Change of the Thermal Profile in the Modern MCCB by the Different Electrical Contact Resistance

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The paper deals with the change of temperature rise of the MCCB at the steady state. The critical parts under the study are main contacts and contact lever. The movable contact in focus is modern, rotoactive system which moves contact along a circular path and his material is harder than the fixed one. It causes sequential sag of the movable contact followed by a deformation of the fixed one. Consequently, the contact area between the pair of contacts is increasing, but the contact material is losing during the arc quenching. Rests and dirt layers appear on the contact surfaces and causes increase electric and thermal resistances between contacts. Temperature rise of the device with additive layers after arcing increases against new one at the steady state.

The profiles of the temperature rises are computed using finite volume method (FVM). The first part of the paper focuses on the calculation of the thermal losses of the electrical current path at rated current with the different electrical contact resistance.

The last part of the paper describes laboratory measurements performed for numerical calculations verification. Results of the laboratory measurements proved the accuracy of the finite volume method model.

Keywords: MCCB, temperature profile, thermal losses, Computational Flow Simulation

1 INTRODUCTION

From the tripping method point of view, molded case circuit breakers (MCCB) are equipped with the electronic and thermo-magnetic (TMA) trip units. The electronic tripping units contain a microprocessor that monitors and evaluates the overcurrent. The TMA tripping unit includes a bimetal part, which trips a circuit breaker in case of an overcurrent (a low multiple of the rated current) and an electromagnet, which evaluates the short circuit (the higher multiples of the rated current). Basic function of the tripping units consists of the generation of a tripping order when the circuit-breaker current exceeds the allowed overcurrent.

Overload tripping is executed by the thermal tripping unit with calibrated setting. This setting could be influenced by thermal losses, between the contact lever with the movable contacts and the hold contacts, be the layers of dirt's due do proximity of contacts and TMA unit.

2 CONTACT RESISTANCE

Contact resistance refers to a quality of connection of two contacts. Minimization of this resistance is highly required mainly in closed area of MCCB. Any contact surface is not evenly smooth and an electric current passes from one contact to the other only through certain areas. This so called constriction effect is one of the main causes of the contact resistance between contacts.

Only a small part of the total contact surface presents its own contact area for contact surface (S_Z). The current paths, which get narrower in this place, are called constriction surfaces, and current flows just through this small contact surface (S_U). Contact surface (S_P) is the surface, where the body of the contact is deformed by the contact force. This surface can be covered by non-conductive layers in some parts. Therefore, the surface (S_P) is larger than the surface (S_U) through which the current flows.

Actually, for the most metals constriction surface is covered by oxide or dirt layers with different properties in comparison with the pure metals. For the thin layers (e.g. molecular layer of an oxide), the electrons can penetrate by tunneling effect and the behavior of the layer corresponds to the pure metal. In fact, this layer of oxide or impurity should be thicker and consequently the resistance rises.

2.1 TEMPERATURE RISE OF A CONTACT

When the current flows through the contact resistances, the contacts are heated ant it should lead to oxidation of the contact areas. An excessive temperature rise can cause softening of the contacts, leading to the melting of the constriction surfaces and finally to the contacts welding. The temperature rise $\Delta\vartheta_S$ of the constriction surface is approximately proportional to the square of the voltage between contacts [4]

$$\Delta\vartheta_S = \vartheta_S - \vartheta_0 = \frac{\Delta U_S^2}{8\lambda\rho} \qquad (1)$$

where ϑ_S is the contact surface temperature [°C]; ϑ_0 is the conductor temperature near the contact surface [°C]; ΔU^2_S is the voltage drop on the constriction surface; ρ is electrical resistivity of the material [Ωm]; λ is the coefficient of thermal conductivity [$Wm^{-1}K^{-1}$].

The temperature rise of the material of contacts consists of two parts:

- steady-state temperature rise $\Delta\vartheta_i$ on the conductor dependent on a square of current

$$\Delta\vartheta_i = \frac{I_Z^2 R_V}{\alpha S_{chl}} \qquad (2)$$

- temperature rise $\Delta\vartheta_U$ on the terminal dependent on voltage between contacts

$$\Delta\vartheta_U = \frac{U_S\sqrt{\Delta\vartheta_i}}{2\sqrt{\lambda\rho}} \qquad (3)$$

The total temperature rise is:

$$\vartheta_S = \Delta\vartheta_i + \Delta\vartheta_U + \Delta\vartheta_S + \vartheta_{ambient\ temp.} \qquad (4)$$

2.2 NUMERICAL MODEL

Numerical model is based on the real MCCB. Figure 1 shows current-carrying path of MCCB model. All parts (include splitter plates, case, mechanism etc.) of MCCB are involved to model for proper heat transfer modeling. Also there were included neighborhood and income and outcome conductors properly rated. The main part of the MCCB is the cassette with contacts and arc-quenching system. The most critical part is the movable contact with measuring points MP5 and MP6. This part is heated from both end contacts, and has a very low cooling surface.

Evaluation is carried on the middle pole of the MCCB, which is influenced from both sides by the other two poles with the same current flowing through.

Real model contains 9 measuring points with thermocouples marked as (MP..) connected directly with current carrying part for measuring of the temperature. This method also enables to measure voltage drop using the DC current between these points. This voltage data was used for the setup of the evaluation configuration heating on the current-carrying part.

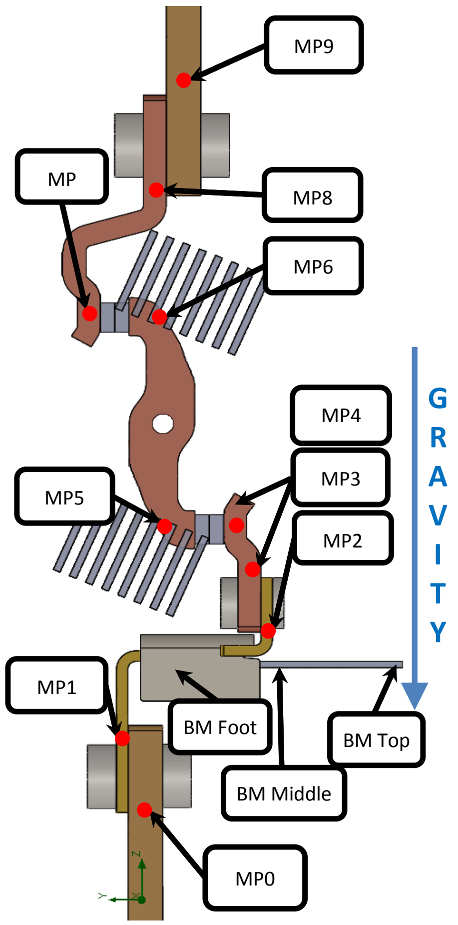

Fig.1: Simulation model with measuring points

2.3 INPUT DATA FOR SIMULATION

There are several boundary conditions used in the model, which are very important for appropriate results. The most important are as follows:

- Material prop. - Thermal Dependent (TD)
  - specific heat
  - thermal conductivity
  - electrical conductivity
- Thermal and electrical resistances (TD)
- Emissivity, electric current (DC), gravity, ambient temp., humidity, pressure etc.

Flow simulation is evaluated by the finite volume method (FVM) all using computational code Flow Simulation made by SolidWorks corporations

3 RESULT AND DISCUSSION

In the test are measured data for first sample from the sample set. Data of recorded temperature are displayed in the fig.2. For the same case of voltage drops is created the FVM model that outputs very close results in the temperature rise. Curves for temperature rise measured (Msg T: Sa01) and voltage drops (Msg U: Sa01) of fig 4 are near the same with value evaluated, see curve (Sim T(U): 0%) in both graphs. Remark: 0% means the same resistivity as the Sample 1.

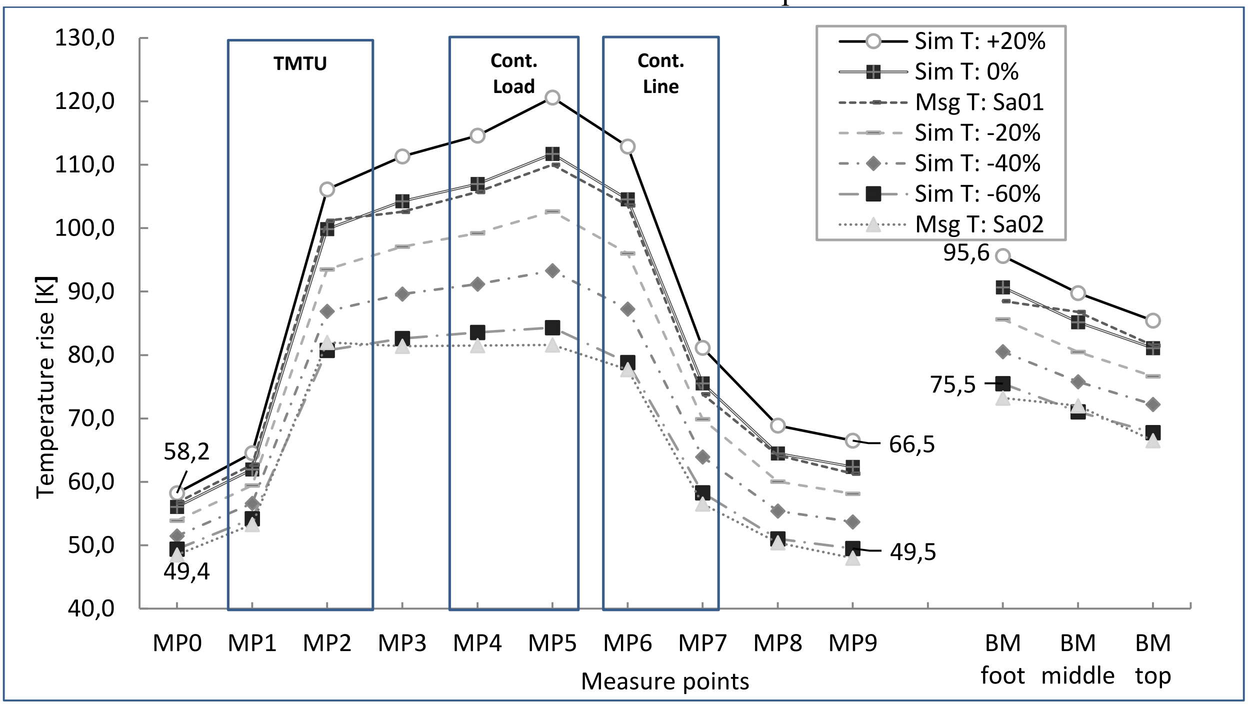

Fig. 2: Numerical model and recorded data with measuring points

Measured overall resistance of sample 1 is higher than mean value of standard samples. The model with no deviation of resistance of contacts from the original sample 1 is set for evaluation. Also there were performed simulations with same model with resistivity of contacts decreased by the 20%, 40% and 60% off and raised up by the 20% of overall resistivity of current path. These changes should decrease or increase temperature on the MCCB terminals which is limited to 70K by the standard.

In the fig. 2 are solutions of temperatures and comparison. The highest temperature is on the contact close to heated bimetal (MP5 and MP6). Temperatures on bimetal itself are marked as BM foot, BM middle and BM top.

In cases with increased and decreased resistivity of one contact significant change of temperature of terminal occurs. Also it is possible to predict from overall resistivity of MCCB pole the temperature rise of contact. This should prevent wrong function of contact system after tripping or detect possible problem in manufacture process before the final test.

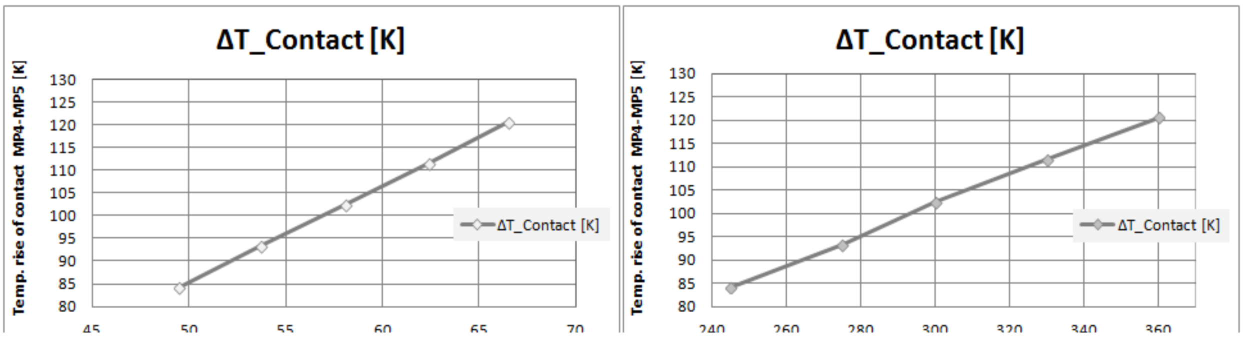

Fig. 3: Numerically modeled prediction curves for temperature rise of contact from temperature rise at terminals and from DC resistivity of MCCB model

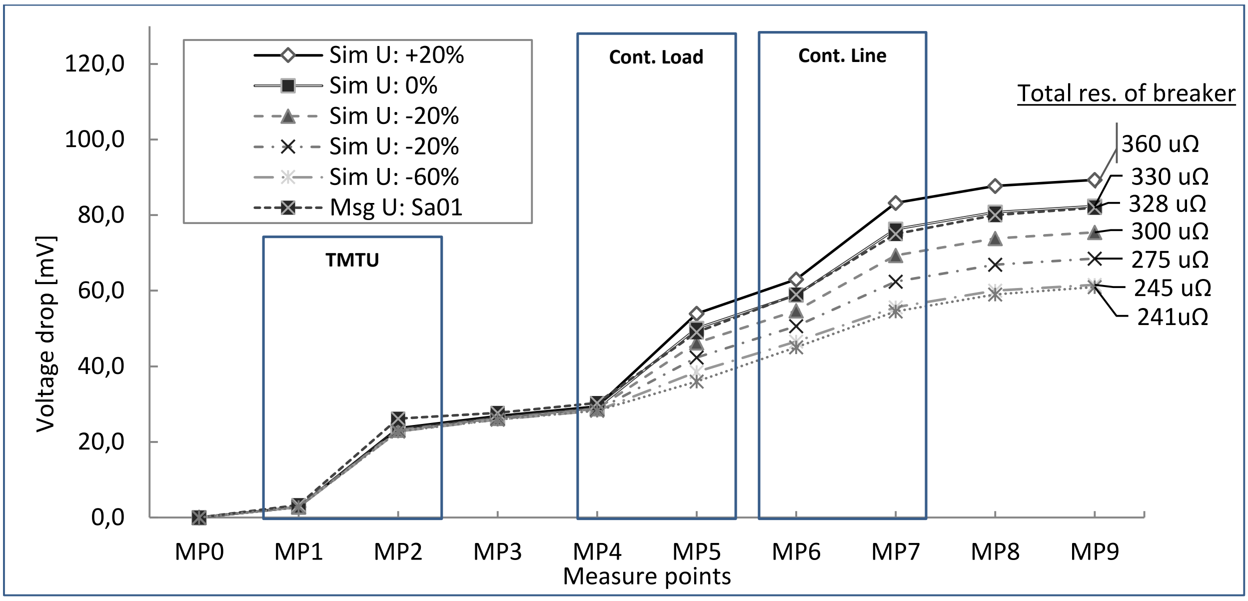

Fig. 4: The resistivity curves – voltage drops against income flag at various contact resistivity and total DC resistivity of the circuit breaker

Prediction curves are shown in fig. 3.The FVM solution was verified on the second sample with voltage drop decreased by the 21mV over whole current-carrying path at rated current related to decreased resistivity at contact area. It is nearly equal to -60% case in the model. In fig. 2 is shown thermal profile of this model, as Msg T: Sa02. It is clear, that the model corresponds with measured data in both cases.

This referred model in 3D system is now "trained" for the evaluation of problems related to this contact from whole contact system. Now are added features for prediction of two parametrical (both contacts independently) due to unpredictable behavior after breaking of highest current (shorts) near to breaking capability of MCCB.

The aim of research through the modeling is also the bimetal which maintains inverse delay switching of overcurrent. There are affect between contact and his temperature and temperature. Bimetal is heated up with contact heating, so if there is wrong contact with higher resistivity it could involve higher temperature at bimetal and change of inverse time curve to short of its time or decreasing set limiting current.

4 CONCLUSION

The article deals with innovative system of design and diagnostics of modern MCCB. For design of newest circuit breakers are used minimal amount of materials and heating of contacts and current-carrying path rises up to temperature rises over 100K are necessary to optimize current-carrying parts for temperature rise at terminal according to given standards. Described method is one of more outputs of accurate model used for easy design and diagnostics of MCCB in the switchboard, mainly after the heavy network faults braked up by MCCB. This method should be used also for purposes in examination of new MCCB or recheck of MCCB in service.

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REFERENCES

[1] Bergheau J M, Fortunier R, Finite Element Simulation of Heat Transfer, Wiley, Hoboken NJ 2008, ISBN 9781848210530.

[2] Balaji C, Essentials of Radiation Heat Transfer, 2014, ISBN 978-1-118-90831-0.

[3] Moran M J, Principles of Engineering Thermodynamics, 8th ed., Wiley, Hoboken NJ 2015, ISBN 978-1-118-96088-2.

[4] Szandtner K, Contact resistance, temperature rise and losses of the electrical terminals, Hungarian Copper Promotion Centre 2007. Available at: http://www.medportal.sk/system/files/publikace/prechodovy_odpor.pdf.