

การศึกษาและออกแบบหม้อแปลงลกดแรงดันไฟฟ้า  
ที่แรงดันไฟฟ้า 12 กิโลโวลต์



นาย ชัยสิทธิ์ พงศ์มรกต

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

แผนกวิชา วิศวกรรมไฟฟ้า

บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

พ.ศ. 2519

000658

I15516015

**DESIGN & CONSTRUCTION**  
**OF**  
**A 12 KV VOLTAGE TRANSFORMER**

**Mr. Chaisith Pongmorakot**



**A Thesis Submitted in Partial Fulfillment of the Requirements**

**for the Degree of Master of Engineering**

**Department of Electrical Engineering**

**Graduate School**

**Chulalongkorn University**

**1976**

Accepted by Graduate School, Chulalongkorn University in partial fulfillment of the requirements for Degree of Master of Engineering.

*Kiud Prochnom*  
.....

Dean of the Graduate School

Thesis Committee :

*Paiy Fungthira* .....Chairman

*Jatke Sumittra*  
.....

*San No. San*  
.....

*Tatchai Sumittra*  
.....

Thesis Supervisor :

Dr. Tatchai Sumittra

หัวข้อวิทยานิพนธ์ การศึกษาออกแบบหม้อแปลงลดแรงดันไฟฟ้า ที่แรงดันไฟฟ้า  
12 กิโลโวลต์

ชื่อ นาย ชัยสิทธิ์ พงศ์มรกต

แผนกวิชา วิศวกรรมไฟฟ้า

ปีการศึกษา 2518



บทคัดย่อ

วิทยานิพนธ์นี้ เป็นการศึกษา ออกแบบสร้าง และทดสอบหม้อแปลงลดแรงดันไฟฟ้า จากแรงดันไฟฟ้า 12 กิโลโวลต์ เป็นแรงดันไฟฟ้าทางคานแรงดันต่ำ 120/240 โวลต์ ขนาด 200 โวลต์-แอมป์แปร accuracy class 0.5 ที่ความถี่ 50 แอร์ทซ์ ตามมาตรฐานของ International Electrotechnical Commission (IEC) Recommendation Publication 186 (1969) จากการทดสอบหม้อแปลงลดแรงดันไฟฟ้าที่ ออกแบบและสร้างขึ้นนี้ ปรากฏว่าได้ผลเป็นไปตามมาตรฐานของ International Electrotechnical Commission (IEC)

Thesis Title : Design and Construction of a 12 KV.  
Voltage Transformer

Name : Mr. Chaisith Pongmorakot

Department : Electrical Engineering

Academic Year : 1975



#### ABSTRACT

The purpose of this thesis is to study, design, construct and test the voltage transformer having primary voltage rating 12 KV. and secondary voltage rating 120/240 volts, rated burden 200 VA., accuracy class 0.5, rated frequency 50 Hz. The design and construction follow The International Electrotechnical Commission (IEC) Recommendation Publication 186 (1969). The final results show that the voltage transformer constructed posses full qualification and conforms to the standards of The International Electrotechnical Commission (IEC).

### Acknowledgement

The author wished to avail himself of the opportunity to express his gratitude to Dr. Tatchai Sumitra and Dr. Pramote Un-Nahavaitaya, the advisors; for their comments and criticisms. It is a pleasure to record my deep indebtedness to all the staffs of SIRIWIWAT (1972) Co.,Ltd., such as; Mr. Somjet Watanasin, the Directing Manager, Mr. Kiatipong Noichaiboon, the Plant Engineer Manager, Mr. Pordee Chanyaman for their valuable assistances and supervisions. Grateful appreciation is also express to Mr. Sumet Sirisawatpipat and to all contributors.

## CONTENTS

	Page
Abstract (Thai).....	IV
Abstract (English).....	V
Acknowledgement.....	VI
List of Tables.....	IX
List of Figures.....	X
Chapter	
1. Introduction.....	1
2. Theory.....	3
2.1 Voltage Transformer Equivalent Circuit.....	5
2.2 Actual Ratio and Phase Angle Formulas.....	6
2.3 Method for Reducing Ratio Error and Phase Angle Error.....	10
2.4 Correction for Ratio and Phase Angle Errors...	11
2.5 Service Conditions Affecting Voltage Transfor- mer Errors.....	13
2.5.1 Burden.....	13
2.5.2 Wave - Form.....	14
2.5.3 Frequency.....	14
2.5.4 Voltage.....	15
3. Design of Voltage Transformer.....	16
4. Materials and Constructional Details.....	38
4.1 Materials.....	38
4.1.1 Silicon Steel.....	38
4.1.2 Magnetic Wire.....	39
4.1.3 Paper Insulation.....	40

4.1.4	Bushings.....	45
4.1.5	Transformer Oil.....	46
4.2	Constructional Details.....	50
4.2.1	Core and Laminations.....	50
4.2.2	Coils construction.....	53
4.2.3	Tank.....	57
4.2.4	The Assembly.....	60
4.2.5	Cost of Materials.....	64
5.	Voltage Transformer Testing.....	65
5.1	Routine Tests.....	65
5.1.1	Verification of Terminal Markings.....	66
5.1.2	Power Frequency Tests on Primary Winding	68
5.1.3	Power Frequency Tests on Secondary Winding.....	72
5.1.4	Determination of Errors According to the Requirements of Appropriate Accuracy Class.....	74
5.2	Type Tests.....	99
5.2.1	Temperature Rise Test.....	99
5.2.2	Impulse Voltage Tests.....	109
6.	Discussion and Conclusion.....	115
	References.....	117
	VITA.....	119



## List of Tables

Table		Page
3.1	Summary of ratio correction factor (RCF), phase angle ( $\delta$ ) and transformer correction factor (TCF) at 80% , 100% and 120% rated voltage (240 volts) at 25% and 100% rated burden (200 VA), power factor 0.8 lagging at rated frequency (50 Hz) .....	35
3.2	Summary of ratio correction factor (RCF), phase angle ( $\delta$ ) and transformer correction factor (TCF) at 80% , 100% and 120% rated voltage (120 volts) at 25% and 100% rated burden (200 VA) power factor 0.8 lagging at rated frequency (50 Hz).....	36
5.1	Limits of voltage errors and phase displacement	74
5.2	Percent voltage ratio error, ratio correction factor and phase angle at no load and 200 VA 0.85 P.F. at 80% and 100% rated voltage.....	79
5.3	Temperature rise test data.....	105



## List of Figures



Fig.		Page
1 - 1	Voltage transformer connection .....	2
2 - 1	Voltage transformer equivalent circuit .....	6
2 - 2	Voltage transformer vector diagram .....	7
3 - 1	Core dimensions, window opening, mean magnetic path and cross - section of the windings and insulations .....	29
3 - 2	Arrangement of high - voltage and low - voltage coils and the mean length of turn of the windings .....	29
3 - 3	The shape of the tank section and the position of the transformer in the tank .....	31
4 - 1	D.C. Magnetization Curve and D.C. Permeability Curve .....	41
4 - 2	Core Loss Curve .....	42
4 - 3	Exciting RMS Current Curve .....	43
4 - 4	The dielectric strength of pressphane insulations .....	44
4 - 5	High - Voltage Bushing and Accessory .....	48
4 - 6	Low - Voltage Bushing and Accessory .....	48
4 - 7	Transformer oil dielectric strength .....	49
4 - 8	Core leg cross - section .....	50
4 - 9	The dimension of the laminations for the core ...	51
4 - 10	Core of laminations showing modified lap joints with corner diagonally .....	52
4 - 11	Core clamping method .....	52

Fig.		Page
4 - 12	a) Wooden hobbin and b) Coil winding machine .....	53
4 - 13	The insulation between core and low - voltage coil .....	55
4 - 14	The low - voltage coil winding method .....	55
4 - 15	Oil ducts between high - voltage and low - voltage coils .....	56
4 - 16	The high - voltage coil winding method .....	56
4 - 17	Tank specification .....	58
4 - 18	Tank lid specification .....	59
4 - 19	Connection diagram of low - voltage coil .....	61
4 - 20	12 KV. voltage transformer .....	63
5 - 1	Polarity by inductive kick .....	67
5 - 2	Applied potential test connection diagram .....	69
5 - 3	Induced voltage test connection diagram .....	71
5 - 4	Power frequency test on secondary winding connection diagram .....	73
5 - 5	Voltage transformer uniload test set .....	77
5 - 6	Voltage transformer uniload test set connection diagram .....	78
5 - 7	The variation of RCF and $\gamma$ with varying burden at 0.8 P.F. lagging .....	82
5 - 8	The variation of RCF and $\gamma$ with varying power factor at burden 200 VA .....	83
5 - 9	Connection for the short circuit test.....	85

Fig.		Page
5 - 10	Connection for the open circuit test.....	87
5 - 11	Exciting current curve .....	89
5 - 12	Core loss curve .....	90
5 - 13	Temperature rise testing connection diagram .....	101
5 - 14	Temperature rise test .....	101
5 - 15	Temperature rise of oil .....	106
5 - 16	High - voltage winding resistance at shutdown.....	107
5 - 17	Low - voltage winding resistance at shutdown.....	108
5 - 18	Impulse voltage test .....	111
5 - 19	Impulse voltage test connection diagram .....	111
5 - 20	Reduced full wave voltage oscillograph .....	112
5 - 21	First full wave voltage oscillograph .....	113
5 - 22	Second full wave voltage oscillograph .....	113
5 - 23	Third full wave voltage oscillograph .....	113
5 - 24	Fourth full wave voltage oscillograph .....	114
5 - 25	Fifth full wave voltage oscillograph .....	114