			Phase to Earth (GΩ)		
	R – Y Phase	R – B Phase	Y – B Phase	R – E	Y – E	B – E
Cable side	0.05	0.06	0.04	1.50	1.30	1.50
Bus-bar side	0.12	0.47	0.50	1.10	1.0	2.0
Interconnected bus-bar	60.0	OL	65.0	1.20	1.20	1.10

TABLE 5. TABULATED READING OF INSULATION TEST ON VCB4 TRUCK

Test Connection	Phase to Phase (GΩ)			Phase to Earth (GΩ)		
	R – Y Phase	R – B Phase	Y – B Phase	R – E	Y – E	B – E
Cable side	0.26	0.12	0.10	0.20	OL	0.80
Bus-bar side	0.08	0.10	0.12	0.20	OL	0.80
Interconnected bus-bar	60.0	OL	65.0	1.20	1.20	1.10

Based on the tripping that occur at that VCB “to DATC” there must be over-current phenomenon that happen. This over-current effect was confirmed based on the indication which usually exists on the VCB panel. Then, insulation testing was conducted to identify whether all VCB truck and bus-bar having insulation breakdown or faulty after over-current tripping condition. The testing on VCB truck is on two part which are cable and bus-bar part of terminal. It is mean the cable terminal will be connected to cable and the bus-bar part will be connected to the interconnected bus-bar. Another measurement is performed on the interconnected bus-bar.

After all the equipment found having good condition of insulation, inspection was made on the termination of supply cable to the bus-bar. Faulty cable was identified on the phase cable terminate to bus-bar. The figure 4.2 shows that black mark that indicates broken insulation of the supply cable. The mark occurred was confirming the insulation breakdown and its need to be replaced. Insulation type which using polyethylene was proved that will subject to a condition of treeing. Based on the environment condition discussed early the presence of water containing contaminants caused unwanted moisture. This unwanted

moisture is proven caused oxidation and it is become serious when react to electrical stress caused growth of trees within the material. Based on the data collected, the cable that interconnected between DATC substation and Sewerage Plant substation was in operating since year 2008. There was 6 years of operation is enough for treeing phenomenon to occur with the irregular condition observed. To be more clear comparisons was made with another case study that was studied on the growing of tree in polyethylene material. The comparison was rearranged in table 4.6.

The breakdown occur caused fire and flashing at that point of fault. The breakdown strength of the cable might be reduced and usually faulty cable need to be change to restore its service. Finally, repairing work was decided to maintain continuous electrical supply by changing the oxidized interconnected bus-bar and that fault cable.

TABLE 6. ENVIRONMENT OF SITE ANALYSIS TABLE

Characteristics considered	Sewerage Plant substation supply cable (UiTM Shah Alam, Malaysia)	Mankhurd-Ghatkopar link road (Mumbai, India)
Type of cable	11kV XLPE (SWA) 3-cores Buried underground with conduit	33kV & 11kV XLPE 3-cores 400sqmm. Directly buried underground
Aged of operation	Since the operation of DATC substation in 2008. About 4 to 5 year's operation.	In operation for 10 to 13 years
Weather seasons	Total rainfall in Malaysia is high from 2006 to 2010 and dropping until current year. <i>Source: Malaysian Meteorological Department</i>	Wet seasons almost 3 to 4 months in a year
Presence of water	Substation area besides operating sewerage plant. Existing of other substances in water.	Cable link connected with drainage system. Drainage system contains wasting from house. Existing of other substances in water.

C. Proposed Solution

The second part of analysis is on the proposed solution that might be considered. The suggested solution is to eliminate Sewerage Plant substation from operation. Before this suggestion was made as a solution to this problem there

are a few conditions that were considered to make this solution more compatible. The first condition is clearly because of the environment condition that was not suitable for local substation to operate and it was discuss in the first part of analysis. The unwanted situation must not be at the same condition for the next 6 to 10 years because it might lead to the same failure.

The second consideration was made on the load incur by Sewerage Plant substation. Based on the interview that was made with electrical engineer of facility where conducting of substation operation the total load support by that substation is too small which the highest demand recorded was between 250 to 300 Ampere. Figure 4.4 shows the list of load that supply by Sewerage Plant substation and it is considered small because it is covered by 1000 kVA transformer.

$$I_{\text{rated}} = \frac{1000 \text{ kVA}}{\sqrt{3} \cdot 400V} \dots (1)$$

The secondary rated current supply from Distribution Transformer, = 1443 A

Rated current supply of 1443 A supplies by an 11kV substation with the maximum load demand up till 300 A is not compatible with cost of maintenance every year of operation. Therefore, it is suggested to be supply from DATC substation which 150 m from the mentioned substation.

Based on Current Carrying Capacity

$$\text{Current Carrying Capacity} \geq \frac{I_n}{Ca \cdot Ci \cdot Cg \cdot Cr} \dots (2)$$

$$\text{Current Carrying Capacity} \geq \frac{300}{(0.81)(1)(1)}$$

$$\text{Current Carrying Capacity} = 370 \text{ A}$$

$$\text{Cross Sectional Area} = 185 \text{ mm}^2$$

Based on Voltage Drop

$$VD_{3\phi} = \frac{\left(\frac{mV}{A} \right) \times I_b \times L}{1000} \dots (3)$$

$$VD_{3\phi} = \frac{\sqrt{3} I_b (Rc \cdot \cos \theta + Xc \cdot \sin \theta) L}{1000}$$

$$VD_{3\phi} = \frac{\sqrt{3} (200)[(0.343)(0.95) + (0.0726)(0.95)](150)}{1000}$$

$$VD_{3\phi} = 20.52 \text{ V}$$

$$\%VD_{3\phi} = 5.1 \% \text{ from } 405 \text{ V } 3\phi \text{ voltage supply}$$

$$\text{Cross Sectional Area} = 70 \text{ mm}^2$$

**By using higher cross sectional area of cable which at 95 mm² the percent of voltage drop will be reduce to 15.74 V which is 3.9% from nominal voltage (405V).*

TABLE 7. ECONOMIC COMPARISON BETWEEN MAINTAINING AND REPAIRING SOLUTION

Economic Comparison between Maintaining and Improving of Supply System									
End of Year	Repairing Maintenance Work				Eliminating HV Room Solution				
	Initial Cost of Investment (RM)	Annual Cost of Preventive Maintenance (RM)	Total Annual Cost (RM)	Total Net Present Worth (RM)	Initial Cost of Investment (RM)	Annual Spending Cost on Maintenance (RM)	Total Annual Cost (RM)	Total Net Present Worth (RM)	Total Annual Cost Saving Achieved (RM)
0	27 000	0	27 000	27 000	53 000	0	53 000	53 000	-26 000
1	0	0	0	0	0	0	0	0	0
2	0	22 000	22 000	22 000	0	0	0	0	22 000
3	0	0	0	0	0	0	0	0	0
4	0	22 000	22 000	22 000	0	0	0	0	22 000
5	0	0	0	0	0	0	0	0	0
6	0	22 000	22 000	22 000	0	22 000	22 000	22 000	0
	LCC_1 (RM)			93 000	LCC_2 (RM)			75 000	18 000

Payback Period:

$$= \frac{\text{Additional Cost of Investment} - \text{Salvage Value}}{\text{Annual Cost Saving}} \dots (4)$$

$$= \frac{(53\,000 - 27\,000) - 0}{18\,000/6}$$

$$= 8.6 \text{ years} / 8 \text{ years } 7 \text{ months}$$

Focusing on the solution which suggested in this study, the payback period was calculated in order to identify compatibility of project. By referring to this method there are a few assumptions that were made because of a few reasons. First, this analysis assume that all cost that was mentioned in this case study remain the same throughout the six years. The percentage of ROI assumes to be at zero percent throughout the six years. All the cost that will be spending before six years of operation on that substation was neglected. The cost of the project is fully payable during the first year of operation. All this assumptions was made because of lack of information along this development of analysis.

Based on the economic analysis that was made, cost of maintenance becomes the main contribution of saving that could archive in this project. Based on the table 4.8 salvage value was assume to be zero based on the facility demand. The estimation of scrap value such as cable, transformer and VCB usually need details measurement to be considered. If it is not measure or accurately estimate it could contribute to faulty to the economic analysis in this case of study.

The analysis was made on the economic comparison between the cost spending by repairing work and the cost estimate on the improvement solution. Through six years of operation the changed cable are estimate to be facing the same problem and the same cost will be spend to that problem. Therefore, this analysis was compared to improvement of eliminate HV room at that site and there will be no substation at that site. By taking this improvement, cost of preventive maintenance could be eliminated. Preventive maintenance is schedule to be two

years repetition and it will cost as shown in table 4.9. Then, there will be RM 18 000 of savings with RM 3000 savings per year and the savings will pay back the different of investment in 9 years of operation.

IV. CONCLUSION

From analysis that was made in this case of study, it could be said that moisture problem is not be able to maintain by routine and preventive maintenance. It is also causing bigger contribution to cost of repairing if there are fault happen. Place characteristics of substation to be developed are the main factor that should consider. It is due to the serious effect that was incurred by power equipment in studied substation. For this case, 11 kV substation was affected by moisture because it environment was changed since there is a new buildings development cause it become lower land. Therefore, this substation was not designed incorrectly since there was no cable fault six years before the mentioned changing. This Sewerage Plant was operated smoothly till the development of DATC which caused huge land changing. In view of the fact that this problem could not be avoid this studies are perform and the affect were on external and internal. The internal affect was on the operating power equipment in the system covered by 1000 kVA transformer load. For the reason that of the moisture affect in that substation, it cause of money spending more than RM 20 000 in order to maintain power supply to the consumer. Then, from all combination of analysis it could said that an elimination of that substation could be made. It was defend by conclusion that the cable fault problem estimated to be occurred after six years of operation from the repairing maintenance.

V. RECOMMENDATION

For future work, this study could be improved by study on the other cause that could cause power cable failure. This improvement is concern by facility because in 2013 there are more than three cases cable failures happen in UiTM distribution system. The study is suggested to identify all possibilities that could intend to cause supply cable faulty. This situation is not only effect on the buildings supply reliability; it is also caused increasing of maintenance cost used on repairing work. The research should focus on every procedure that should be maintained during maintenance work and the well prepared routine maintenance can be improved. The data available is on all the failure cable case that was occurs on entire local distribution sistem.

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