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Development of Overload Protection Trip Unit for Higher Rating Current of MCCB

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Abstract—*This paper deals a new development of overload protection trip unit of electromechanical release for higher rating current of moulded case circuit breaker (MCCB). This is a replacement of microprocessor release by using both mechanical as well as electrical concept. Electromechanical release provides two types of protection which are overload current protection and the short-circuit protection. The thermal property of bimetal (gets elongated when heating) is used to sense the overload of current and magnetic property (magnetic flux/induction) is used to sense the short circuit. This paper deals with the protection against overload of the current. Here by using reverse engineering concept, bimetal for higher rating current is selected and the shape and size of the bimetallic strip is decided as per the movement required for trip plate to trip the MCCB. The prototype of new developed bimetal has also been validated on MCCB. After completion of concept validation, the proposed bimetallic strip of electromechanical release would be consider for higher rating current MCCB.*

1. INTRODUCTION

Moulded Case Circuit Breaker (MCCB) is the automatically operated electrical switch which is designed to protect an electrical circuit from damage caused by overload or short circuit. MCCBs are used in domestic, commercial and industrial applications. Mainly two types of release are used one is microprocessor release and second is electromechanical release. Both release follow IEC standards 60647-1 and IEC standards 60647-2 for opening under overload and short circuit condition. Due to threatening competitive market in the world, the organization needs to fulfill the client to accomplish best and being contender. In the market, electromechanical release is having maximum demand by the customers as electromechanical release is more cost effective compare to the microprocessor release and additional important feature is that its construction is very simple. These are available only for overload current (thermal only) and short circuit (magnetic only), respectively. The electromechanical release are having low watt loses compare to the microprocessor release and mechanical anti reclosing. This paper presents the development of an overload trip unit of electromechanical release, its validation and testing.

2. LITERATURE

Extensive literature has been studied to develop over load trip unit of electromechanical release, selection of bimetal, its shape and size for overload protection. There are various concepts for development of overload protection trip unit. IEC standards 60647-2 fourth edition Part:2 Circuit breakers[2] provides the details about conditions of the design of circuit breakers for electromechanical release. It also discusses the tripping and non-tripping condition for over load. Kanthal thermostatic bimetal hand book[3] provides basic understanding of design of bimetal for the various applications including temperature of operation, mechanical stress, electrical resistivity, thermal conductivity and the machinability which helps in identifying the appropriate bimetal type for a particular requirement. Shivalik Thermostatic Bimetal Handbook [4], Sb/Hb/1101, discussed the properties and selection of bimetal as per their electrical application. Authors has discussed two deflection calculation method and shown how to select the best method from the two methods for a particular application. He has also discussed the calculation steps for calculating Flexivity, Specific Thermal Curvature and Specific Deflection.

Robert T. Casey et al.[5] patent no:US3278708, have discussed the basic construction of thermal magnetic trip and its working mechanism. They have discussed the bimetallic strip construction with terminal strap for overload purpose. In this, a multi turn magnetic winding interconnects the bimetal support member and an externally located terminal support member.

Walter M. Zoller et al.[7] patent no: US005608367A have discussed about molded case circuit breaker with interchangeable trip unit having assembly of bimetal which registers with permanent heater transformer air gap. Thermal trip unit was connected with the heater. In one circuit breaker of this type, the laminated core was of U-shaped and a steel cross member was secured across the ends of the U by screws extending into the laminations of U-shaped member. From this patent latest indirect method concept is adopted for the bimetal heating.

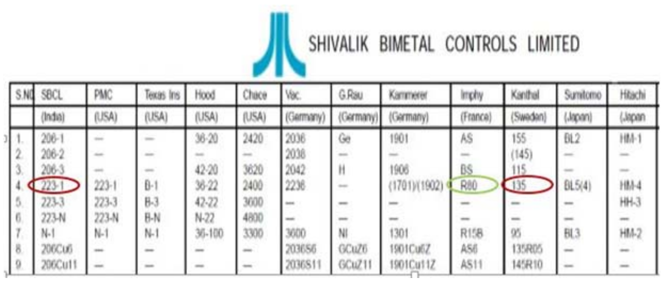
3. METHODOLOGY

Construction of lower rating current electromechanical release and the present construction of higher rating release was observed. Kanthal bimetal hand book is referred for the selection of bimetallic strip for higher rating current MCCB and the concept of reverse engineering is used for finalizing the shape and size of the strip.

3.1 Selection of Bimetal.

Reverse engineering concept is used for selecting appropriate strip of thermostatic bimetal for circuit breaker application which has high generated force with low activity and low resistivity. Kanthal handbook suggests that KANTHAL 135 grade is suitable strip for the higher rating current. Kanthal is not available in market therefore base on same grade of Imphy 80 is selected. Grade equivalency table is shown in Fig. 1.

Figs.[4.1] to [4.4.] indicate the temperature at said location at



SHIVALIK BIMETAL CONTROLS LIMITED

S.NO	SBCL	PMC	Texas Ins	Hood	Chace	Vac.	G.Rau	Kammerer	Imphy	Kanthal	Sumitomo	Hitachi
	(India)	(USA)	(USA)	(USA)	(USA)	(Germany)	(Germany)	(Germany)	(France)	(Sweden)	(Japan)	(Japan
1.	206-1	—	—	36-20	2420	2036	Ge	1901	AS	155	BL2	HM-1
2.	206-2	—	—	—	—	2038	—	—	—	(145)	—	—
3.	206-3	—	—	42-20	3620	2042	H	1906	BS	115	—	—
4.	223-1	223-1	B-1	36-22	2400	2236	—	(1701)(1902)	R80	135	BL5(4)	HM-4
5.	223-3	223-3	B-3	42-22	3600	—	—	—	—	—	—	HH-3
6.	223-N	223-N	B-N	N-22	4800	—	—	—	—	—	—	—
7.	N-1	N-1	N-1	36-100	3300	3600	NI	1301	R15B	95	BL3	HM-2
8.	206Cu6	—	—	—	—	2036S6	GCuZ6	1901Cu6Z	AS6	135R05	—	—
9.	206Cu11	—	—	—	—	2036S11	GCuZ11	1901Cu11Z	AS11	145R10	—	—

Fig. 1: Grade equivalency Table

The shape and size of bimetal strip depends on deflection, force required, available space and the external forces.

3.2 Conceptualize Proposed Model of Bimetal.

Concept generation has been carried out using ProE. The bimetal model and assembly of bimetal in release box is shown in Fig. 2.

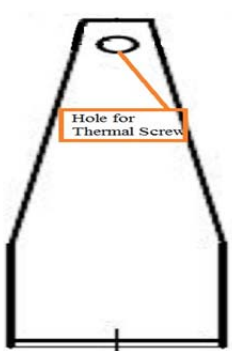


Fig. 2. Proposed model of bimetal

Advantage of this shape of bimetal is having more heating area and small top width which are appropriate for the desired deflection in comparison of the rectangle shape of bimetallic strip. Calibration screw is provided for minor calibration to overcome the assembly error.

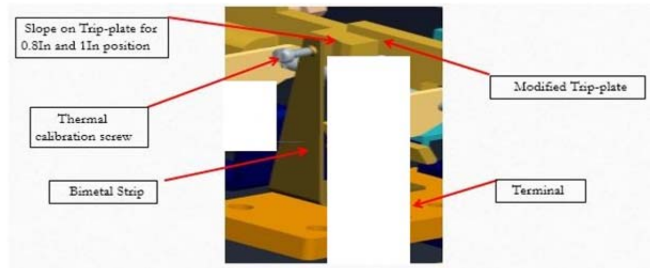


Fig. 3. Assembly model

3.3 IEC 60947-2 Standards for Over Load Condition.

As per IEC 60947-2 standard rated current (800A), Breaker must not trip at 840A for 2 hours and then after increasing the current up to 1040A, it must be tripped within next 2 hours. Whereas for $0.8I_n$, the rated current is 640A, therefore MCCB must not trip at 872A within 2 hours and it must be tripped at 832A within next 2 hours. The trip force of MCCB varies from 200 gram to 600 gram.

3.4. Theoretical Calculation

Representative calculation of deflection, heat generated in heater and heat transfer to bimetal, mechanical force in N (Newton), force required to overcome tripping force in degree centigrade and deflection for the remaining temperature in mm have been calculated in both 0.8In and rated In conditions.

Table 1: Representative calculation of bimetal

Name	Value
Trip force	600 gram
Active length of Bimetal	60.1 mm
Ambient Temp.(T0)	26 °C
Final Temp.(T1)(tripped condition)	114 °C
Δ T(T1 - T0)	86 °C
Material for Bimetal	36 Ni/NiMn-steel
Full Length of Bimetal	86 mm
Density of Bimetal	8.1 g/ cm^3
Width of Heater	37.08 mm
Thickness of Heater	8 mm
Density of Heater	8.96 g/ cm^3
Modulus of Elasticity of Heater	125000 N/mm^2

3.5. Output Result of Bimetal Calculation

Table 2. Representative output result of bimetal.

Name	Value
Resistance of Heater	6.69E-06 Ω
Resistance of Heater at 114°C	9.15E-06 Ω
Heat generated by Heater	24748.43 Joules

50% of heat generated by heater will go to bimetal by conduction	
Heat transfer to bimetal	12374.21 Joules
Mechanical force	4.67 N
Temperature required to overcome tripping force	28.04 °C
Remaining temperature for deflection	91.48 °C
Deflection of Remaining temperature at 1040A	3.79 mm
Deflection of Remaining temperature at 872A	2.0 mm
Difference in Deflection for $1I_n$ and $0.8I_n$	1.79 mm

Some special properties of bimetal are provided by its manufacturer. Other input parameter is shown in Table 1. Representative output result of bimetal defection at $1I_n$ and $0.8I_n$ is calculated and shown in Table 2.

4. RESULT AND DISCUSSION

After receiving prototype samples, testing has been carried out as per IEC standard at 840A and 1040A for $1I_n$ and 672A and 832A for $0.8I_n$ of 800A MCCB. Temperature rise, tripping times are recorded and observed. First testing was done at 840A and breaker was remained in non-trip condition for more than 2 hours. After 2 hours, current was increased up to 1040A. In this case position of calibration screw was 3.5 mm away from the trip plate and the breaker was tripped within 10 min. Second testing has been carried out at 640A and the breaker was remained in non-trip condition for more than 2 hours. After 2 hours, current was increased up to 832A. Here, the position of calibration screw was 1.5 mm away from the trip plate and breaker was tripped within 26 minutes. Third testing was with the same rating but calibration screw was 4 mm away from the trip plate and breaker was tripped within 23 min. Practically it is not possible to do the testing at 1040A for tripping condition on production line therefore in real time testing is carry out more than $2I_n$. Temperatures on each pole and on each bimetal strip was recorded using data-logger and monitored. Prototypes assembly arrangement inside the release of bimetal is shown in Fig. 4.

Fig. 4. Bimetal prototypes assembly

Two more tests were performed at $1.5I_n$ and $2I_n$ to check the tripping time. Result is shown in the form of graph in Fig. 5. It is observed that the circuit-breaker tripped within the IEC 60947-2 standard. In Fig. 5, the line graph shows the tripped/non-tripped temperature with respect to time for a specific value of current. Testing result is also provided in the same graph on $0.8I_n$ and rated I_n.

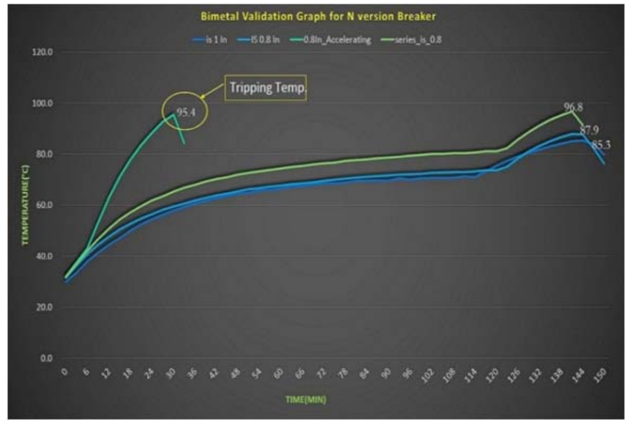


Fig. 5: Bimetal validation graph

5. CONCLUSION

In this research, an overload protection trip unit of electromechanical release for higher rating current of moulded case circuit breaker (MCCB) is developed. Selection and design of bimetal is carried out by using the concept of reverse engineering and the prototypes were validated as per the IEC 60947-2 standards. The prototype results demonstrate that the circuit breaker is tripped within 2 hours at 1040A and was in working for more than 2 hours at 840A whereas for 0.8In condition, the circuit breaker remains in non-trip condition at 640A for more than to 2 hours and after increasing the current it tripped within next 2 hours.

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