# CURRENT CARRYING CAPABILTY OF POLYESTER CARBON COATED FOR ELECTRICAL CONDUCTOR

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To my beloved mum and my late father,
my wife, my children, my siblings,
mother and father in law, brothers and sisters in law,
my colleagues and my friends

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# ABSTRACT

Copper and aluminum has been used as electrical conductor for power system transmission and distribution a long time ago. Due to higher demand of copper and aluminum in various sectors, copper and aluminum price has rose over a time and it has become a catalyst of cable theft activities. The utilities company throughout the world has lost billions of money due to cable theft activities. In this project, a carbon fiber based material known as polyester carbon coated is tested as replacement to copper and aluminum as electrical conductor. The conductor has been approved by SAE and used commercially as conductor in ignition cable for automotive sector. The main objective of this project is to study the characteristic and the current carrying capabilities of the polyester carbon coated as electrical conductor. A various type of test will be conducted on this conductor. Its include conductor resistance and resistivity, voltage drop by measurement and calculation and conductor current carrying capacity. The test that conducts meets British Standard requirement on power cable testing. The result of this project is a set of testing data which that will be analyzed in order to determine whether this conductor is suitable or not suitable to be used as conductor in power system and also a comparison of performance with existing materials.

# ABSTRAK

Tembaga dan aluminium telah digunakan sebagai pengalir elektrik untuk sistem penghantaran kuasa dan pengagihan sejak dari dahulu lagi. Oleh kerana permintaan yang tinggi terhadap tembaga dan aluminium dalam pelbagai sektor, harga tembaga dan aluminium telah meningkat dari masa ke semasa dan ia menjadi pemangkin aktiviti kecurian kabel. Syarikat utiliti di seluruh dunia telah kerugian berbilion ringgit disebabkan oleh kecurian kabel. Dalam projek ini, bahan berasaskan serat karbon dikenali sebagai '*polyester carbon coated*' diuji sebagai bahan gantian kepada tembaga dan aluminium sebagai pengalir elektrik. Pengalir tersebut telah digunakan secara komersial dalam kabel pencucuhan untuk sektor automotif dan telah mendapat keluluskan dari SAE. Objektif utama projek ini adalah untuk mengkaji ciri dan keupayaan membawa arus '*polyester carbon coated*' sebagai pengalir elektrik. Pelbagai jenis ujian akan dijalankan pada pengalir ini. Ia termasuklah pengujian rintangan dan kerintangan pengalir, kejatuhan voltan melalui pengiraan dan pengukuran dan keupayaan pengalir membawa arus,. Ujian yang dijalankan adalah memenuhi piawaian '*British Standard*' pengujian terhadap kabel kuasa . Hasil projek ini adalah satu set ujian data yang yang akan di analisis untuk menentukan sama ada pengalir ini sesuai atau tidak sesuai untuk digunakan dalam sistem kuasa dan juga perbandingan prestasi dengan bahan-bahan yang sedia ada.

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| | |
|---|---|
| BS | British Standard |
| IET | Institution of Engineering and Technology |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronic Engineer |
| TNB | Tenaga Nasional Berhad |
| TM | Telekom Malaysia |
| IACS | International Annealed Copper Standard |
| SI | Système Internationale |
| PVC | Polyvinyl Chloride |
| XLPE | Cross Linked Polyethelyene |
| PAN | Polyacrylonitrile |
| RFI | Radio Frequency Interference |
| EMI | Electromagnetic Interference |
| SAE | Society Automotive Engineers |
| RTD | Resistance Temperature Detector |

# LIST OF SYMBOLS

| | |
|---|---|
| μ | Micro |
| Ω | Ohm |
| $^{O}C$ | Degree Celsius |
| K | Kelvin |
| A | Ampere |
| kA | kiloAmpere |
| mA | miliAmpere |
| Amp | Ampere |
| V | Volt |
| kV | kilovolt |
| mV | miliVolt |
| W | Watt |
| ρ | Rho |
| m | meter |
| cm | centimeter |
| mm | millimeter |
| % | percent |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Definitions of Conductor

Conductor is a material or medium which permits an electron flow through it. The electron in low resistivity material will flow when electromotive force (emf) was applied on it. The flow of this electron is known as electric current and measured in unit Amperes (A). Copper and aluminum is an example of conductor materials. Copper and aluminum is widely used as conductor in wire and cable. It has been used for power generation, transmission, distribution, telecommunication, electronic circuitry and wiring for residential, commercials and industries.

The capability of material to conduct electric current is very relying to it resistivity. Material with low resistivity is the best conductor and the material with high resistivity is a bad conductor. The example of material with low resistivity is silver, but it is too expensive to be used as conductor. Some material resistivity is depicted in table 1.1 below.

**Table 1.1 :** Resistivity of material (metal)[1]

| Material | Resistivity |
|---|---|
| Cooper | 0.0178μΩm |
| Aluminum | 0.0285 μΩm |
| Tin | 0.114 μΩm |
| Silver | 0.0163 μΩm |
| Brass | 0.06-0.09 μΩm |
| Iron | 0.100 μΩm |
| Lead | 0.218 μΩm |

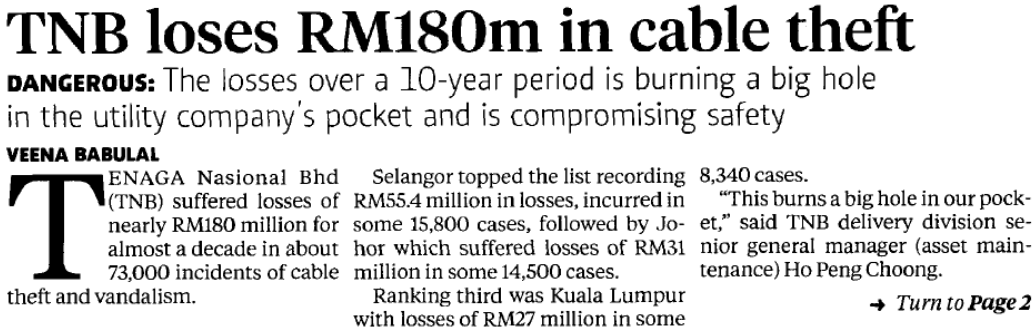
From the table the less expensive material but has good resistivity after silver is copper and aluminum. The selection of conductor not only depending to it resistivity, but the tensile strength, stiffness, thermal conductivity, life span include corrosion and oxidization also has to considered.

There are also non-metallic conductor such as graphite, solution of salt, carbon, plasma and etc. It has been found that carbon fiber is a good electric conductor. In this project, a carbon fiber known as polyester coated carbon is tested to find the potential of the material to be used as replacement for copper and aluminum for wire and cable conductor in power system transmission and distribution. This conductor currently has used as conductor in ignition cable for automotive sector.

## 1.2 Problem Statement

Copper and aluminum is widely used as conductor in wire and cable since in the early stage of electric power system is developed. Copper and aluminum also popular in industrial sector, commercials and house appliance, building construction, automotive parts, machinery parts and etc. Due to high demand in multiple sectors, the price of copper and aluminum is steadily rose year on year. This caused electric cable theft activities which peoples can resale the cable as scrap metal to earn money. Even though there are some efforts from the utility company and authority to prevent these activities, it is cannot be fully prevented.

There are a lot of impact due to cable theft activities to utility company, industries and consumer site. As reported by News Straits Times, Tenaga Nasional Berhad (TNB) loses RM180 million in cable theft almost a decade. Utusan Malaysia reported that Telekom Malaysia (TM), loses RM29 million in eight months due to cable theft. The impact of this cable theft is the utility company need to spend much money to replace the missing cable. In addition, cable theft caused a fault in power system and telecommunication system. This will increase their interrupting time to troubleshoot and restore their services. Figure 1.1 shows the newspaper cutting regarding to this problem.



**TNB loses RM180m in cable theft**

**DANGEROUS:** The losses over a 10-year period is burning a big hole in the utility company's pocket and is compromising safety

**VEENA BABULAL**

TENAGA Nasional Bhd (TNB) suffered losses of nearly RM180 million for almost a decade in about 73,000 incidents of cable theft and vandalism.

Selangor topped the list recording RM55.4 million in losses, incurred in some 15,800 cases, followed by Johor which suffered losses of RM31 million in some 14,500 cases.

Ranking third was Kuala Lumpur with losses of RM27 million in some 8,340 cases.

"This burns a big hole in our pocket," said TNB delivery division senior general manager (asset maintenance) Ho Peng Choong.

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**Figure 1.1** Problem statement[2]

In consumer site, cable theft caused failure to their electrical equipment and appliance due to voltage incremental. The industrial, commercial and services sector suffers a lost in millions due to power interrupting. The power interrupting will impact on their productivity as their plant cannot operate as usual. In commercial and services sector, telecommunication services interrupting caused difficulties on operation since they were unable to communicate via internet or intranet. The situation is worsening when electric and electronic equipment cannot operate due to power supply is not available. Many of tasks cannot be done until the power system and or telecommunication services were restored.

One way to overcome the problems is by replacing copper and aluminum with other material which did not have a resale value. Through this project, polyester coated carbon was proposed to solve cable theft problem. Polyester carbon coated is material which were derived from man-made fiber through carbonization process, which are stronger than metal, lighten than copper and aluminum. It also has a high tensile strength, and good electrical properties.

## 1.3 Objective

The objective of this project is as below:

1. To study characteristic of polyester carbon coated as high voltage cable conductor.
2. To conduct current carrying capacity test on the material.
3. To compare the performance with existing material.

All testing and experiment will be done at High Voltage and High Current Institute, Universiti Teknologi Malaysia. To meet the objectives, all test or experiment that will conduct on this conductor will follow to standard testing procedure on power cable.

## 1.4 Scope of work

Scope of work on this project is to complete the following tasks:

1. Testing the current carrying capability of polyester carbon coated.
2. Measurement on resistivity, losses and voltage drop of the conductor.
3. Determination the capability of the conductor to conduct continuous AC current.

## 1.4 Expected Result

The result expected from this project is an understanding of the characteristic of polyester carbon coated as electric conductor through the analysis of the testing data. The data will be analyzed to find the performance of the material, current carrying capability and comparison with existing material. The result will be determined the advantages and disadvantages of the material as electrical conductor. These result also will determined whether the conductor is suitable or not suitable to be used as electric conductor for power transmission and distribution.

## 1.5 Thesis Outline

This thesis is divided into five chapters. There are:

i. **Introduction.** This chapter describes the problem statement, objective, scope of work and expected result.

ii. **Literature review**. This chapter is concentrate in detail on cable, copper and aluminum as conductor, carbon fiber properties and characteristic, advantageous and disadvantageous of carbon fiber.

iii. **Methodology**. This chapter explains in details the project methodology, conductor resistance testing technique, voltage and current measurement procedure in electric circuit and conductor temperature measurement technique.

iv. **Result, Analysis and Discussion**. This chapter presenting in details the testing and measurement result of conductor resistance and resistivity, voltage drop measurement, load current measurement, power dissipation measurement, and conductor temperature measurement, the detail analysis and discussion on data from calculation and testing result, characteristic of the conductor under AC current, and determination of current carrying capability of polyester carbon coated.

v. **Conclusion.** Summary of project findings and further works.

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