Faculty of Engineering

CALIBRATION OF TRANSMISSION LINE THERMAL MODEL OF THE DYNAMIC THERMAL CURRENT RATING SOFTWARE IN WIDE AREA MEASUREMENT SYSTEM

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Final Year Project Report ☑

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CALIBRATION OF TRANSMISSION LINE THERMAL MODEL OF THE DYNAMIC THERMAL CURRENT RATING SOFTWARE IN WIDE AREA MEASUREMENTS SYSTEM

SHERFRIZ SHERRY MUSA

A dissertation submitted in partial fulfilment

of the requirement of the degree of

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Dedicated to my beloved family, supervisor and friends

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ABSTRACT

Dynamic Thermal Current Rating (DTCR) is one of the software tools in Wide Area Measurement (WAM) system that has been widely used by many system operators. It is mainly used to calculate the line rating based on measured or predicted weather conditions on overhead transmission lines. However, around five years ago, the accuracy of the DTCR has becoming an issue in Sarawak Energy Berhad (SEB). Hence, this project is intended to study and discuss in detail of the transmission line thermal model of DTCR software. Accordingly, an improved thermal pi (π) model is proposed. The performance of the improved π model will be distinguished with the existing thermal model. The weather factors that bring a substantial impact on the current rating is also considered. Therefore, this research focusses on calibrating the DTCR through phasor measurement in WAM system, as well as the field measured data. The performances analysis of the thermal models are evaluated using Matlab software based numerical analysis.

ABSTRAK

Dinamik Termal Arus Penilaian (DTCR) adalah salah satu alat perisian dalam sistem Pengukuran Luas (WAM) yang telah banyak digunakan oleh operator sistem. Ia digunakan terutamanya untuk mengira penarafan garisan berdasarkan keadaan cuaca yang diukur atau diramalkan pada talian penghantaran atas. Walau bagaimanapun, sekitar lima tahun yang lalu, ketepatan DTCR telah menjadi isu di Sarawak Energy Berhad (SEB). Oleh itu, projek ini bertujuan untuk mengkaji dan membincangkan secara terperinci mengenai model termal penghantaran haba perisian DTCR. Oleh itu, model pi terma (π) yang lebih baik dicadangkan. Prestasi model π yang lebih baik akan dibezakan dengan model haba sedia ada. Faktor cuaca yang membawa kesan yang besar terhadap penarafan semasa juga dipertimbangkan. Oleh itu, penyelidikan ini memberi tumpuan kepada kalibrasi DTCR melalui pengukuran phasor dalam sistem WAM, serta data diukur bidang. Analisis prestasi model haba dinilai menggunakan perisian numerik berdasarkan Matlab.

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LIST OF SYMBOLS

V	-	Voltage
I	-	Current
Ω	-	Ohm
R	-	Resistance
Z	-	Impedance
P	-	Active power
Q	-	Reactive power
T_c	-	Conductor temperature
l	-	Conductor length
$R(T_c)$	-	Conductor temperature at T_C

LIST OF ABBREVIATIONS

PMU	-	Phasor Measurement Unit
WAM	-	Wide Area Measurement
SDC	-	State Dispatch Centre
PDC	-	Phasor Data Concentrator
DTCR	-	Dynamic Thermal Current Rating
DTLR	-	Dynamic Thermal Line Rating
DTR	-	Dynamic Thermal Rating
DLR	-	Dynamic Line Rating
SLR	-	Static Line Rating
SCADA	-	Supervisory Control and Data Acquisition
HMI	-	Human Module Interface
EKF	-	Extended Kalman Filter

CHAPTER 1

INTRODUCTION

1.1 Project Background

Most of the 275kV substations in the Sarawak Energy (SEB) Grid System are equipped with phasor measurement units (PMU). These PMUs measure the GPS's synchronized voltage and current phasor of the transmission line feeders in these substations, and transmitted them back to be archived in a historian of centralized Wide Area Measurements (WAM) system located in the State Dispatch Centre (SDC) in Kuching. Figure 1.1 shows the overview of WAM system.

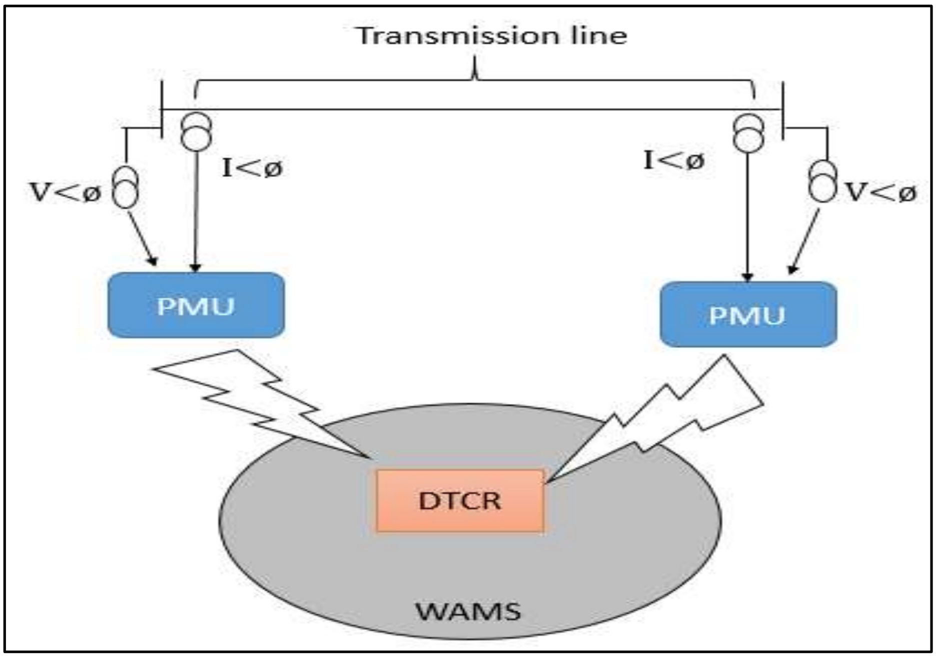

Figure 1.1: Overview of WAM system

Currently, the main usage of these data is for visual display to facilitate system monitoring and situational awareness in the SDC. The WAM system also has a number of application software that makes use of these phasors measurement data for many purposes such as system control, system protection and security analysis and measurement as well. One of such applications is Dynamic Thermal Current Rating (DTCR). The DTCR software uses the phasor measurement data at the remote ends of a transmission line. A thermal heat balance model is built-in on DTCR in order to estimate the maximum current rating of transmission line.

1.2 Data Communication

Wide area measurement system is an efficient system that employed Phasor Measurement Unit (PMU) to collect data at distant location. It is categorized as a system that have a great performance in monitoring and controlling power system dynamically. The PMU is installed at substations to generate and transmit data to the Phasor Data Concentrators (PDCs) which gather and groups all the data in different sets based on the time stamp [1]. PMU is an upgraded system that have high tendency to overcome the limitations in Supervisory Control And Data Acquisition (SCADA) system [2]. Following are the recognized limitations in SCADA system.

a. Data obtained from different location at a particular time are less precise
b. Slow changes in reactive power (Q), active power (P), and voltage magnitude (V)
c. Monitoring system for dynamic behaviour needs synchronized data rapidly

PMU is a high cost device which used to provide dynamic view of the transmision line and therefore it requires an optimal position [3]. For each bus, PMU can show the voltage, current and power flow on the grid. In short, PMU provides phasor measurement of voltages and currents on overhead transmission lines.

The data of PMU will be transmited to a central location where PDC is installed. In the communication framework, data is transmitted in form of byte that also known as message frame. Once the data has reached the PDC, it will be transmitted to the next level of PDC for various applications [1]. Figure 1.2 represents the structure of PMU.

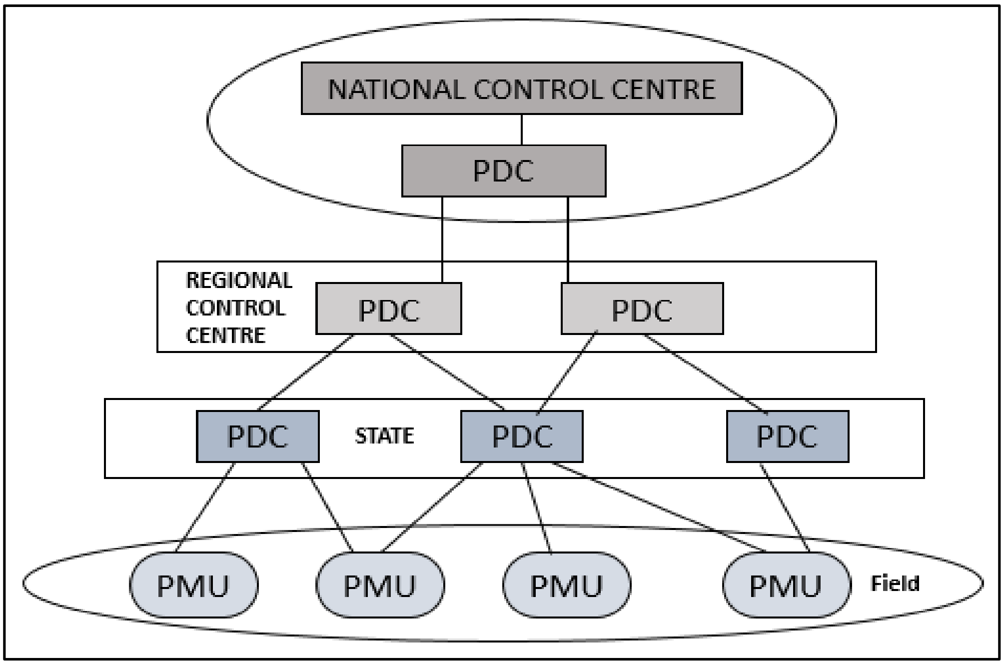

Figure 1.2: Structure of PMU [1]

1.3 Dynamic Line Rating

There are numbers of transmission lines system monitoring that are available in the market all around the world. One of the most viable techniques used to increase the transmission line capacity is Dynamic Line Rating (DLR) or Dynamic Thermal Current Rating (DTCR). DLR is a method of exploiting the existing transmission lines where it has the capability to increase the loading capacity, avoid new line investment, and provide attachments in faulted section of transmission line [4].

Thermal current limit or ampacity refers to the maximum current that can flow through a conductor or device. There are two types of thermal ratings used under normal operating in transmission lines system [5]. The first one is static thermal rating. Static thermal ratings are defined as current that lead conductor to operate under presumed atmospheric conditions from ***wind, solar and rain***. Dynamic current thermal on the other hand is a current which allows the conductor to operate under real atmospheric conditions. In overhead transmission line, line ratings were controlled by the importance of statutory clearance between the conductor and other elements. The rise in the line sag is mainly caused by the high temperature in conductor.

Theoretically, in short transmission line and distribution networks, the capacity of loading limit can be determined by maximum thermal of conductor. Whereas, for long transmission line, aspect such as economic energy losses, system stability and voltage regulation are taking into account in determining its maximum loading capabilities. For some particular loading system conditions, the thermal rating of transmission line is explained in term of current or MVA at nominal voltage limit (experts system) and this is usually based on the level of normal, seasonal and emergency load. Under normal and fault condition, aspects such as loading limit, electrical characteristics and real atmosphere conditions will affect the conductor temperature of power transmission line.

1.4 Problem Statement

One of the problems that always occur on the transmission line is overcurrent. Due to the thermal effect, the amount of current flowing through the conductor may reach its maximum value. When overcurrent occurs, it affects the performance of the transmission line. As a result, it decreases power efficiency of the overhead transmission line. DTCR is a software to estimate the thermal effect in transmission lines in order to make sure loading (i.e. thermal current) does not exceed the limit. It is useful to calculate the line rating based on predicted or measured weather condition. However, currently, the existing DTCR is not fully functional due to some PMU and thermal estimation issues. For example, such issue might due to some uncertainty and reservation in the calibration and also accuracy of the existing thermal model that considers the atmospheric conditions (wind speed, solar irradiation intensity, and ambient temperature) as constant. However, these weather conditions cannot be constant due to the random weather effects on the transmission line. Therefore, in calibrating the dynamic thermal model in DTCR, these weather factors are integrated with the extended thermal model in the empirical estimation to improve the DTCR performance.

1.5 Objectives

The following objectives will be achieved:

1. To verify the validity of the conductor temperature on transmission line that is estimated using existing DTCR software of WAM system.
2. To improve the existing DTCR thermal model by integrating the dynamic parameters.
3. To compare the measured data of WAM system (using PMU measurement) with the estimated data that is achieved through the empirical assessment. This is to distinguish the performance of the improved DTCR thermal model with the existing model.

1.6 Project Scope

This study emphases the improvement of the DTCR thermal model in WAM system through the PMU measurement. These PMUs are mainly engaged to measure the synchronised voltage and current along the transmission line. The atmospheric conditions such as wind speed and solar irradiation intensity that might have a great impact on the thermal occurrences of the DTCR model will also be investigated accordingly in this project. Consequently, the DTCR model accuracy can be studied and analysed using the PMU measurement. In this project, the calibration of the DTCR model is mainly concentrated on the conductor temperature calculation. For the conductor temperature calculation, there will be two formulas based series (existing model) and π (improved) model will be applied. This is to distinguish the performance of improved DTCR model with existing model. Last but not least, the calculation model of the existing DTCR model can be improved by following the IEEE standard 738-2012.

1.7 Project Outline

This project outline consists of following chapters.

Chapter 1 is the introduction of the project. This chapter discussed the background of the study, objectives, problem statement and project scope. It also highlights the outline of this dissertation.

Chapter 2 is the Literature Review. This chapter starts with the overview and the synopsis of the related methods, models, and standards. Mostly, the study covers the recent five years literatures on the Dynamic Thermal Current Rating (DTCR) models. Finally at the end of this chapter it highlights the summary of the contribution, merits and demerits (existing limitation) of the existing DTCR models.

Chapter 3 is the methodology. It gives the overall key ideas and layouts of the proposed model. It also explains all the processes, mathematical derivations, and schematic diagrams of entire contribution.

Chapter 4 is the performance analysis. This chapter evaluates the performance of the proposed model. Each of the result will be compared, analysed and discussed accordingly. It also compares the proposed result with the existing model.

Chapter 5 presents the overall conclusion on the study and followed by some recommendation for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In recent years, due to the increasing demand of electricity and several addition of new generation capacity, the trend of uprating the existing overhead transmissions are getting more widespread. Dynamic Thermal Line Ratings (DTLR) is one of the most practicable technique to deal with uncertainties, reservation, and accuracy issues. Due to these issues, the dynamicity of the thermal occurrences varies in the transmission lines. Therefore, many researchers from the academy and the industry have shown their interest to conduct studies on the improvement of the Dynamic Thermal Line Ratings (DTLR) challenges.

At the beginning of this chapter, it emphasizes the current trends and its standards. Hence, the consequences of the study is discussed in the following sections and subsections. Each of the section, it defines, classifies, categories with the parameters of the application. This chapter also highlights the merits and the limitation of the existing models. In consequences, the chapter ends with the summary.

2.2 Dynamic Thermal Line Rating (DTLR)

The dynamic thermal line rating includes the real time data measurement such as local measurement data and loading asset on transmission line [6]. It is calculated based on various parameters that are available in real time monitoring data of overhead transmission lines. Due to the capability of increasing maximum loads and allowing thermal constraint, the demand of DTLR is always higher than static line rating (SLR).