INSULATION ASSESSMENT OF HIGH VOLTAGE OIL IMPREGNATED PAPER BUSHING AND RESIN IMPREGNATED PAPER BUSHING

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DEDICATION

This project report is dedicated to my late father, mother and my twin sister.

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ABSTRACT

Transformer diagnostic testing is perform to reveal the condition of the transformer. Early detection of problems can minimize the repairs involved and mitigate catastrophic failures. CIGRE findings show that bushings are common reason for power transformer failures. There are few research development conducted over the years to improvise construction of condenser bushings. One of the first technologies was the Resin Bonded Paper (RBP), but not manufactured anymore due to many technical & environmental reason. Secondly and the most widely used is Oil Impregnated Paper (OIP) technology apparently because of its low primary cost. In the circumstances' whenever there is problem with the insulation or internal degradation, it can accumulate high internal pressure inside bushing which can cause explosion of OIP bushing. That why migration from Oil Type to Dry Type Bushing Technology chosen to reduce risk of explosion /caught in fire during bushing failures .The new safer alternative considered is the Resin Impregnated Paper (RIP) technology which offer better technical performance over OIP bushings. This study presents comparison on insulation assessment of both types of bushing through power factor measurement and dielectric frequency response (DFR) analysis that contributing to assessment of failure characteristics of OIP and RIP bushings. Field testing was implemented to capture data for comparison purpose focusing on selection power transformer in grid division installation. The measurement of bushing insulator capacitances and measurement of the dissipation factor is to determine bushing health condition while DFR measurements as a supporting diagnostic tool for bushing condition assessment on paper inside the bushing. Commonly, both OIP & RIP constructions are that they are subject to very high mechanical, electrical and thermal stresses during operation. With result of this study, it may become possible to identify failure characteristic of insulating material between Oil Impregnated Paper Bushings (OIP) and Resin Impregnated Paper Bushings (RIP) and explain that moisture content in oil and paper has significantly contributed to the degradation of bushing. This methodology can be utilize for effective way to monitor moisture content at site and as a tool to decide condition of insulation bushing.

ABSTRAK

Ujian diagnostik dilakukan untuk mengetahui keadaan penebat yang terdapat didalam alatubah kuasa. Pengesanan awal masalah dapat meminimumkan pembaikan yang terlibat dan mengurangkan berlakunya kegagalan yang teruk. Penemuan CIGRE menunjukkan bahawa bushings adalah punca utama bagi kegagalan alatubah kuasa. Terdapat beberapa perkembangan penyelidikan yang dilakukan selama bertahun-tahun untuk menambahbaik pembinaan *condenser bushing*. Salah satu teknologi pertama ialah *Resin Bonded Paper* (RBP), tetapi tidak dihasilkan lagi disebabkan oleh isu pencemaran alam sekitar. Kedua yang paling banyak digunakan adalah teknologi *Oil Impregnated Paper* (OIP) kerana kos yang rendah. Tetapi apabila terdapat masalah dengan penuaan penebat disebabkan kelembapan dan pencemaran ia boleh mengumpul tekanan dalaman yang tinggi dan boleh menyebabkan letupan.Tambahan lagi dengan struktur luar *porcelain* akan menyebabkan keterukan yang melampau. Oleh itu penukaran penebat bushing dari jenis minyak ke arah teknologi jenis kering dipilih untuk mengurangkan risiko letupan ketika kegagalan berlaku. Alternatif yang lebih selamat ini dianggap dikenali sebagai teknologi *Resin Impregnated Paper* (RIP) yang menawarkan prestasi teknikal yang lebih baik daripada bushing jenis *Oil Impregnated Paper* (OIP). Kajian ini memberi perbandingan kepada penilaian penebat kedua-dua jenis *bushing* ini melalui pengukuran faktor kuasa dan analisis tindak balas frekuensi dielektrik (DFR) yang menyumbang kepada penilaian kegagalan ciri-ciri OIP dan RIP bushings. Ujian lapangan dilaksanakan untuk mendapatkan data bagi tujuan perbandingan yang memberi tumpuan kepada alatubah kuasa amnya dan khusus kepada penebat bushing dan pengukuran *power factor* adalah untuk menentukan keadaan kesihatan *bushing* sementara pengukuran DFR sebagai alat diagnostik sokongan untuk penilaian keadaan kelembapan kertas yang terdapat didalam struktur *bushing*. Biasanya, kedua-dua pembinaan OIP & RIP adalah tertakluk kepada tekanan mekanikal, elektrik dan terma yang sangat tinggi semasa operasi. Dengan hasil kajian ini, dapat mengenal pasti ciri kegagalan bahan penebat antara OIP dan RIP. Dengan cara ini dapat menjadikan cara pengujian kelembapan *bushing* mudah dan secara effektif dapat menentukan keadaan penebat didalam *bushing*.

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LIST OF ABBREVIATIONS

RBP	-	Resin Bonded Paper
OIP	-	Oil Impregnated Paper
RIP	-	Resin Impregnated Paper
RIS	-	Resin Impregnated Synthetics
DFR	-	Dielectric Frequency Response
PF	-	Power factor
R	-	Resistance
C	-	Capacitance
L	-	Inductance
HV	-	High voltage
TV	-	Tertiary voltage
LV	-	Low voltage

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CHAPTER 1

INTRODUCTION

1.1 Background

Power transformer bushing are use as insulated current pathway that connecting HV, LV, TV and Neutral windings terminals of a transformer. The purpose of the bushing is to keep the conductor insulated from the surface it is passing through [1,2]. Figure 1.1 shows description of graded condenser bushings that mostly high voltage bushings can be categorised in following three types based on their material, manufacturing & design:

i. RBP (Resin Bonded Paper)
ii. OIP (Oil Impregnated Paper) Bushing
iii. RIP (Resin Impregnated Paper) Bushing.

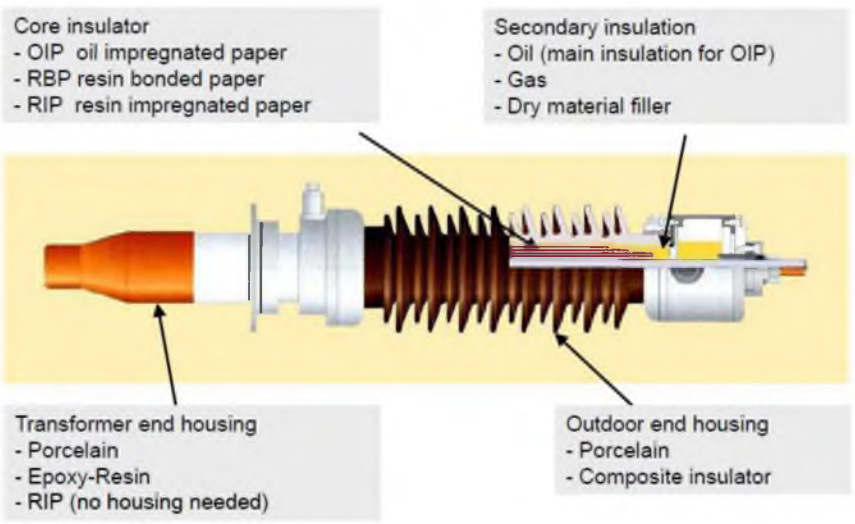

Figure 1.1 Description of graded condenser bushings

Inside of the bushing contain paper insulation and the bushing is often fill with oil to provide additional insulation. Common bushings failure mode due to partial discharge degradation in the insulation and cause a catastrophic failure to the power transformer.

Figure 1.2 Power transformer HV and LV bushing

Figure 1.2 shows power transformer HV & LV bushing installed. Different power utilities have adopted various methods monitoring to ensure the healthy condition of this power equipment. Solid insulation paper impregnated with transformer oil work as the chief insulation component in the condenser bushing. Hence ageing of pure (cellulose) paper becomes important aspect in judging the life of high voltage bushing [2]. Operating records show that about 90% of all preventable bushing failures are cause by moisture entering the bushing through leaky gaskets or other openings [3].The moisture can root to reduction of the dielectric strength and could be further lead to discharges or tracking which may bridge the insulation at over-voltage/transient stress during the event.

Measurement of capacitance and dissipation factor at rated frequency is relatively easy to conduct and inferences can be made of overall condition of the insulation. Insulation diagnostic tests of dissipation factor and capacitance are traditionally measure at power frequency (50/60 Hz) and mostly at 10 kV. However in recent developments, dielectric response methods using Polarization-Depolarization Current (PDC) and Frequency Dielectric Spectroscopy (FDS) has been established to evaluate the status of the insulation moisture and aging state of the Oil and Paper Insulation(OIP)[2,3,4]. The Dielectric Frequency Response (DFR)

Analysis is a measurement of the dielectric properties (i.e. capacitance and dissipation factor) as a function of frequency, while the standard dissipation factor test is only performed at 50 Hz. The very low frequencies contain information on moisture in the solid insulation, while the position of the slope in the mid-range frequencies indicates the conductivity of the liquid insulation. This curve is compare to model curves and the moisture content of the cellulose insulation is calculated.

Why RIP Bushing are required? Like other power utility in the world, mostly install of High Voltage bushing install in the system are OIP bushing. However, RIP bushing is one of the best solution available today to overcome almost all the bushing failure cause, increase the system reliability and human safety. Therefore, the urge to change from OIP to RIP bushing is slowly on going and been actively conduct research.

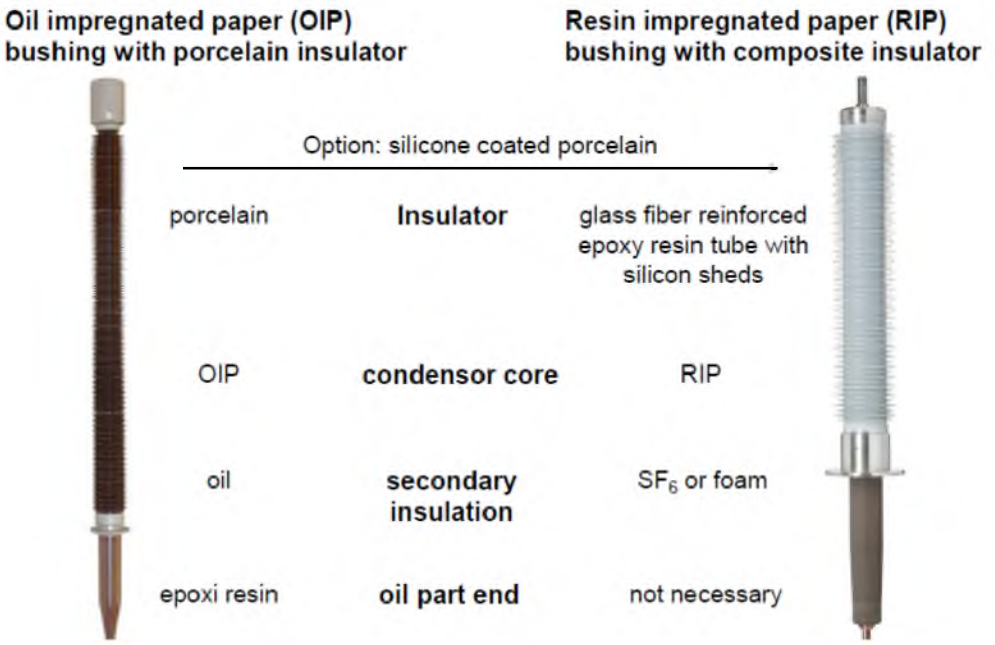

Figure 1.3 Power transformer bushing construction

Figure 1.3 shown comparison of bushing construction between OIP and RIP bushing. In order to reduce the OIP bushing failures and to overcome the disadvantages of OIP bushing, RIP bushing is one of most appreciated & latest solution available today.

1.2 Problem Statement

The major problem of OIP bushing is fire hazard and changes in power factor due to decrease in insulation resistivity caused by moisture ingress or external contamination. The reliability of transformer will be effected through unavailability to continue in service. Furthermore, explosions of transformer bushings have led to transformer failure and oil main tank spillage.

RIP bushing as compare to OIP based on its structure being an all-solid system, the oil phase is eliminated[11].Value of Tan Delta will not change significantly due to insulation degradation typically occurs over a very small area.Considered to be a safer alternative because the ability of self-extinguishing properties and no projection of dangerous broken pieces during a failure. Free maintenance cleaning of the insulator and hydrophobic - repel water rather than absorb also it can withstand temperatures up to 120 °C and better seismic withstand.

1.3 Research Objectives

The objectives of the research are:

i. To conduct testing measurement on power factor & dielectric frequency response test for OIP & RIP bushings
ii. To compare result on OIP & RIP bushings for insulation condition assessment.
iii. To justify and improve decision to replace unhealthy bushing condition through result of moisture content in paper as DFR bushing testing is not a compulsory test during routine maintenance of transformer.
iv. To identify failure characteristic of insulating material between OIP & RIP bushings.

1.4 Scope of Work

The scopes of this comparative study are to make sure development of the study is heading to the direction in fulfilling the objectives. There are several scopes to be follow:

i. This study is focus on HV bushing of Power transformer installation in grid division
ii. To conduct testing on power factor & dielectric frequency response for OIP & RIP bushing.
iii. To find correlation of power factor & dielectric frequency response that contributing to failure characteristics of OIP vs. RIP Bushings

1.5 Thesis Outline

This thesis is dividing into five main chapters. Firstly, Chapter 1 is the introduction of the whole project including problem background, problem statement, objectives and scope of works. Chapter 2 will cover about concept and measuring technique in insulation model include insulation power factor and dielectric response measurement and other related topics. Data collection and analysis techniques will be discuss in Chapter 3. The analysis includes the comparison between both OIP and RIP Bushing measurement field-testing. Chapter 4 will contain data analysis results. The results obtained will be discussed and compare in term of OIP & RIP bushing failure characteristics, capacitances and insulation power factor. Finally, Chapter 5 will comprise project summarised and recommendations for further improvement and future studies.

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