“IMPROVEMENT OF THERMAL STABILITY IN MCCB FRAME-1”

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Technology

In

Electrical Engineering
(Electrical Power Systems)

By
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Certificate

This is to certify that the Major Project Report (Part-I) entitled "Improvement in thermal stability in MCCB frame-1" submitted by Mr./Ms. Bhargav Darji (21MEEE02) towards the partial fulfillment of the requirements for Semester-III of Master of Technology (Electrical Engineering) in the field of Electrical Power Systems of Nirma University is the record of work carried out by him/her under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for an award of any degree or diploma.

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I, **Bhargav Darji**, Roll No. **21MEEE02**, give undertaking that the Major Project entitled "**Improvement of thermal stability in MCCB frame-1**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Electrical Engineering (Electrical Power System)** of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Acknowledgment

I am quite pleased to share this thesis work on "**IMPROVEMENT OF THERMAL STABILITY IN MCCB FRAME-1**." I am grateful to everyone who assisted me in completing my thesis and provided important suggestions during the project work. It is a pleasure for me to express my gratitude to them.

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Abstract

The use of new technology is increasing today more than it did a decade ago. It will cause penetration into the Power grid and stress on both commercial and industrial equipment. Commercial and industrial machinery costs a lot of money, so it is important to protect it from any power system disturbances. The protecting devices' design must be good enough to defend the equipment and isolate it from the system if any undesirable events affect the equipment's supply.

An MCCB must have the ability to break the circuit to protect against overload and short-circuits happening in the power system with the least amount of energy loss, if possible, for the breaker to function properly for a longer period. MCCB offers the necessary robustness operation with a variety of current rating capacities. Current is constant in the breaker, so temperature rise, and voltage drop occur in the breaker mainly depend upon the internal resistance offered by the current path. As the breaker is in continuous operation if current loading is increased onto the breaker, then the temperature also rises in the breaker. The body of the breaker has its limitation for withstanding the temperature rise so beyond that limit breaker may be damaged and it further leads to its impact on the other surrounding machinery as well.

It is necessary to control temperature rise occurring in the breaker and this only happens by controlling the value of the milli volt drop occurring in the breaker. Therefore, in the worst installation condition of machinery or breaker temperature should not exceed the pre-defined limits.

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Nomenclature

MCCB	Molded Case Circuit Breaker
IEC	International Electro-technical Commission
TMR	Thermal Magnetic Release
MAC	Mechanical Operated Contact
N-pole	Neutral pole
NT	Non-Trip
ET	Early-Trip
OCV	Operational Current Transformer Voltage
CTQ	Critical to Quality
PCN	Permanent Change Note
OT	Over Travel
FTFM	Fix Thermal Fix Magnetic
FM	Fix Magnetic
VTVM	Variable Thermal Variable Magnetic
VTFM	Variable Thermal Fix Magnetic
CP	Contact Pressure
IS	Indian Standards
mS	Milli Seconds
ATC	Ambient Temperature Compensation
ACF	Ambient Correction Factor
DCmV	Direct current milli volt

Content

Table of Contents

Chapter 1 Introduction

This project was undertaken to provide thermal stability in MCCB frame-1 with the help of IEC/IS standards.

This project is divided into three parts:

a) To find ACF for different Temperature ratings.
b) Develop N-pole Protected Circuit breakers.
c) To provide Thermal Stability in MCCB.

1.1 Ratings of MCCB

- Current Ratings I_n 16, 20, 25, 32, 40, 50, 63, 80, 100, 125, 160, 200.
- Rated Operational Voltage U_e:230V/ 415V 50/60 H_Z.
- Impulse Withstand Voltage U_{imp}: 6kV, 8kV.
- Overload Protection I_r: 1.3I_n and above
- Short-circuit Protection I_i: 6I_n, 10I_n, 12I_n

1.2 Application and Limitation

Major use in commercial buildings and industry.
Compact Design, Modular pole structure, Breaking capacity up to 36kA.

1.3 Construction detail

- The MCCB has a single brake contact mechanism that is appropriate for the current path with the least amount of resistance. From the heat source to the termination, the MCCB is made up of numerous current-carrying sections and poles.
- On the moving contact, which is constructed of copper braids with a 10 sq mm thickness, a special cold-forming operation profile has been implemented. It provides a larger area for brazing the button, allowing current to flow more easily, and reducing contact erosion.
- Utilize silver contact buttons as much as you can for greater anti-weld properties and longer electrical life. The design of a fixed or moveable contact button must consider OT. To avoid degradation, silver buttons require to flow of current from the moving contact to fix contact.
- The MAC contact and TMR are joined by electrical and mechanical bolts. The latch lever and mechanism are indeed the essential aspects that MAC and TMR work together to control.
- To provide overload protection against currents that exceed 30% of their rated current, TMR has bimetal welded with a heater. To prevent short circuits, C-core and I-core are used. The two cores are made up of ferromagnetic material.

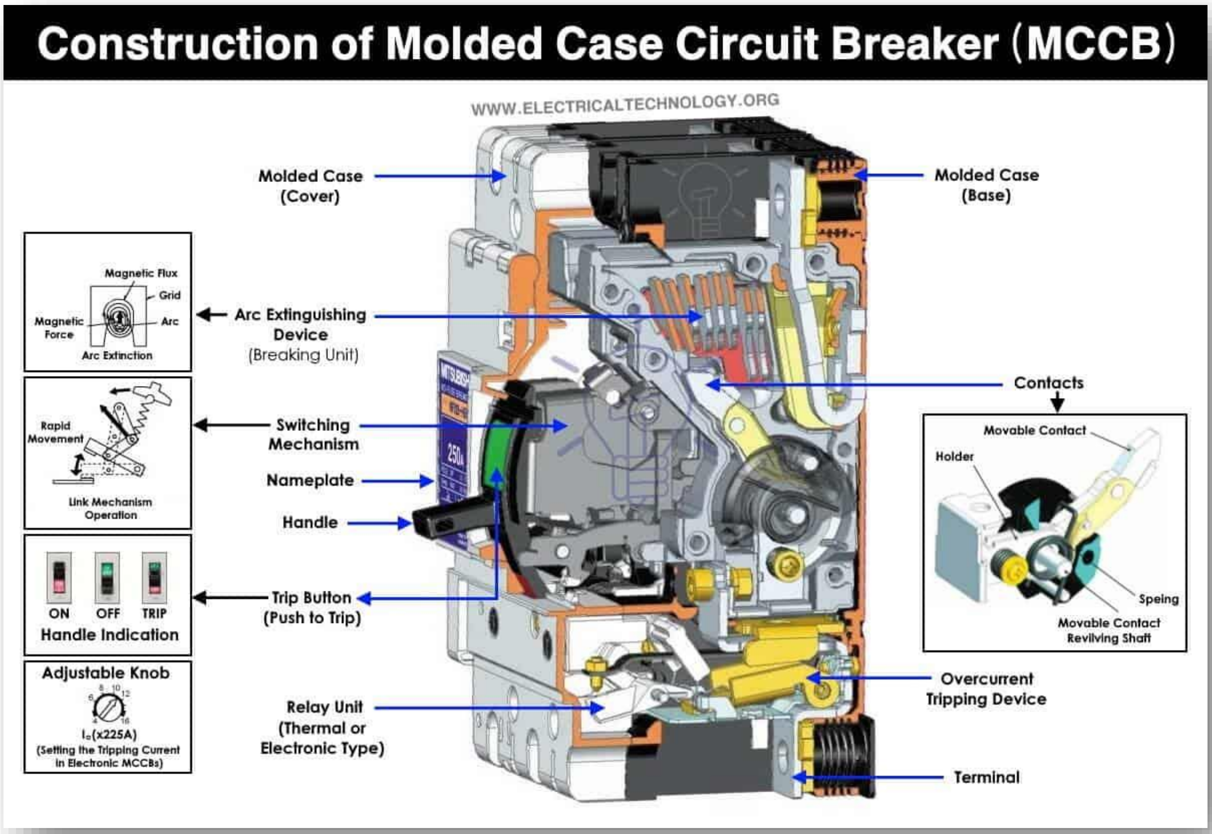


Figure 1: Cut section view of MCCB

1.4 Operation

- MCCBs' main purpose is to safeguard circuit components if an overcurrent event occurs in the power system. When an electrical circuit experiences overload or a short circuit, the MCCB immediately trips and places it in an isolated state.
- The heater produces excessive heat that is transferred to the bimetal if an overcurrent can flow through the breaker. Bimetal characteristics cause it to start deflecting over a certain pace and hit the triplet. The triplet disconnects the latch's mechanism and trips the circuit breaker.

Figure 2: Moving contact

- In the meantime, a pole assembly's fixed and moving contacts break apart, creating an arc in the pole structure. Arc chutes work with a deionized plate to prevent arcs from being produced by contacts.
- Deionized plates lengthen arcs, produce highly resistive paths, and cause arcs to be quenched as a result.

Figure 3 Arc chute

1.5 Organization of Thesis

Details of work done Available in this thesis are sectorized in various chapters. The details are as follows.

- Chapter 2

  Chapter 2 gives a brief Introduction to, the literature survey of the temperature rises in MCCB and thermal stability of MCCB, in which the different IEEE papers and other journal Papers are introduced.

- Chapter 3

  Introduce the future strategy for project work, and somehow like identification of problems in finding ACF, Provide N-pole Protected MCCB, and Thermal improvement and study of tools which will use in the analysis.

- Chapter 4

  Chapter 4 Introduce the procedure, calculation, and test setup for finding the ACF of a breaker in different temperature ranges.

- Chapter 5

  This Chapter introduces a whole bunch of temperature rise analysis, tripping of breaker, and details study of Bi-metal and heater material and its characteristics for provide a solution for developing N-pole protected MCCB.

- Chapter 6

  This Chapter introduces a whole bunch of temperature rise analysis, magnetic test, mV drop test, material identification and its characteristics for provide a solution for providing thermal stability in MCCB.

- Chapter 7

  Chapter 7 gives a summary of projects that carried out and its conclusion with some future scope related work.

- Chapter 8

  Chapter 8 gives a brief about some references containing different kinds of journal papers, patent papers, and so on for completing this project.

Chapter 2 Literature Survey

2.1 IEEE and another journal paper

2.1.1 Paper 1

Title: Measuring Molded case circuit breaker resistance
Author: J. J. Shea and J. A. Bindas
Publication: *IEEE Transactions on Components, Hybrids, and Manufacturing Technology*, vol. 16, no. 2, pp. 196-202, March 1993

Summary: This paper illustrates how circuit breaker resistance can be significantly affected by the millivolt drop test itself. The millivolt drop technique can provide very useful information on the breaker condition if properly performed. ASTM standard B-539 is an excellent reference for contact resistance measurements in general, but it excludes circuit breakers. Additional guidelines are necessary if reliable resistance measurements on circuit breakers are desired when using a millivolt drop technique. The millivolt drop measurement itself can influence breaker contact resistance. Millivolt drop parameters include applied circuit voltage, current, and measurement time. Their effect on breaker contact resistance will be measured and discussed.

2.1.2 Paper 2

Title: Effect of Ambient temperature and contact force on contact resistance and temperature behavior for power engineering contacts

Author: Volker Behrens, Edgar Siegle, Jonas Schreiber, Thomas Honig, Michael Finkbeiner
Publication: *2012 IEEE 58th Holm Conference on Electrical Contacts (Holm)*, 2012, pp. 1-6

Summary: This paper describes the setup of the model switch and gives the first results of tests related to typical conditions of MCCB with a rated current of 160 A. Parameter variations include contact force (5N to 30 N), ambient temperature (25°C to 125°C) and contact material (Ag/C, Ag/Ni, Ag/W, AgNi0,15). Results obtained are discussed on the background of contact surface roughness as well as contact material properties such as electrical conductivity and hardness as a function of temperature.

2.1.3 Paper 3

Title: Introduction to Heat Transfer
Author: S.K. Som
Publication: PHI Learning Private Limited.

Summary: This book represents the transfer of heat from various methods, how it affects the material, and how the ambient temperature effect heat transfer. It also analyses steady-state heat conduction.

2.1.4 Paper 4

Title: Ambient Temperature Influence on Temperature Of MCCB
Author: S. Lv, M. Zong

Publication: *2017 IEEE International Magnetics Conference (INTERMAG)*, 2017, pp. 1-1

Summary: This paper gives an idea about how ambient temperature affects the temperature of a breaker. When the ambient temperature changes from 22°C to 35°C, 37°C to 50°C, 22°C to 50°C, the final temperature increases 12.3°C, 25.8°C and 22.8°C respectively. When the ambient temperature changes from 22°C to 50°C then to 22°C, the maximum temperature difference is 26°C

2.1.5 Paper 5

Title: Advanced Thermal Simulation of a Circuit Breaker
Author: Peter U. Frei, Hans O. Weichert
Publication: *50th IEEE Holm Conference on Electrical Contacts and the 22nd International Conference on Electrical Contacts, 2004.*, 2004, pp. 104-110

Summary: This study is focused on the steady-state thermal analysis of normal operation (as opposed to short circuit conditions), the heating effect of the switching arc is not considered here. The solution of the finite element model described a huge amount of data. Both electrical (current density, voltage) and thermal (temperature, heat flux density) results are available for every single element of the model.

2.1.6 Paper 6

Title: Thermal simulation of switchgear
Author: J. Paulke, H. Weichert, P. Steinhauser
Publication: *Forth-Seventh IEEE Holm Conference on Electrical Contacts (IEEE Cat. No.01CH37192)*, 2001, pp. 6-11

Summary: The combination of mechanical relations, electrical properties, and contact phenomena for thermal analysis of switchgear made it possible to build up a simulation tool that already serves well, especially for studying design parameters. Additional implementation of heating due to arcing lead to a simulation model for a contactor which allows even virtual switching operations

2.1.7 Paper 7

Title: Implications of Direct and Indirect Heating of Bi-Metallic Strip in MCCBs – Challenges and Solutions
Author: Sapuram, S., Srikantaiah, S., Vishnoi, A. K., & Satyanarayana, S
Publication: *Power Research - a Journal of CPRI*, *16*(1), 33. (2020)

Summary: In this article Direct & Indirect method in a breaker for thermal tripping are described and include current passing through bimetal and how much heat generated at tip of the bimetal with 2In test. Deflection of a bimetal at particular temperature are measured with the help of direct and indirect heating method.

2.1.8 Paper 8

Title: Coupled thermo-structural analysis of a bimetallic strip using the absolute nodal coordinate formulation
Author: Čepon, G., Starc, B., Zupančič, B. et al.
Publication: Multibody Syst Dyn 41, 391–402 (2017).

Summary: This study provide new model of a bimetallic strip is proposed based on a coupled thermo-structural analysis using the absolute nodal coordinate formulation. Dynamic response of a bimetal is analysed with shear-deformable beam analysis

2.1.9 Paper 9

Title: Analysis of tip deflection and force of a bimetallic cantilever microactuator
Author: Wen-Hwa Chu, M Mehregany and R L Mullen
Publication: IOPSCIENCE 1993

Summary: This paper identify a Finite element analysis of a temperature occur on a tip of a bimetal

2.1.10 Paper 10

Title: THERMO STRUCTURAL ANALYSIS OF BIMETALS USING ANSYS
Author: Jaya Kumar R K, Ashokkumar T
Publication: SREC 2021.

Summary: This study provides comparison of a two different material based on specific thermal conductivity, specific heat, thermal expansion, density and with some other mechanical parameters. Software base finite element analysis of a bimetallic strip with copper and stainless steel material also carried out and identify a temperature rise in a direct heating method.

Chapter 3 Problem Statement and strategy for the objective

3.1 Problem Statement for objective 1

- The temperature profile of breaker is influenced by ambient temperature, which alters the change in a temperature of the breaker. The performance of breakers is impacted by these phenomena' properties.

3.1.1 Strategy for solution

- Before anything else, it's important to evaluate the real trip duration and temperature rise that occur on the breaker.
- Then, using trip time, the temperature is determined under the thermal dissipation computation and the relevant current.

Problem Statement for objective 2

- The N-pole is not thermally protected by the existing four-pole breaker. It is a demand in an international market to purchase a breaker with protected N-pole (Neutral).

3.2.1 Strategy for solution

- First of all, an analysis of the trip time in the IS test following standards is required.
- Following that, it was essential to perform thermography on the breaker and record temperature increases using thermocouple references and ambient temperature.
- Using the equation given in the bimetal catalog, calculate the necessary temperature rise, trip force, and bimetal deflection to trip the breaker.
- Modify the bimetal material, heating material combination, and heater design as necessary.

3.3 Problem Statement for objective 3

- Due to cable weight and mounting position, a fixed contact in a breaker is displaced, increasing the millivoltage drop therein and raising the MCCB's temperature while in an operating condition.

3.3.1 Strategy for solution

- First and foremost, it is necessary to analyze an mV decrease to see how frequently it is changing.
- With the application of a new substance to the fixed contact. At the same time that breakers' behavior is examined, the mV drop following each magnetic test is also determined.
- Modify the fixed contact design and see how frequently an mV drop is changed and how much.

Chapter 4 Find ACF for Breaker

4.1 Project Details

- A compensating component for a breaker called ambient temperature compensation lessens the impact of ambient temperature on the temperature of the breaker.
- ACF, or ambient correction factor, is a tool used by breakers to determine the proper tripping temperature and when to trip them based on a reference temperature.
- When producing and conducting tests, the producer provides a reference temperature.
- In this study, we examine the relationship between temperature rise, I-t characteristics, and ambient temperature.

4.1.1 Scope

- To provide thermal stability, provide a breaker to trip within the pre-defined range by the manufacturer.
- Provide a de-rating chart of a breaker for usages in different temperature ranges with considering reference temperature.

4.1.2 Requirement

- At various locations throughout the world, the ambient temperature changes, and because of the rising temperature on the breakers, there is a possibility that the breakers won't trip as stipulated in Standards.

4.1.3 Problem Statement

- The temperature profile of a breaker is influenced by ambient temperature, which alters the change in a temperature of the breaker. The performance of breakers is impacted by these phenomena' properties.

4.1.4 Problem Objective

- The objective of a Project is to provide thermal stability, I-t characteristics, and compensating factors for a breaker.

4.2 Test data

4.2.1 Procedure for the test

- The procedure for performing the test is given below.
  - Calibrate Breaker at a reference temperature.
  - Perform 1.5In, 2.5In, and 3In tests on fresh calibrate breaker at reference temp. and note down tripping time and temp. of a breaker.
  - Provide enough time to cool down a breaker after every test.
  - Test the same breaker on 1.5In, 2.5In, and 3In @different temp. and note down tripping temp. and tripping time.

4.2.2 Testing Data

Temperature °C	Trip time(second)	Terminal top temp. °C	Terminal bottom temp. °C
55	373	120	110
50	407	101	92
40(reference temp.)	511	88	84
20(reference temp.)	985	78	76
10	1120	64	56
0	NT	52	42
-5	NT	38	36
-10	NT	34	31

Table 1: 160A MCCB data

4.3 Analysis

- According to the statistics above, below reference temperature breakers are not trappable but breakers above reference temperature trip more quickly than they would otherwise, which increases the likelihood that a breaker would trip Early during an IS testing.
- The temperature rises slowly below 20 °C, which prevents the bimetal from deflecting and producing trip force. As a result, the breaker is not tripped.
- Above 40 °C, the temperature rise on the bimetal tip exceeds the reference temperature. As a result, the bimetal deflects quickly, generating more force than is necessary and causing the breaker to trip early.

4.4 Improvement

- All the aforementioned data were analyzed, and it was determined that to trip the circuit breaker in the low-temperature range, additional current must be supplied.
- Decreased current is required to deliver or generate lower temperatures for higher temperatures. rise to trip the breaker in a specified range when compared to a reference temperature.

4.4.1 Calculation and validation

- For finding ACF

According to the heat loss calculation

Equation 1

$$I^2Rt = K$$

According to the above equation

For 20℃

$I = 160 \times 1.5 = 240A$
$t = 985$ sec

W1 $= 240 \times 240 \times 985$

For 10℃

$I = 160 \times 1.5 = 240A$
$t = 1110$ sec

W2 $= 240 \times 240 \times 1110$

- After solving W1$\&W2$

Current for 10℃ is:

Equation 2

$$I_2 = \sqrt{((I_1^2 \times t_1)/t_{2)}}$$

$I_2 = 244.2$A

This answer shows that the 244.2A current is 2% higher than the 240A trip current

This calculation is made for 160A breaker @ 1.5In

According to the above equation and calculation for other ratings of breaker current inflation and deflation can be calculated.

4.5 Methodology

The required standard procedure is given below:

- Calibrate Breaker at a reference temperature.
- Perform 1.5In, 2.5In, and 3In tests on fresh calibrate breaker at reference temp. and note down tripping time and temp. of a breaker.
- Allow enough time for a breaker to cool down after each test...
- Test the same breaker on 1.5In, 2.5In, and 3In @different temp. and note down tripping temp. and tripping time.
- According to energy loss calculation compare point 2 & point 4 Data.
- Find out the energy loss difference between point 2 & point 4 data.
- Calculate Compensation current from Point 6 data.
- Test the same breaker on 1.5In, 2.5In, and 3In @different temp. with Compensation current and note down tripping temp. and tripping time.
- If tripping time and temp. of breaker are not within the acceptable limit with Point 2 data, then repeat the process from point 6 and compare Point 2 and Point 8 data.
- Repeat Point 9 until Point 2 and Point 9 data are within the acceptable limit.

4.6 Test Data and Result After improvement

4.6.1 Corrected current and temperature analysis

Temperature ℃	% Of ACF of 160A	Trip time(second)	Terminal top temp. ℃	Terminal bottom temp. ℃
55	5.5% Deflation	488	94	91
50	4% Deflation	470	92	89
40(reference temp.)	0%	511	88	84
20(reference temp.)	0%	985	78	76
10	2% Inflation	1020	76	74
0	8% Inflation	998	72	67
-5	10% Inflation	978	68	65
-10	15% Inflation	1045	64	61

Table 2: 160A MCCB % ACF Data

4.6.2 Corrected current data for different ratings.

Temperature	ACF %	Corrected Current for 200A	Corrected Current for 160A	Corrected Current for 125A	Corrected Current for 100A	Corrected Current for 80A	Corrected Current for 63A	Corrected Current for 50A	Corrected Current for 40A	Corrected Current for 32A	Corrected Current for 25A	Corrected Current for 20A	Corrected Current for 16A
55	-5.5%	189.0	151.2	118.1	94.5	75.6	59.5	47.3	37.8	30.2	23.6	18.9	15.1
50	-4%	192.0	153.6	120.0	96.0	76.8	60.5	48.0	38.4	30.7	24.0	19.2	15.4
40	0	200.0	160.0	125.0	100.0	80.0	63.0	50.0	40.0	32.0	25.0	20.0	16.0
30	0	200.0	160.0	125.0	100.0	80.0	63.0	50.0	40.0	32.0	25.0	20.0	16.0
20	0	200.0	160.0	125.0	100.0	80.0	63.0	50.0	40.0	32.0	25.0	20.0	16.0
10	3%	206.0	164.8	128.8	103.0	82.4	64.9	51.5	41.2	33.0	25.8	20.6	16.5
0	8%	216.0	172.8	135.0	108.0	86.4	68.0	54.0	43.2	34.6	27.0	21.6	17.3
-5	10%	220.0	176.0	137.5	110.0	88.0	69.3	55.0	44.0	35.2	27.5	22.0	17.6
-10	15%	230.0	184.0	143.8	115.0	92.0	72.5	57.5	46.0	36.8	28.8	23.0	18.4
-20	23.6%	247.2	197.8	154.5	123.6	98.9	77.9	61.8	49.4	39.6	30.9	24.7	19.8

Table 3: corrected current for different ratings of breaker

4.6.3 graphical representation of ACF

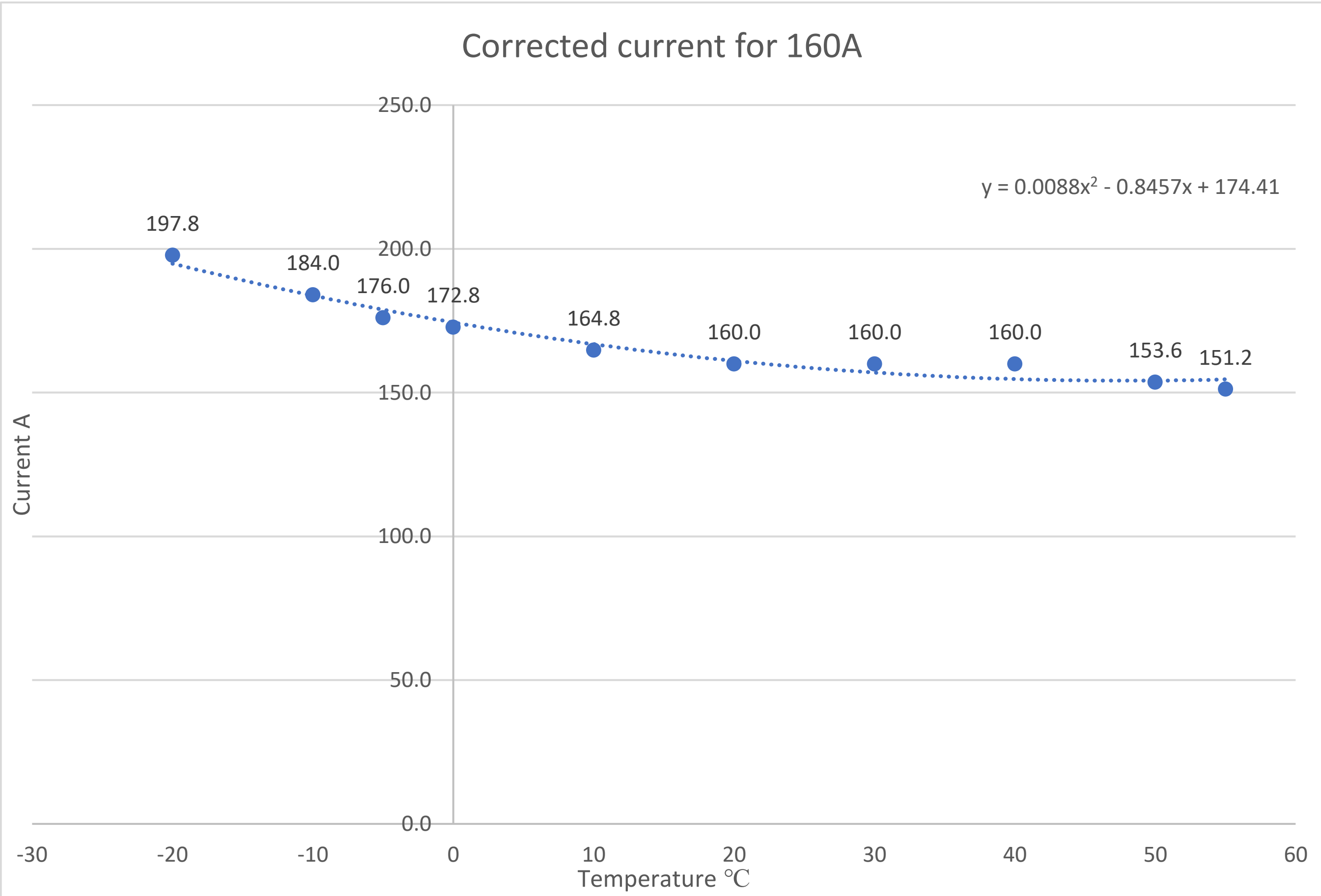


Figure 4: Graph of 160A breaker

- The above graph shows the Current changes from its rated current to a different value for 160A breaker for different temperature

Chapter 5 Thermal Protected N-Pole

5.1 Project details

- In this project protected N-pole is developed.
- There are numerous assessments in this project, including thermal, trip force, bi-metal, heater material, and recommended new designs.

5.1.1 Scope

- Provide a protected N-pole and improve the yield of thermal protection for the N-pole.

5.1.2 Requirement

- There are many industries where protected neutral pole is concern and due to that there is a requirement in an international market to purchase a MCCB with thermal as well as magnetic protection.

5.1.3 Problem statement

- The N-pole is not protected by the existing four-pole breaker. It failed to trip a breaker following the requirements for offering a protected N-pole with the present heater and bimetal combination.

5.1.4 Problem objective

- The objective of this project is to provide protected N-pole MCCB according to IEC/IS standards.

5.2 Bi-metal and Heater material

5.2.1 Bimetal

- Two or more layers of various alloys are tightly bound together to form bimetal. An alloy with a large thermal expansion coefficient makes up one surface, whereas an alloy with a lower coefficient of thermal expansion makes up another layer.
- Every material has unique features that allow it to function in a variety of temperature ranges and has unique thermal and electrical characteristics.

Figure 5: Bi metal

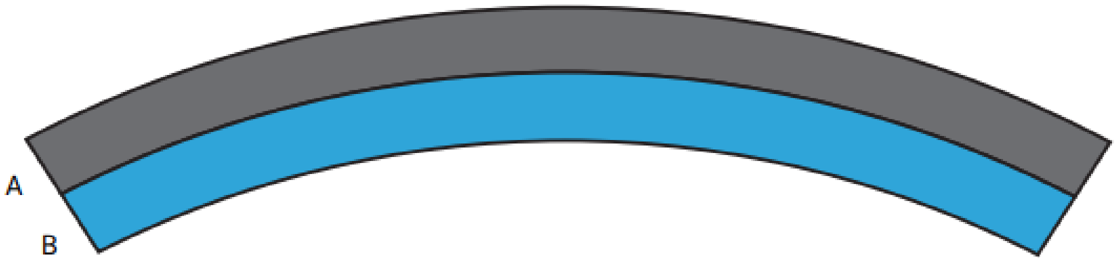


Figure 6: Thermal expansion of Bimetal

- There are many types of bimetals used in MCCB:
    - Cantilever Fixed
    - Simple beam
    - U-shape
    - Spiral and Helix
    - Creep-type disc,
    - Snap-acting discs, and many more according to their application in different industries.

- In MCCB Cantilever fixed and U-shape types of bimetals are used

5.2.1.1 Bimetal design

- based on the Frame size restriction Bimetal comes in different lengths, widths, and densities. However, the typical design of bimetal employed in the majority of frames is represented in the image below.

Figure 7: Bimetal Design

Figure 8: Side view of Bimetal

- The primary bimetal concept for the breaker is shown in the photograph above, in which two distinct materials are joined together by an adhesive.

5.2.1.2 Bimetal material

- There are few specifics accessible regarding the materials used to create bimetal, but after researching various material qualities for the 721-112 kind of bimetal, iron, nickel, and low-grade carbon with manganese are employed.
- For the 721cu35 type, materials such as bimetal iron, nickel, and low-grade carbon are employed with copper sheaths.

5.2.2 Heater

- Having a higher thermal coefficient and lower resistance, a heater is a thermal and electrical conducting substance.
- It has many designs depending on the ratings and frame design. Copper and zinc get combined to create the heater material. The amount of copper and zinc combined varies for different ratings.
- Welded joints are used to join the bimetal to the heater.

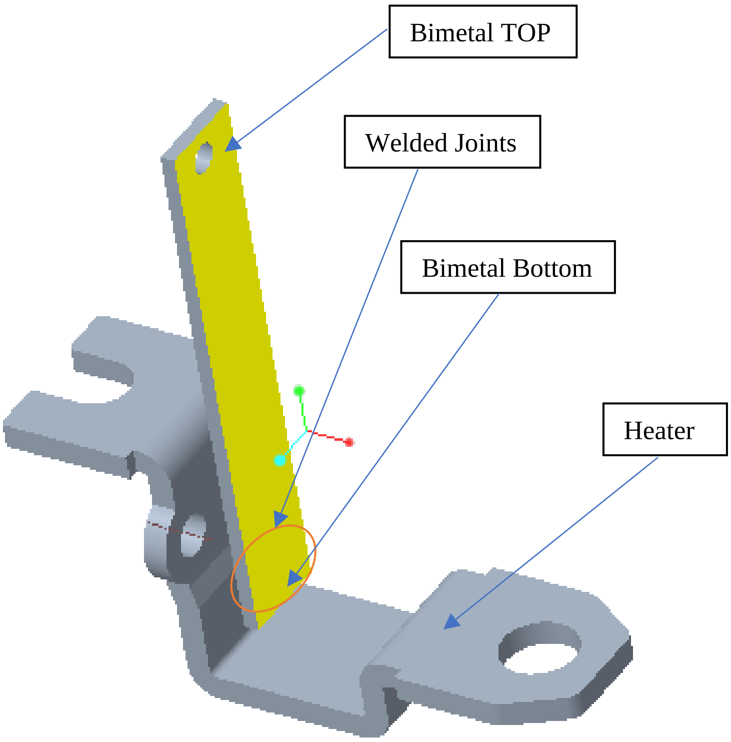


Figure 9: Heater Design

- Images show how a bimetal and heater are assembled with welded joints.

5.2.3 How it works?

- Due to the heater's thermal coefficient, as current flows through it, heat is produced and transferred to the bimetal.

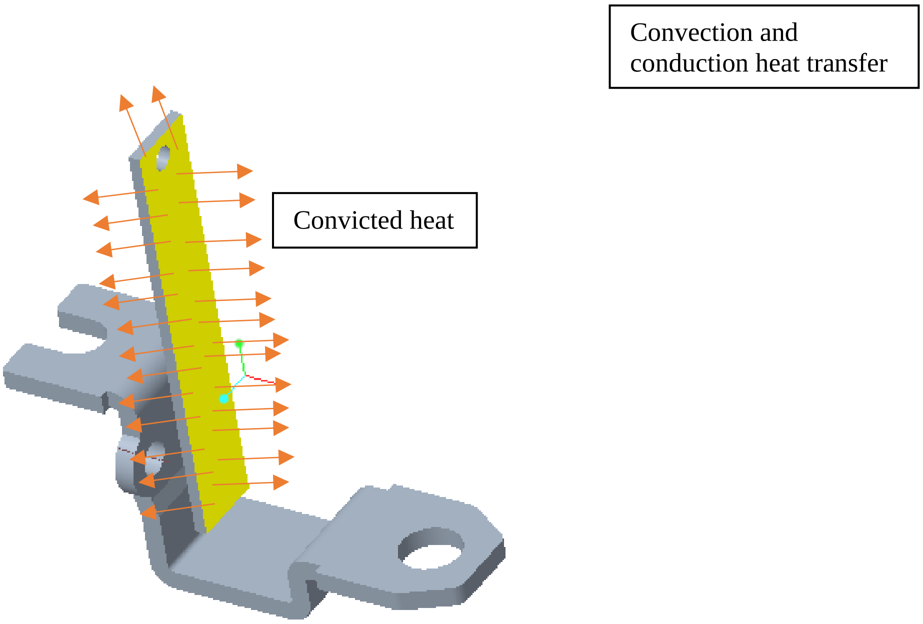


Figure 10: Heat Transfer in Bimetal

- Since bimetal has its unique thermal coefficient, heat is often transferred from the bottom to the top side. Due to this, the bimetal will deflect by its degree of flexibility, produce trip force, and collide with the OL shaft.

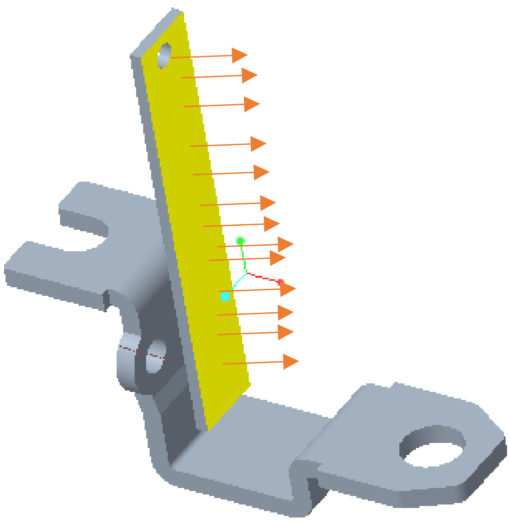


Figure 11: Deflection area of Bimetal

- As soon as the trip force produced by the deflection of the bimetal exceeds the latch spring's restraining force, it will leave the leaver, strike the mechanism, and deliver trip force to the MAC contact of a breaker, causing the breaker to trip.

5.3 Process for carried out the test

- For carrying out an N-pole Thermal test some standard procedures must be followed by the manufacturer according to IEC/IS standards.
    - Do IS test for N-pole for 2 hours @1.05In current and then change current from 1.05In to @1.56In.
    - After applying @1.56In breaker must have a trip within 1800 sec

5.3.1 Testing procedure

- The procedure for performing the test is given below.
    - ➢ Calibrate the Breaker on 3In and note down the tripping time of the N-pole.
    - ➢ According to IEC/IS standards 60947-1/2 apply 1.56In and note down tripping Time & Temp.
    - ➢ Perform IS test of N-pole.

5.3.1.1 Test Data

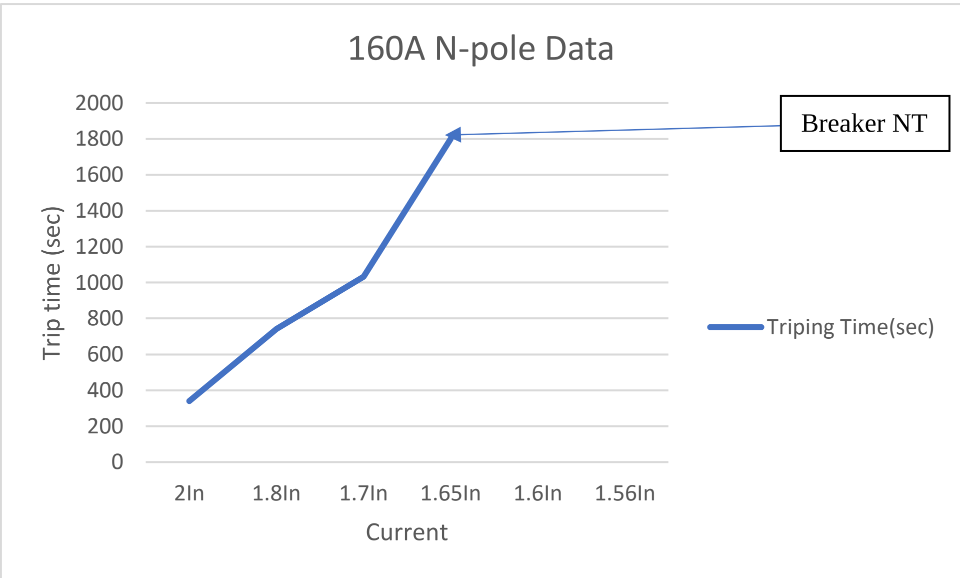


Figure 12: 160A N-pole Trip data 721-112 type bimetal

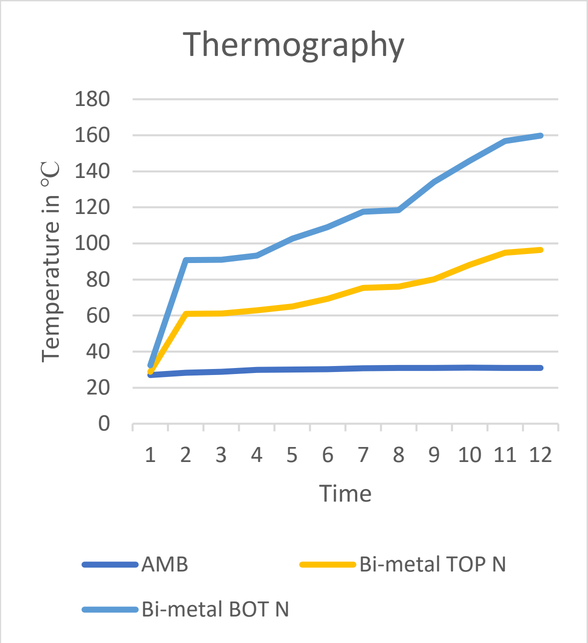


Figure 13: 160A max condition 721-112 type bimetal

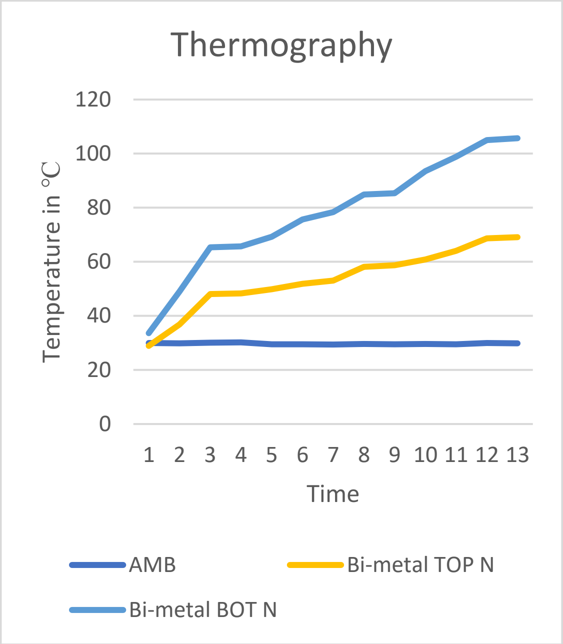


Figure 14: 160A min condition 721-112 type bimetal

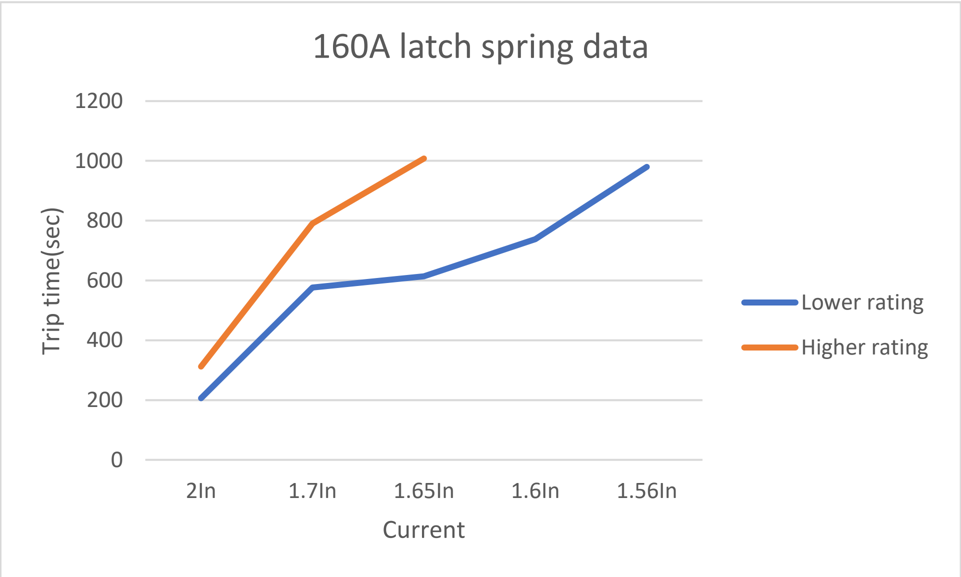


Figure 15: spring combination

5.4 Analysis

- It is evident from the accompanying graph that there is a significant temperature difference between the bottom and top of the bimetal.
- The low temperature on the bimetal top reduces the rate of deflection created by temperature rise, and thus the trip force is not produced at lower current values due to the reduced rate of deflection.
- This huge temperature variation is the main reason why the breaker gets NT.
- Many other issues also create breaker NT.
    - Bimetal brazing
    - Thermal screw calibration
    - Insufficient cooling time
    - Loose connection, and many others.
- Opposition force created by latch spring is also considered a major concern for breaker got NT
- The issues mentioned above pale in comparison to the concern of rising temperatures. Therefore, it can be overlooked once to conclude what can be done to reduce the temperature difference that has been produced.

5.4.1 RCA analysis

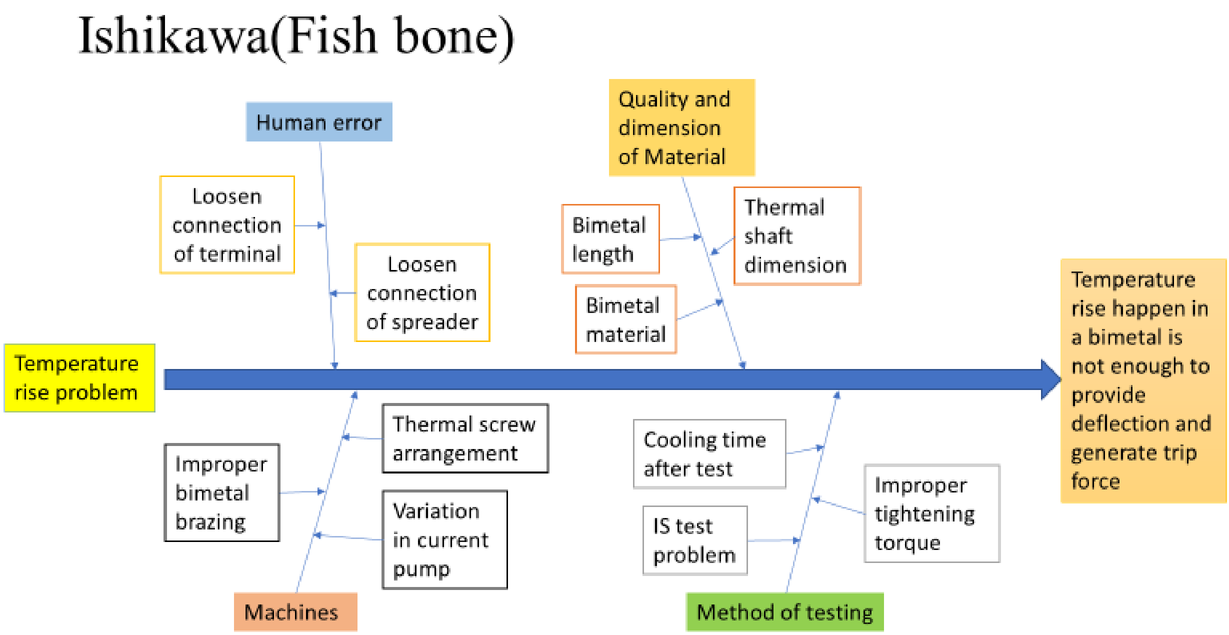


Figure 16: 160A N-pole Analysis

5.4.2 Trip travel and force analysis

	Trip Travel	Trip Force
Higher load latch spring(max)	1.7mm	800gm
Higher load latch spring(min)	1mm	850gm
lower load latch spring(max)	1.6mm	700gm
Lower load latch spring(min)	0.9mm	750gm

Table 4: force and travel analysis

- The trip distance and trip force needed for a breaker to trip while using a single pole is shown in the above table.
- Bimetal fails to produce the necessary force to trip the breaker in single-pole breakers now in use. This issue is caused by temperature buildup on the bimetal tip.

5.5 Methodology

- We chose the appropriate material following the trip travel and force data mentioned above, pursued thermography to learn about temperature rise data, and calculated a new force and deflection of bimetal at different currents to determine whether the force calculated has a margin for a breaker trip or not.

5.5.1 Equation for Calculation

- D = Deflection in mm
- A = Angular deflection in degrees
- ΔT = Temperature change in degree C
- L = Active length in mm, i.e., the length free to deflect
- t = Thickness in mm
- w = Width in mm
- a = Specific thermal deflection in per degree C
- E = Youngs modulus in N/mm2
- Fm = Mechanical force in N, i.e., the force required to mechanically cause a deflection of D.
- Ft = Thermal force in N, i.e., the force that would be developed if the bimetal is completely restrained.
- σ max= Maximum bending stress in N/mm2

Equation 3: Fin Energy

$$Q_{bimetal} = \sqrt{hpkA}\theta_b \tanh mL$$

Equation 4: Convection coefficient

$$Q = h*A_{Heater}(T_{base} + T_{local}) + h*A_{terminal}(T_{base} + T_{ambient})$$

Equation 5: Heat Generation

$$Q=I^2R$$

- For cantilever type Bimetal

Equation 6: Deflection D

$$D = \frac{a \times \Delta T L^2}{t}$$

Equation 7: Mechanical Force

$$F_m = \frac{E \times wt^3 \times D}{4 \times L^3}$$

Equation 8: Trip force

$$F_t = \frac{E \times a \times t^2 \times w \times \Delta T}{4 \times L}$$

Equation 9: Bending Stress

$$\sigma_{max} = \frac{6 \times F \times L}{t^2 \times w}$$

5.5.2 Calculated Data

Current	Deflection in mm	Force in grams
721-112 @1.05	0.8	846
721cu35 @1.05	0.92	1006
721-112 @1.3	1.11	1326
721cu35 @1.3	1.34	1521
721-112 @1.56	1.53	1847
721cu35 @1.56	1.83	2146

Table 5: Deflection in mm

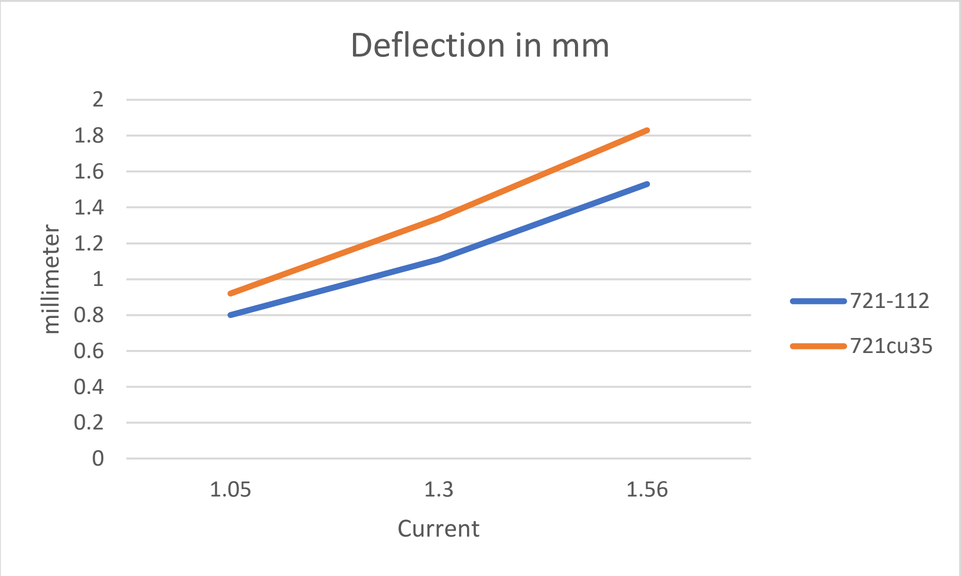


Figure 17: Graphical representation of Deflection

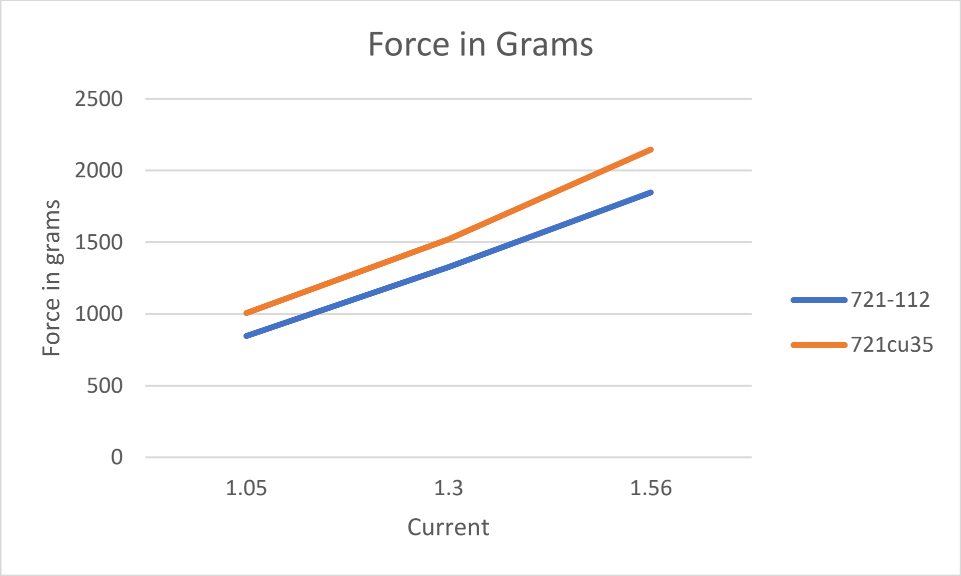


Figure 18: Graphical representation of Force

5.6 Improvement

- After considering every possibility, we selected various bimetal combinations with high heater ratings and various material compositions.
- Analyze the temperature increase using thermography, and then carry out the necessary tests under the criteria for the development of a Protected N-pole breaker.
- Higher and lower ratings of latch spring force are taken into account in the aforementioned combination.
- Verify the proper lubrication on the OL shaft, latch, and leaver.
- Thermal and magnetic knob for VTVM need to check while testing so that Breaker doesn't go NT/ET

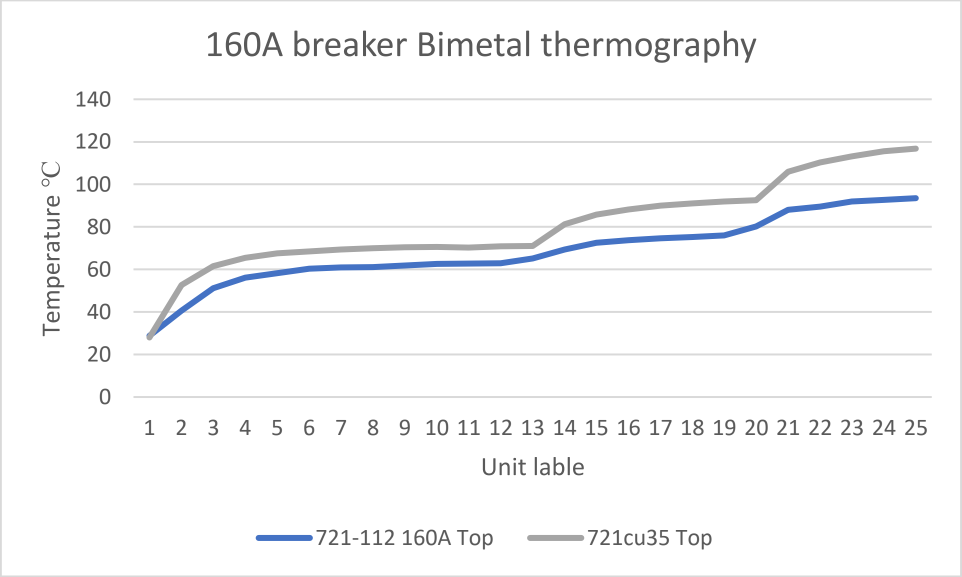


Figure 19: 721-112 vs 721cu35 thermography

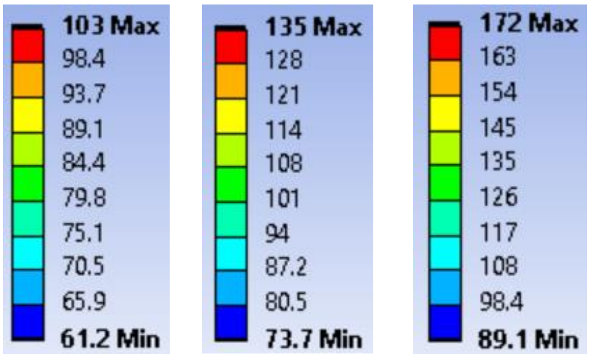
- From the graph above, it is evident that the temperature rise at the bimetal's tip in 721cu35 is more than that of the 721-112 type bimetal.
- Both bimetals' bottom temperatures are practically equal.

5.7 Software analysis

- To examine how heat travels into a heating element and bimetal combination in addition to the degree to which the bimetal deflects in response to material changes, software analysis is required.

5.7.1 Thermal analysis

5.7.1.1 721-112 type bimetal



a *b* *c*

Figure 20: Temperature scale analysis of 721-112 type bimetal (a) @ 1.05In, (b) @ 1.3In, (c) @1.56

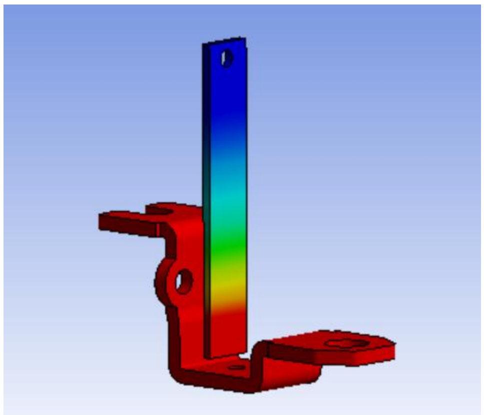
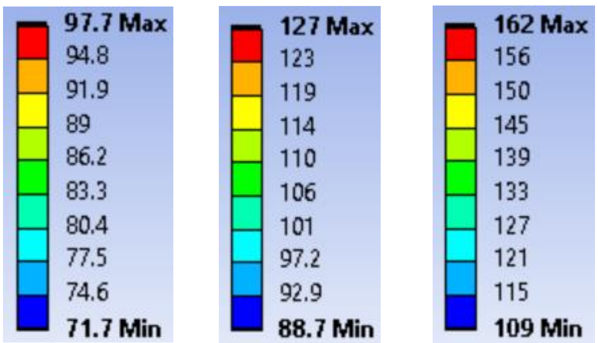


Figure 21:- 721-112 type Assembly thermal analysis

- Since the bottom side of the bimetal is in contact directly with the heater material, it is evident from the figure that this side heats up quickly.
- On a bimetal, heat will flow upward as we move up due to the material's characteristics and the convection process of heat transfer.
  Following the change of the bimetal substance, as previously discussed, additional analyses are performed using the same criteria.

5.7.1.2 721cu35 type bimetal



a *b* *c*

Figure 22: Temperature scale analysis of 721cu35 type bimetal (a) @ 1.05In, (b) @ 1.3In, (c) @1.56

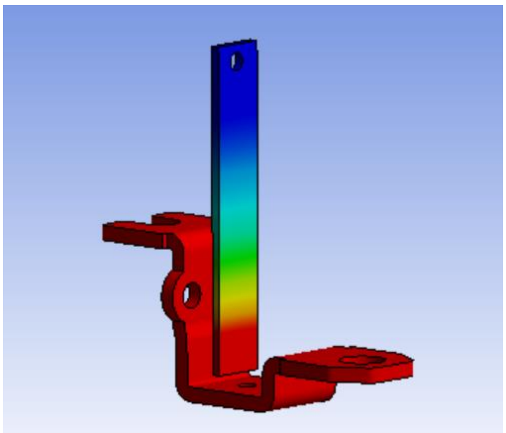


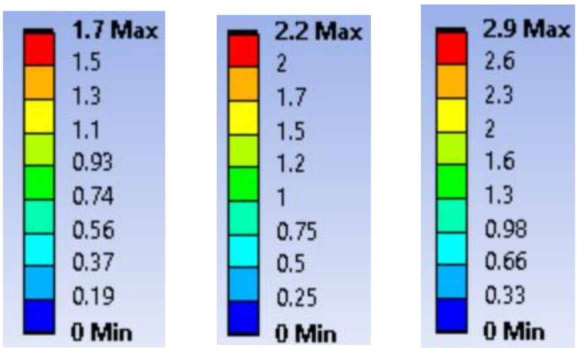
Figure 23: 721cu35 type Assembly thermal analysis

- Because of the more effective deflection and greater trip force generated by the 721cu35 type of bimetal, it is clear from the preceding figure that its temperature rise is greater than that of the 721cu112 type.

5.7.2 Deflection analysis

- Additional images compare the deflection of each bimetal based on the temperature rise that occurs onto the bimetal tip. The mechanical opposing loads are not taken into consideration in this deflection analysis.

5.7.2.1 721-112 type bimetal



a b c

Figure 24: Deflection scale analysis of 721-112 type bimetal (a) @ 1.05In, (b) @ 1.3In, (c) @1.56

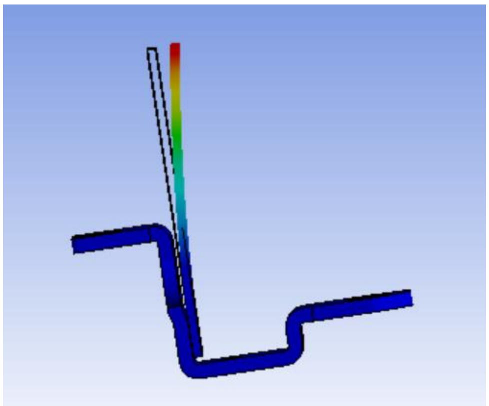
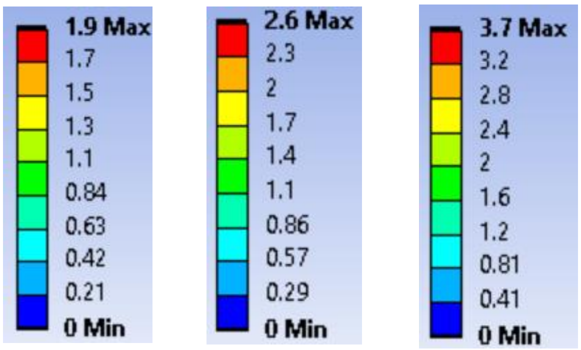


Figure 25: 721-112 type bimetal deflection analysis

- In the image above, the deflection of a bimetal under different currents can be observed and it appears by the amount of heat generated and the rise in temperatures.
- The deflection in the figure is shown without accounting of the mechanical opposing load.

5.7.2.2 721cu35 type bimetal



a b c

Figure 26: Deflection scale analysis of 721cu35 type bimetal (a) @ 1.05In, (b) @ 1.3In, (c) @1.56

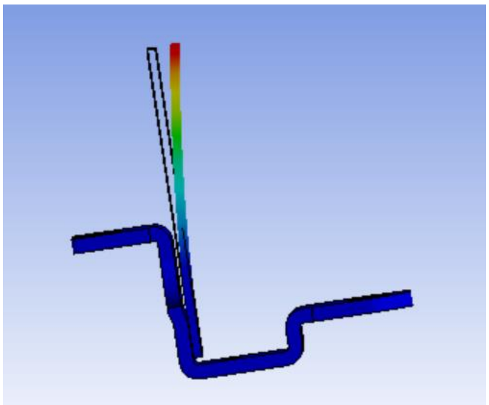


Figure 27: 721cu35 type bimetal deflection analysis

- The deflection of a bimetal of the 721cu35 type is shown in the above figure at various current levels. As the current produces more heat, the deflection increases.
- Bimetals of the 721cu35 type deflect more and produce more mechanical force than those of the 721-112 types.

5.8 Stress reliving Process

- As a result of manufacturing processes, internal material tension within a part or assembly can be reduced by heat treatment for stress reduction. Parts will have internal tension that results in distortions after manufacturing procedures including shaping, machining, cutting, or fabricating assemblies by welding.
- Most internal tensions can be reduced by heating the materials used in the component or assembly to the proper temperature and maintaining them there for a predetermined amount of time so that the entire part can attain this temperature.

5.9. Validation Data

- Stiffness, hardness, along with other relevant properties have been eliminated from a heater-bimetal assembly after the stress-relieving procedure.
- The graph below displays the results of IS testing performed on a 4-pole breaker connected 3 poles in series as well as the alone N-pole in accordance with IEC/IS regulations.

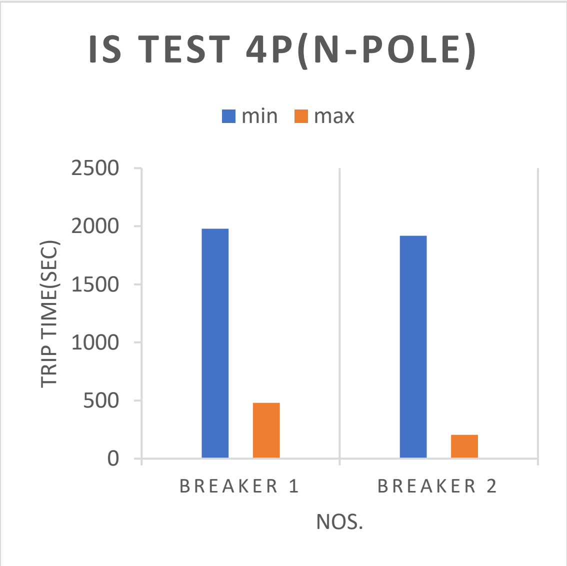


Figure 28: IS test of N-pole

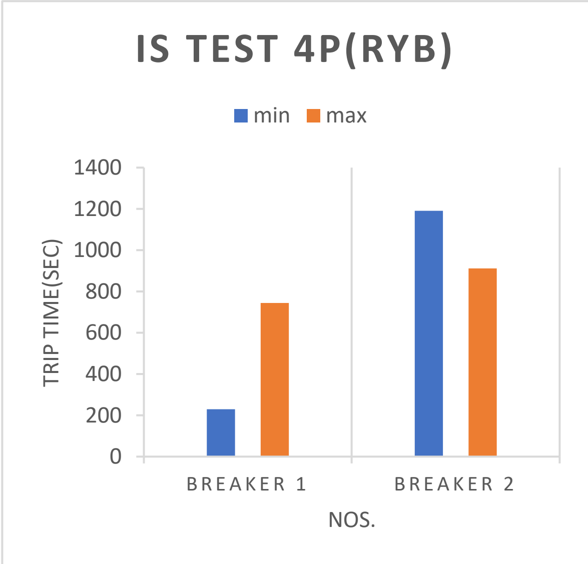


Figure 29: IS test of 3-pole in series

- One may quickly determine a breaker's tripping time in an IS test for both minimum and maximum loading by looking at the graph above.

Chapter 6 Improvement of Thermal Stability

6.1 Project details

- To ensure a healthy life and longer operational condition, a breaker must maintain a constant mV drop.
- It will aid in regulating temperature increases that take place in a breaker.
- The thermal stability of a breakers is enhanced in this study.

6.1.1 Scope

- Minimize the increase in temperature and millivolt loss in a breaker to provide thermal stability.

6.1.2 Requirement

- in order to improve thermal consistency in a breaker.
- to regulate a breaker's rise in temperature.

6.1.3 Problem statement

- Fixed and moving contacts are the primary temperature hotspots. Therefore, an mV drop occurs if any of the connections are improperly positioned during assembly or due to an external physical situation.
- A fixed contact in a breaker is moved due to cable load and mounting position, which increases the millivoltage drop therein and raises the temperature of the MCCB while it is in operation.

6.1.4 Problem objective

- The objective of this initiative is to offer thermal stability by regulating the rise in temperature and the drop in mV that take place in a breaker.

6.2 Problem identification

- When a breaker's fix contact is slightly moved during installation because an inappropriate cable size was chosen or because of cable weighting, and because a breaker's mV drop varies when it is operating, this will result in an increase in the breaker's operating temperature, which could have a dangerous effect on nearby equipment.
- It is required to stabilize the breaker's mV drop within a predetermined range in order to maintain a steady temperature rise on the breaker.

6.3 Test

- According to IS/IEC standards 60947-1/2, some pre-analysis testing has been conducted in this part, which called for data to be produced.
- As specified in IS/IEC standards 60947-1/2, a breaker's rated current is used for a temperature increases test.

6.3.1 TR test

- TR test stands for temperature rise test, and in accordance with IS/IEC standards 60947-1/2, the rise in temperature in a healthy and functional condition shall not exceed 80 °C.
- This test must be performed in accordance with some prescribed conditions and within the allotted time frame.
- Therefore, if my room temperature is 30 °C, a breaker's temperature will not rise above 110 °C even after current loaded for 6–8 hours.
- A thermocouple is used to continuously monitor the temperatures at both the outgoing and incoming terminals of a breaker.

6.3.2 mV test

- When doing a millivolt drop test, a multimeter is used to measure the drop in voltage that happens in a breaker.
- Applying a standard determined current allows it to be measured on each pole across both the outgoing and incoming terminals.

6.3.2.1 cold mV

- When initiating the TR test on each pole between the incoming and outgoing terminals at rated current, it is measured in a fresh breaker.
-

6.3.2.2 Hot mV

- While the TR test is running, it is measured in a breaker at a specific interval of time in the middle of the test.
- It is measured at the rated current on individual pole across the outgoing and incoming terminals.

6.3.3 mV difference

- In spite of repeated on/off and reset operations, a breaker's mV drop between the incoming and outgoing terminals on individual pole happens at rated current and should be within a defined or mentioned in standards limit.
- The difference between the both hot and cold mV should stay within a predetermined range while the device is in operation.

6.4 mV drop test data

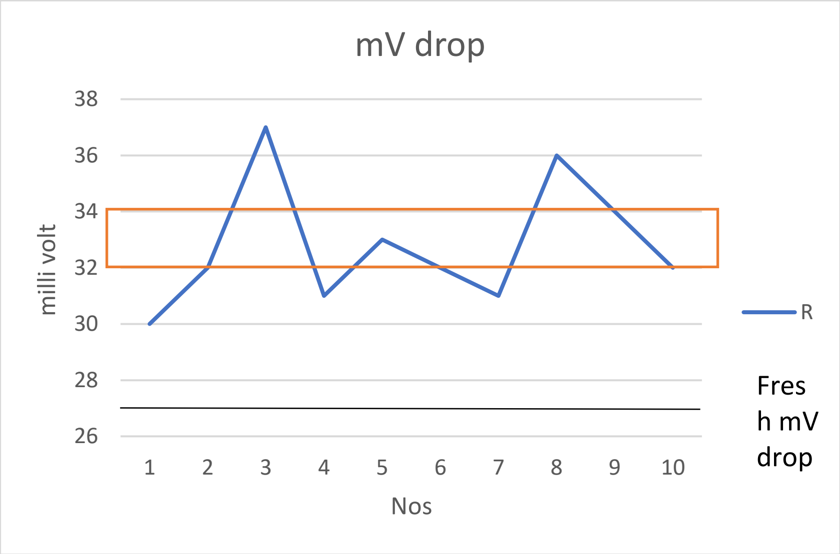
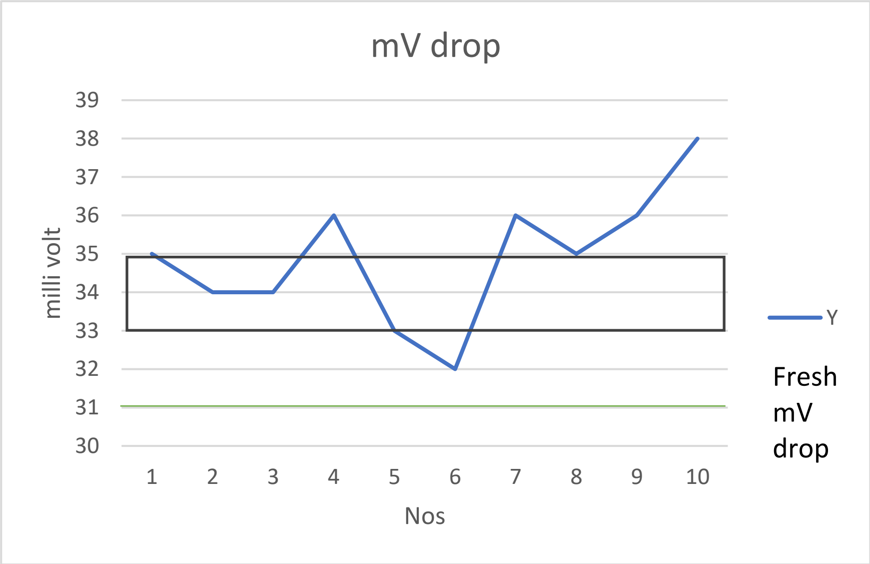


Figure 30: R pole mV drop

Figure 31: Y pole mV droop



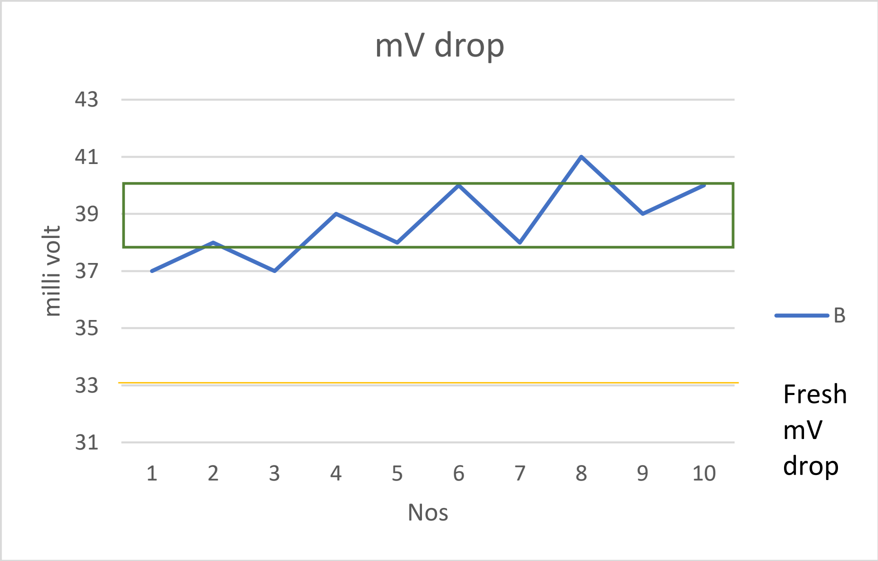


Figure 32: B pole mV drop

- The graph above makes it very evident that there is a significant fluctuation in mV drop when compared to fresh mV drop.
- To maintain a good operating state for the breaker, the mV drop of the breaker must be controlled.

6.6 Analysis

- As was indicated before, a breaker's mV drop varies continually regardless of the number of tests, and as a result, while the breaker is operating at rated current, its temperature rises above the limit specified in IS/IEC standard 60947-1/2.

6.7 RCA analysis

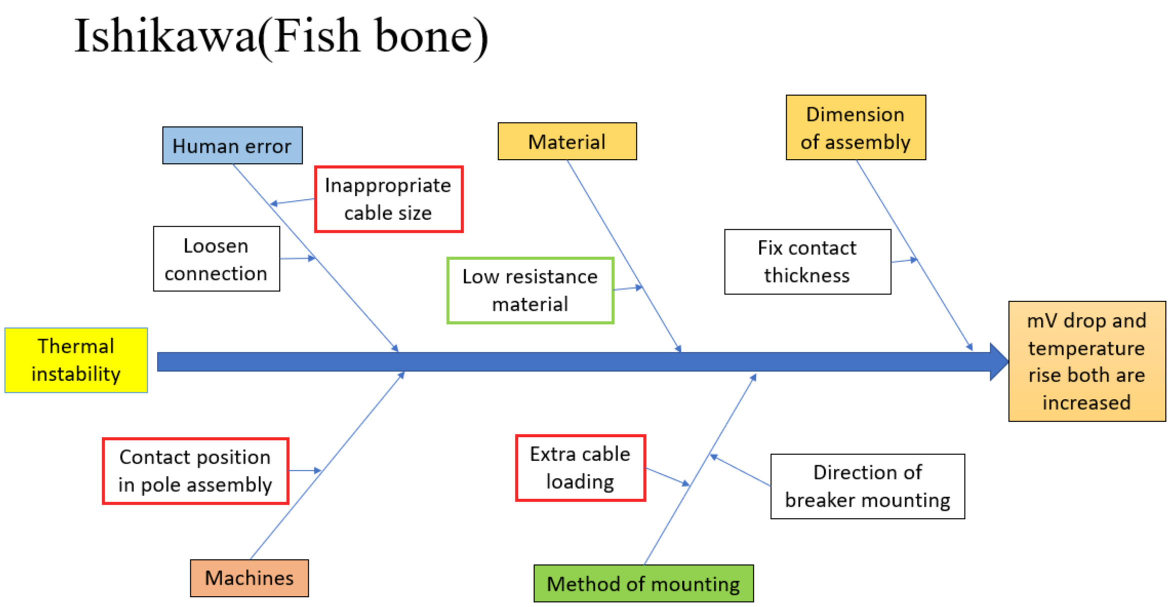


Figure 33: Thermal Stability analysis

- Troublesome parameters for uncertainty that arise in the temperature rise test and the mV drop test are shown in the diagram above.
- It is emphasized in the diagram as the primary issue parameter for the causes.

6.8 material analysis

- The present care path's substance affects the millivolt decrease.
- A fix contact assembly can have some extra material added, but doing so takes time. Therefore, joining an extra material sheet to the lower side of the fix contact is our only available choice.
- Silver is a good choice for providing a less resistive channel, but because of its high thermal conductivity, it is not a viable answer for preserving temperature and it is also expensive, so we can't use it.
- Another material is copper, which offers a less resistive channel and has strong thermal conductivity but is not a practical alternative due to its good thermal conductivity for sustaining temperature. In an electromagnetic field, it is going to repel and may change positions because it is a diamagnetic material.

- The most suitable material for accomplishing all of the aforementioned standards is brass.

6.9 validation

- Further confirmation testing has been performed for analysis purposes in this section following material research and suggestions.

6.9.1 testing

- The data for mV drops on various breakers is graphically represented in the image below.
- The additional mV drop of a breaker is assessed to determine what kind of changes exist in a mV drop prior to and following a magnetic test.

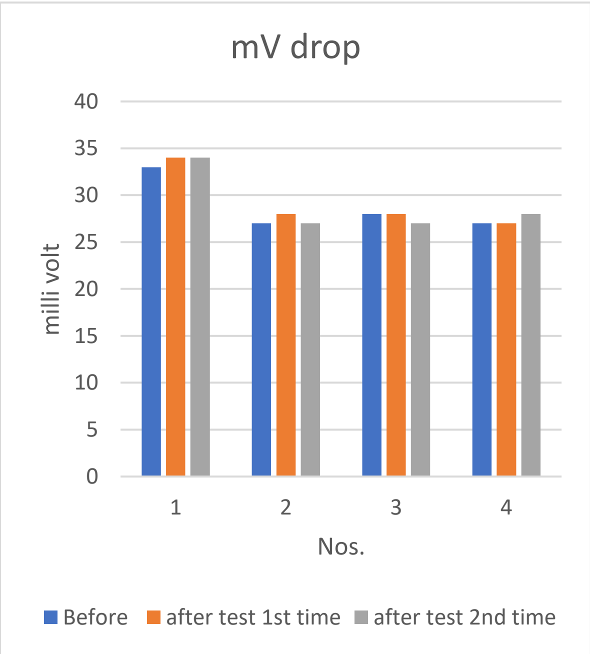


Figure 34: R-pole mV drop

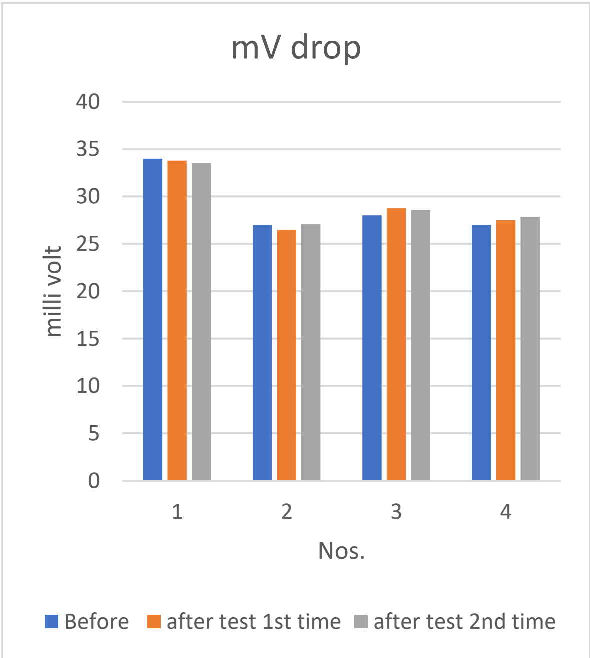


Figure 35: Y-pole mV drop

- The variance in an mV drop happening in a breaker is not discernible when compared to the brand-new mV drop of a breaker, as is seen from the preceding figure.
- The same breaker is then put through a TR test to demonstrate that its thermal stability has improved. This test also measures the breaker's cold and hot mV drops so that the differences between the two may be seen.
- The mV drop of four distinct breakers is graphically represented in the below image with both cold and hot mV drops.

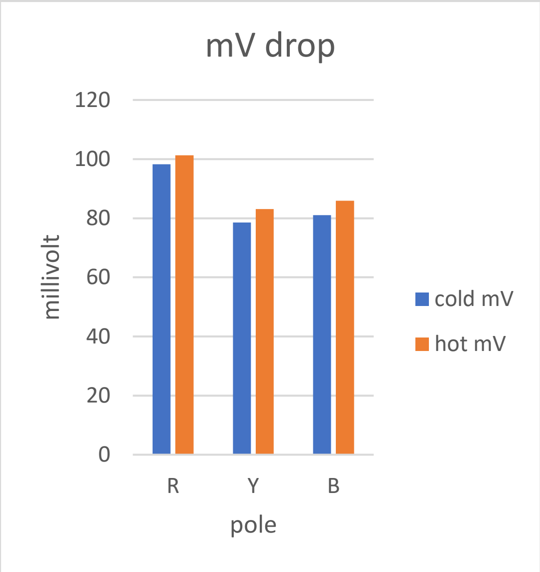


Figure 36: Breaker-1 mV drop

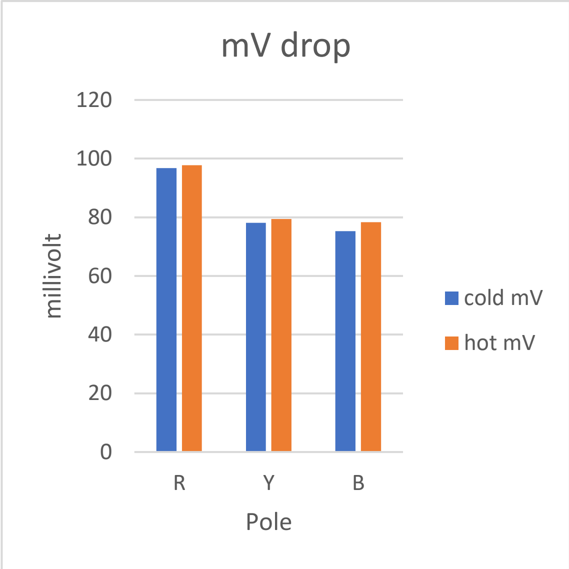


Figure 37: Breaker-2 mV drop

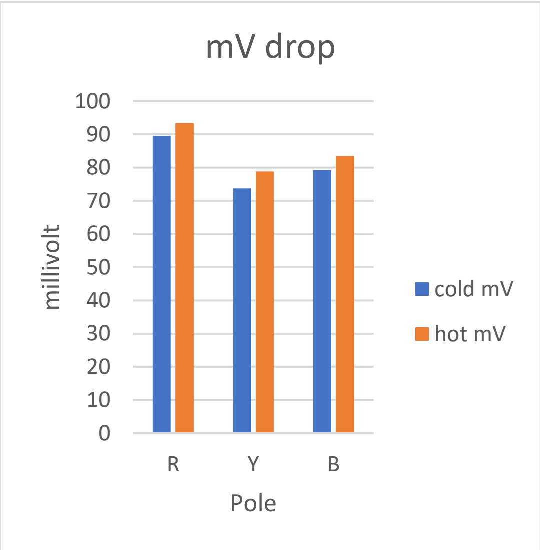


Figure 38: Breaker-3 mV drop

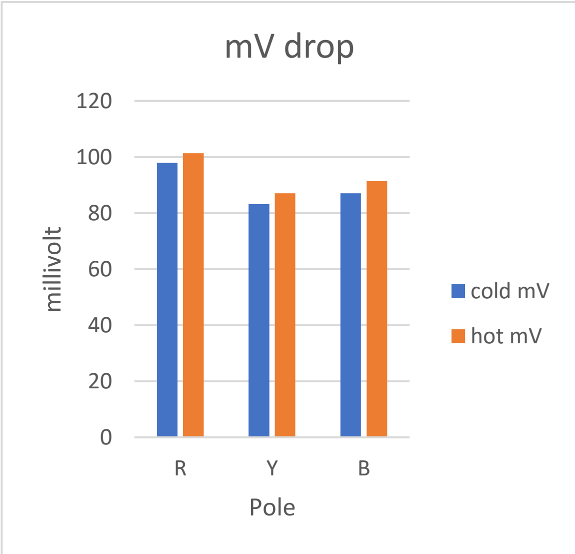


Figure 39: Breaker-4 mV drop

- The figure primarily shows the data for millivolt drops over several breakers.
- It is clear from the preceding figure that during the TR test, the breaker experiences an mV drop in both hot and cold conditions. The values are nearly identical.

Chapter 7 Conclusion & future scope

- Pre-analysis testing has been done in Objective 1 for determining ACF at various ambient temperatures. A breaker's tripping time at reference temperature is taken into account as a testimonial for other ambient temperatures after pre-analysis testing, which is followed by additional validation tests on a different rating of a breaker using power loss calculations under the assumption that the breaker's resistance is constant. Breaker validation testing results unmistakably show that the computed correction factor is offering a solid solution for all ratings of a breaker at both lowest and maximum loading as well as tripping time that is consistent with the reference temperature.

- Pre-analysis testing is done as part of objective 2 to improve thermal performance. On the basis of pre-analysis testing, additional force calculations are made, as well as bimetal deflection and the required temperature for deflection. An updated design for a bimetal with a different material is suggested before moving further with the validation. An FEA tool (ANSYS) is used to first validate a new proposed design constraint. A thermal-electric tool is used to analyses temperature, and a static structural tool is used, under certain assumptions, to analyses the deflection of bimetals. Following FEA analysis in the FEA tool, testing for validation is done on a prototype using the new proposed design with restrictions. This idea operates as intended and satisfies all necessary criteria.

- In order to provide thermal improvement for objective 3, pre-analysis testing is done to see how an mV drop changes with cable stress and cable movements, and then a TR test is done. In addition to this goal, certain material recommendations are given after taking the constraint into account. After that, additional validation testing is carried out using the right material (brass). The recommended material satisfies all the criteria needed to manage the mV drop that takes place within a breaker, and additionally it further reduces the rise in temperature that occurs in a breaker when it is in operation.

Chapter 8 References

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