


**GENERATE AND TESTING  
HIGH VOLTAGE AC, DC AND IMPULSE ON  
THE MATERIAL OF INSULATOR ON OIL  
TRANSFORMER**

**Sabaruddin Bin Mohammad**

**BEKP**

**2009**

“I hereby declared that I have read through this report entitles “Generate and Testing High Voltage AC, DC And Impulse On The Material Of Insulator On Oil Transformer and found out that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature : .....  .....

Supervisor's Name : MR. ALIAS BIN KHAMIS

Date : ..... 7/5/2009 .....  
.....

**GENERATE AND TESTING HIGH VOLTAGE AC, DC AND IMPULSE ON THE  
MATERIAL OF INSULATOR ON OIL TRANSFORMER**

**SABARUDDIN BIN MOHAMMAD**

**This Report Is Submitted In Partial Fulfillment Of Requirement For The Degree of  
Bachelor In Electrical Engineering (Industrial Power)**

**Faculty of Electrical Engineering  
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**MAY 2009**

I declare that this report entitle “Generate And Testing High Voltage AC, DC And Impulse On The Material Of Insulator On Oil Transformer” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature

: .....  .....

Name

: SABARUDDIN BIN MOHAMMAD

Date

: 07 MAY 2009 .....

To my beloved mother and father, sister and brothers,  
Mohammad Manap, Munah Binti Majid, Mariam Mohammad and Zamri Mahat

## ACKNOWLEDGEMENT

First and foremost I would like to express my deepest gratitude to Allah S.W.T for his guidance and blessing throughout this final year project. Second, I would thank too my university to give me opportunity to use and finished my project by used the high voltage lab. Then, I would like to take this opportunity to express my special regards to En. Alias bin Khamis as my supervisor for the final year project. Because his attention, helpful, and his encouragement, I success to finish this report on time.

I also would like to extent our thanks to other lecturers in high voltage especially to En. Aminuddin, Pn. Jurifa Mat Lazi, P.M. Dr. Musse Mohamud Ahmed and En Yusri as a technician for generosity in spending time, knowledge and providing a lot of commitment in the way to finish this report and also giving as well sharing the experience, advice, opinions and encouragement in process to complete this report.

I also want to thank everyone who involved in process of making this report success especially too especially to my housemate. Beside that, thanks to my parents for their supporting me as long as I'm studies in this University.

## ABSTRACT

This project is about to generate and testing high voltage AC, DC and Impulse on the material of insulator and oil transformer. HV test objects are limited to measuring the inception voltage (in kV) and the largest discharge magnitude (in pC) and comparing these to the test specifications. Impulse voltage test demonstrates the strength of an insulation system and its components against impulse voltage. The problems of Ordinary transformer insulating oil is that arise are most frequently due to contaminant by dirt, air and water. The condition of the oil as initially installed must be good. If an accidental over-voltage results in a flashover, the oil will have a small amount of carbon in it, weakening the oil. Filtering is a wise thing to do if any spark-over occur. If the oil should inadvertently become so carbonized that it becomes perceptibly darkened, then the oil is weakened point where corona established on the solid on which the transform are wound. Once corona is established, which happen at less than once oil is badly weaken tracks will grow until breakdown occurs. The pre-breakdown characteristics of transformer oil in the presence of different levels of contamination.

## ABSTRAK

Projek ini adalah berkaitan penjanaan dan pengujian voltan tinggi AC, DC dan Impulse pada penebat dan minyak transformer. Pengujian objek Voltan Tinggi (HV) ialah terhadap kepada pengukuran voltan (in kV) dan magnitud cas (pC) dan perbandingan antara spesifikasi ini. Ujian voltan impulse digambarkan sebagai kekuatan sistem penebatan dan komponen itu berlawanan dengan voltan impulse. Masalahnya, bagi alatubah biasa dalam minyak penebatan ialah kenaikan berdasarkan pencemaran bendasing oleh habuk, udara dan air yang mengganggu kualiti minyak tersebut. Keadaan minyak yang digunakan mesti dalam keadaan baik. Apabila berlakunya voltan lebih minyak tersebut akan mengandungi karbon menyebabkan berlakunya kejatuhan fungsi minyak. Penapisan adalah cara untuk mengelakkan kelemahan pada minyak tersebut daripada berlakunya kehilangan penebatan. Apabila korona hadir ia akan menyebabkan minyak hentitugas sehingga mencapai tahap kritikal minyak berfungsi. Sifat Pra-hentitugas minyak alatubah akan hadir pada peringkat pencemaran bendaing yang berbeza keadaan.



## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	<b>SUPERVISOR'S ENDORSEMENT</b>	<b>i</b>
	<b>PROJECT TITLE PAGE</b>	<b>ii</b>
	<b>DECLARATION PAGE</b>	<b>iii</b>
	<b>DEDICATION PAGE</b>	<b>iv</b>
	<b>ACKNOWLEDGEMENT</b>	<b>v</b>
	<b>ABSTRACT</b>	<b>vi</b>
	<b>ABSTRAK</b>	<b>vii</b>
	<b>TABLE OF CONTENTS</b>	<b>viii</b>
	<b>LIST OF TABLES</b>	<b>xii</b>
	<b>LIST OF FIGURE</b>	<b>xiii</b>
	<b>LIST OF ABBREVIATIONS</b>	<b>xv</b>
	<b>LIST OF APPENDIX</b>	<b>xvi</b>
<b>I</b>	<b>INTRODUCTION</b>	<b>1</b>
	1.1 Introduction to AC Voltage	1
	1.2 Introduction to DC Voltage	1
	1.3 Introduction to Impulse Voltage	2
	1.4 Problem statement	2
	1.5 Objective	3
	1.6 Scope	4
<b>II</b>	<b>LITERATURE REVIEW</b>	<b>5</b>
	2.0 Introduction	5
	2.1 Generating High Voltage Alternating Current	5
	2.1.1 Cascade Transformer	6

2.2	Generating High Voltage Direct Current	8
2.2.1	Half Wave Rectifier Circuit	8
2.2.2	Full Wave Rectifier Circuit	8
2.3	Generating Impulse Voltage	9
2.4	Oil Transformer	10
2.5	Hyrax Oil Transformer	11
2.5.1	Container of oil sample	12
2.6	Proper Oil Transformer Sampling	13
2.7	Insulating Oil and Dielectric Strength	14
2.8	Oil Strength Determination	15
2.9	Spark Gaps for Measurement of High Voltage DC, AC and Impulse	16
2.10	Testing of Isolator	16
2.11	LTSpice Software	17
2.12	Standard For High Voltage Testing	17
2.12.1	IEEE standards std 4-1995 Standard Techniques for High Voltage Testing	18
2.12.2	The IEC 60156 (1995) Standard for Determining Breakdown Voltage Of Electroinsulating Oils	19
2.12.3	The American Society for Testing and Materials (ASTM) Standard	20
2.12.3	Differences between IEEE STD 4-1995 Standard Techniques for High Voltage Testing and International Electro technical Commission (IEC)	20
2.12.5	Summary	21
<b>III</b>	<b>METHADODOLOGY</b>	<b>22</b>
3.1	Objective	22
3.2	Block Diagram for Methodology Flow	22
3.3	Project Stage	23

3.4 Project Circuit Single Line Diagram	24
3.5 Simulation Flow Chart	24
3.6 Project and Experiment Flow Chart	26
3.6.1 The Project flow chart	26
3.6.2 The experiment flow chart	27
3.7 Equipment Setup	29
3.7.1 Digital Measuring Instrument DMI 551	29
3.7.2 TEKTRONIX Oscilloscope DPO 4034	29
3.7.3 Operating Terminal OT 276	29
3.8 Experimental Work and Method	30
3.8.1 Type of Configuration for first stage	30
3.8.2 General remarks to setup	33
3.8.3 Disruptive discharge voltage test	34
3.8.4 Project background	35
3.8.5 Project component	36
3.8.6 Test object procedure	37
3.8.7 Summary	39
<b>IV</b>	
<b>RESULT AND DISCUSSION</b>	<b>40</b>
4.1 Introduction	40
4.2 Result for Simulation for Generation Circuit	41
4.2.1 Simulation Analysis of High voltage alternating current (hvac)	41
4.2.2 Simulation Analysis of High Voltage direct current (hvdc)	42
4.3 Result High Voltage Alternating Current (HVAC)	43
4.3.1 Data and waveform HVAC for new oil and old oil transformer	43
4.3.2 High voltage alternating current data	46
4.4 Result High Voltage Direct Current (HVDC)	47
4.4.1 Data and waveform positive and negative	

	tested for new oil and old oil transformer	47
	4.4.2 High Voltage Direct Current Data	52
	4.5 Result High Voltage Impulse Tested for Standard Sphere Gap	53
	4.5.1 Data and waveform HVAC for new oil and old oil transformer	53
	4.5.2 High Voltage Impulse Data	56
	4.6 Discussion	57
<b>V</b>	<b>ANALYSIS</b>	<b>59</b>
	5.1 Introduction	59
	5.2 High Voltage Alternating Current Analysis	59
	5.3 High Voltage Direct Current Analysis	62
	5.4 High Voltage Impulse Analysis	64
	5.5 Project Troubleshooting Analysis	65
<b>VI</b>	<b>CONCLUSION AND RECOMMENDATION</b>	<b>67</b>
	6.1 Conclusion	67
	6.2 Recommendation	68
	<b>REFERENCES</b>	<b>70</b>
	<b>APPENDIX</b>	<b>71</b>

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Test object and suitable capacitance value	7
3.1	List of the component required for 1 <sup>st</sup> stages configuration for AC, DC and Impulse	36
4.1	HVAC waveform for new oil	44
4.2	HVAC waveform for old oil	45
4.3	Table for HVAC result	46
4.4	HVDC positive test waveform for new oil	48
4.5	HVDC negative test waveform for new oil	59
4.6	HVDC positive test waveform for old oil	50
4.7	HVDC negative test waveform for old oil	51
4.8	Table for HVDC result	52
4.9	Impulse positive and negative test waveform for new oil	54
4.10	Impulse positive and negative test waveform for old oil	55
4.11	Table for Impulse result	56
5.1	Comparison breakdown voltage between experiment data and standard	60

## LIST OF FIGURES

<b>FIGURE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Cascade Transformer Connections	6
2.2	Cascade Transformer Units with Isolating Transformers for Excitation	7
2.3	Half Wave and Full Wave Circuit	8
2.4	Circuits for Producing Impulse Waves	9
2.5	Hyrax Tank Oil Sample Taken	11
2.6	Oil Test Cup Container	12
2.7	Graph Breakdown Voltages against Gap Spacing	15
3.1	Block Diagram for Methodology	22
3.2	Complete Circuits for AC, DC and Impulse	24
3.3	LTspice Simulation Flowcharts	25
3.4	The Project Flowchart	26
3.5	The Experiment Flowchart	27
3.6	Control Units OT276	28
3.7	DMI 551 Set	28
3.8	AC Single Line Diagram	31
3.9	First Stage AC Configuration	31
3.10	DC Single Sine Diagram	31
3.11	First stage DC Configuration	32
3.12	Impulse Single Line Diagram	33
3.13	Impulse Configuration Circuit	33
3.14	The General Setup for Single Stage	34
3.15	Combined Configuration for AC, DC and Impulse	35
3.16	Test Area	37
4.1	Simulation for AC Configuration 1 <sup>st</sup> stages	41
4.2	Simulation for DC Configuration 1 <sup>st</sup> stages	42

5.1	Graph plotted for HVAC	61
5.2	Positive Tested Graph for HVDC	63
5.3	Negative Tested Graph for HVDC	64
5.4	Breakdown Voltages for Standard Impulse Tested	65

## LIST OF ABBREVIATIONS

AC, ac	-	Alternating current
PD	-	Partial discharge
DC, dc	-	Direct current
C	-	Capacitor
PCB	-	Polychlorinated biphenyl
BS	-	British Standard
IEC	-	International Electrotechnical commission
TNB	-	Tenaga Nasional Berhad
IEEE	-	Institute of Electrical and Electronic Engineers
ASTM	-	The American Society for Testing and Materials Standard
DMI 551	-	Digital Measuring Instrument
OT276	-	Operating Terminal
HV	-	High Voltage
KF	-	Impulse Sphere gap



**LIST OF APPENDICES**

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
<b>A</b>	HYRAX datasheet for Oil Transformer	71
<b>B</b>	Determine the power law dependence between gap spacing	72
<b>C</b>	Main Project Component	73
<b>D</b>	Dielectric Properties of Some Liquid Dielectrics	74
<b>E</b>	Sampling Transformer Oils	75

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Introduction to High Voltage AC Voltage**

In order to properly size an AC Test Set, it is necessary have the maximum test voltage required. The maximum test voltage is determined by the relevant standard that equipment is being built to plus any additional user-defined over sizing to take into account changes to test standards, or special end-user requirements.

PD (Partial discharge) requirements testing is usually performed at lower levels than AC withstand levels. If PD testing is required it is necessary to know the PD sensitivity level for the test and the test voltage. Specifying too high a PD test voltage or unnecessarily low PD free rating for the system inflates the cost of a test system.

#### **1.2 Introduction to DC Voltage**

High voltage direct current (HVDC) is used to transmit large amounts of power over long distances or for interconnections between asynchronous grids. When electrical energy is required to be transmitted over very long distances, it can be more economical to transmit using direct current instead of alternating current. For a long transmission line, the value of the smaller losses and reduced construction cost of a DC line, can offset the additional cost of converter stations at each end of the line. Also, at high AC voltages significant (although economically acceptable) amounts of energy are lost due to corona discharge, the capacitance between phases or, in the case of buried cables, between phases and the soil or water in which the cable is buried [1].

HVDC (High Voltage Direct Current) provides necessary features to avoid technical problems in the power systems, and it increases the transmission capacity and system stability very efficient and it assists in prevention of cascading disturbances.

HVDC links are sometimes used to stabilize against control problems with the AC electricity flow. In other words, to transmit AC power as AC when needed in either direction between two places transmitting would require the (highly challenging) continuous real-time adjustment of the relative phase of the two electrical grids.

DC power at low voltage could not be transmitted over long distances, thus giving rise to high voltage alternating current (AC) electrical systems. Nevertheless, with the development of high voltage valves, it was possible to once again transmit DC power at high voltages and over long distances, giving rise to HVDC transmission systems.

### **1.3 Introduction to Impulse Voltage**

Switching Impulses can be generated on larger loads than lightning impulses since routine values of inductance do not influence the long front and tail times. The wave shaping resistor sets for switching impulse.

In order to maintain a lightning impulse wave within the standards, the overshoot on the front time must be less than 5%. In the special case of testing large capacitance samples, such as power cable, the front time requirement is relaxed for front time ( $<5\mu\text{s}$ ), making overshoot less of an issue.

### **1.4 Problem statement**

This project test is builds according by stage. For this project, I just do the configuration for single stage up to 100kV which is related to my project for comparison between high voltages AC, DC and Impulse sources.

Beside that, I done the research on characteristic on high voltage kit construction to make sure that is no damage on testing object to see the characteristic of the oil transformer. For simulation, there still is no specific software which is related to test this high voltage testing equipment. The software used is LTspice as a high voltage simulation circuit to see the result just can simulate for the generation side without test object.

The testing procedures and safety precaution should be prepared because it involved the high voltage up to 100kV. In order to produce the testing procedures manual, details investigation on the equipment, its characteristic, purposes and testing procedures need to be done. Since this is high voltage equipment, necessary safety precaution needs to be taken when implementing the equipments. It also necessary to ensure that all the equipments are follows the specification which has been given by supplier.

## 1.5 Objective

Through this project, test configurations are available which allow the generation of AC, DC and Impulse up to 100kV in single stages. The aim of this project is to research about generating and testing high voltage AC, DC and Impulse on the material of insulator and oil transformer of:

- i. To analyze the oil transformer output breakdown voltage with high voltage testing between AC, DC and Impulse source of generation voltage.
- ii. To generate and testing high voltage to shows characteristic of oil transformer.
- iii. To find problem related with oil transformer especially oil aging and other infected.
- iv. To test the level of oil transformer insulation and the time breakdown of the oil.
- v. To develop the high voltage testing procedures and safety precaution for high voltage AC, DC and Impulse test on the insulator (oil transformer).

## 1.6 Scope

The scope of this project is involve with different source high voltage testing like alternating current(AC), direct current(DC) and impulse voltage. Then, scope of generation voltage will be up to 100kV for single stage only. Beside that, the characteristic of AC, DC and Impulse voltage, to develop and do testing using new generation set must be analyzed. The test also includes the different sphere gap distance to see the characteristic. Standard testing procedures manual and safety precaution for AC, DC and Impulse high voltage on insulator will be carried out.

To calculate the gap between two ball electrode to see the time of oil breakdown. Actually the standard gap between two balls is 2.5mm, follow the TNB standard and other standard.

Then, made comparison actual result with simulation result about their breakdown voltage and related analysis. The comparison will do between new and old oil transformer with different source of generation AC and DC for only single stage.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.0 Introduction

British Standard BS 7671:2008 defines high voltage as any voltage difference between conductors that is higher than 1000 V AC or 1500 V ripple-free DC, or any voltage difference between a conductor and Earth that is higher than 600 V AC or 900 V ripple-free DC.

#### 2.1 Generating high voltage alternating current (HVAC)

We have resources for system voltages up to 400kV (274 kV to earth) for generation and for measurement alternating current. We can generate and measure alternating current up to 10 kA.

For generation of high voltage alternating current for less than 300kV, a single transformer can be used for the test purpose. The impedance of the transformer should be generally less than 5% and must be capable of giving short circuit current for 1 minute or more depending on the design.

In addition to the normal windings, namely, the low and high voltage windings, a third winding known as meter winding is provided to measure the output voltage. For higher voltage requirements, single unit construction transformer becomes difficult and costly due to insulation problems. So, the large transformer is very expensive. So, the other alternative to generate high voltage is by series several cascade transformers.

### 2.1.1 Cascade Transformer

Refer the Figure 2.1, the cascade transformer units in which the first transformer is at ground potential along with its tank. The second transformer is kept on insulators and maintained at a potential of  $V_2$ , the output voltage of the first unit above the ground. The high voltage winding of the first unit is supplied from the tank of the second unit. The low voltage winding of these units is supplied from the excitation winding of the first transformer, which is in series with the high voltage winding of the first transformer at its high voltage ends [2].

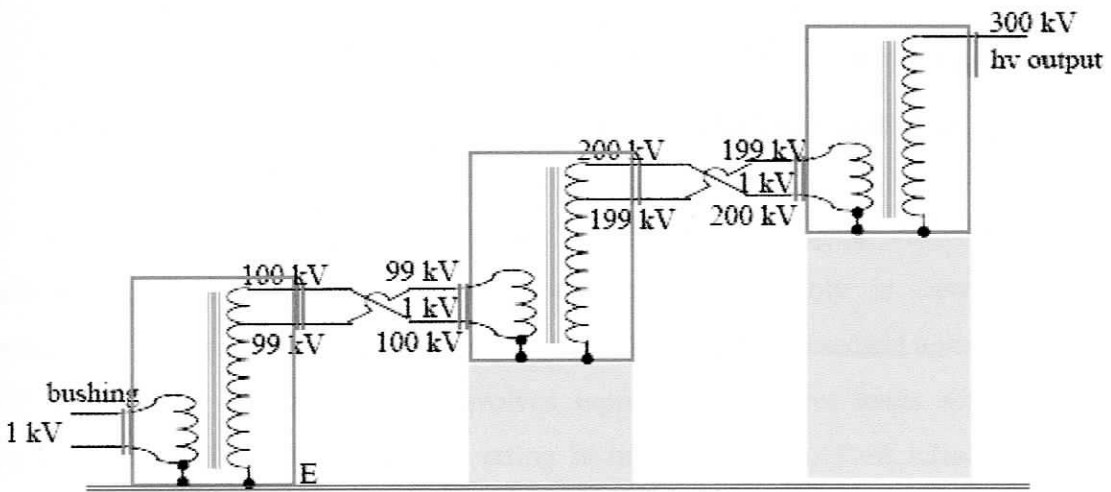
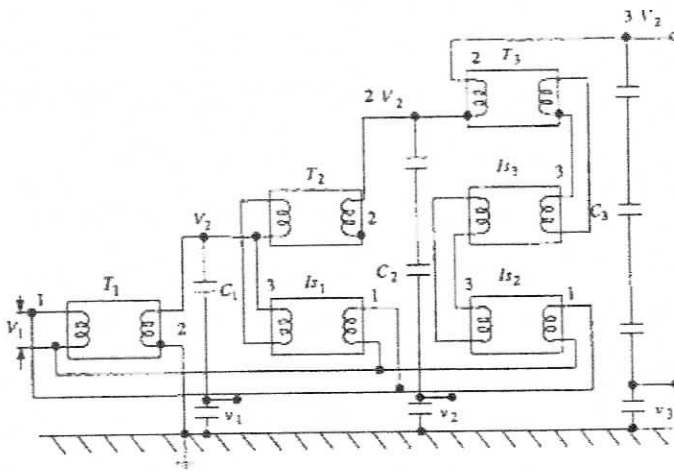


Figure 2.1: Cascade Transformer Connections

Supply to the units can be obtained from motor-generator set through an induction regulator for variation of the output voltage. The rating of the primary or the low voltage winding is usually 230 or 400V for small units up to 100kA. For larger outputs, the rating of the low voltage winding may be 3.3kV, 6.6kV or 11kV.

In Figure 2.2, providing the excitation to the second and the third stages is shown. Insulating transformer is 1:1 ratio transformers insulated to their respective tank potentials and are meant for supplying the excitation for the second and the third stages at third tank potentials. Power supply to the insulating transformer also fed from the same a.c. input.



- $T_1, T_2, T_3$  – Cascade transformer units  
 $IS_1, IS_2, IS_3$  – Isolation transformer units  
 $C_1, C_2, C_3$  – Capacitance voltage dividers for h.v. measurement after 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> stages  
 $V_1, V_2, V_3$  – For metering after 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> stages  
 1.Primary(l.v. winding), 2.h.v. winding, 3.Excitation winding.

Figure 2.2: Cascade Transformer Units with Isolating Transformers for Excitation

The advantage of this scheme is that the natural cooling is sufficient and the transformer is light and compact. Transportation and assembly is easy. Also the construction is identical for isolating transformer and high voltage cascade units. Testing of an HV apparatus or isolation always involves supplying capacitive loads with very low power dissipation. The nominal power rating is related in kVA,  $P=K.V2\omega C$ , where K (>1MV). Typical capacitance value for high capacitance test object is selected base on Table 2.1.

Table 2.1: Test object and suitable capacitance value

Test object	Capacitance value
Power transformer (<1MVA)	1000pF
Power transformer (>1MVA)	1000 – 10000pF
HV power cable (solid insulation)	250 – 300pF/m
HV power cable (gas insulation)	50 – 80pF/m
Metal Clad sub-station (G.I.S)	100 – 10000pF