

# MCCB warm adjustment testing concept

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**Abstract.** This paper presents an experimental investigation in to operating of thermal protection device behavior from an MCCB (Molded Case Circuit Breaker). One of the main functions of the circuit breaker is to assure protection for the circuits where mounted in for possible overloads of the circuit. The tripping mechanism for the overload protection is based on a bimetal movement during a specific time frame. This movement needs to be controlled and as a solution to control this movement we choose the warm adjustment concept. This concept is meant to improve process capability control and final output. The warm adjustment device design will create a unique adjustment of the bimetal position for each individual breaker, determined when the testing current will flow thru a phase which needs to trip in a certain amount of time. This time is predetermined due to scientific calculation for all standard types of amperages and complies with the IEC 60497 standard requirements.

## 1. Introduction

This concept is design to be used during the thermal calibration procedure when a current of  $2,5xI_n$  is applied on the each pole of the breaker. The ideal tripping value is being scientifically calculated using requirement of the IEC 60947 standard and in the same way it is to the running testing procedure using the  $2,5xI_n$  for each type of amperage and then the acceptable deviation limits will be setup.

The warm adjustment testing stand is based on a regular computer controlled power supply generator, a counter having the tripping time control, and a high performance screwdriver.

## 2. Description

Of the main roles of the MCCB is to react when circuit load is being exceeded and to protect the circuit components and prevent further damages of it. This type of protection will be further on named as “tripping mechanism” and is based on the bimetal movement when the current flows thru it.

When the current flows thru the each pole (current way) from a circuit breaker, bimetal needs to react if this current flow exceeds the nominal value and this reaction will change the position of the bimetal. After the bimetal cools up it will come back to its original position. This movement of the bimetal allows us to setup a standard tripping time according to the IEC 60947 standard when the current absorbed by the circuit is higher than the protection is meant to be.

On the bimetal there is special adjustment screw which is giving us the opportunity to setup the required timing for the tripping. The regular method of adjustment is by setting up a standard value for



each type of amperage, on an adjustment station, when the MCCB is cooled and then evaluate the result by testing it.

The setup tripping time is mathematically calculated due to the reason that according to the standard the test should be conducted over a specific period of time, higher than one hour and this test is being performed on 100% of manufactured breakers and on a mass production the testing current is  $2.5I_n$  and has a tolerance of 4-5 seconds that will be further on named as “tripping window”.

When the current will be applied on each pole of the breaker the time counter will start counting time so we can have the perfect view if we have the tripping time is the right one and the current value is being live measured from the start till it trips. In order to increase the stability of the tripping times we took inconsideration the adjustment of this value during the current will flow to each pole and will be described in the next chapter.

### *2.1. Testing the concept*

The warm adjustment testing stand has the following components: a computer controlled power supply, a special designed software that controls the applied current and measures, the testing time, a high performance screwdriver interconnected to a PLC and a current presence sensor. The current presence sensor will give the input for the screwdriver to start turning and setting up the adjustment value when the lower the timer reaches the lower value of the tripping window.

This will allow us to have a controlled and perfect tripping time for all poles due to the fact the adjustment is being setup individually for each pole and not having a standard value for the adjustment as is in the cooled version of the adjustment case. When the MCCB trips the signal for the interrupting current flow will stop, the power supply generator and testing phase may be continued on the next one.

In order to highlight this concept, we chose sample groups of 50 breakers (150 poles) each from different amperage were prepared to be tested. In order to have comparison data we did the same test on the same sample sizes with the regular cooled breaker adjustment stand. After collecting and analyzing these data we start up with warm adjustment testing concept.

The warm adjustment test consisted of an adjustment phase and a factory tripping time test. The test was carried out only once per sample group to replicate first test scenario from the production.

## **3. Problem identification tools used**

### *3.1. PFMEA*

Process Failure Mode Effects Analysis (PFMEA) is a structured analytical tool used by an organization, business unit, or cross-functional team to identify and evaluate the potential failures of a process.

PFMEA helps to establish the impact of the failure, and identify and prioritize the action items with the goal of alleviating risk. It is a living document that should be initiated prior to process of production and maintained through the life cycle of the product.

PFMEA evaluates each process step and assigns a score on a scale of 1 to 10 for the following variables:

- a. Severity — Assesses the impact of the failure mode (the error in the process), with 1 representing the least safety concern and 10 representing the most dangerous safety concern. In most cases, processes with severity scores exceeding 8 may require a fault tree analysis, which estimates the probability of the failure mode by breaking it down into further sub-elements.
- b. Occurrence — Assesses the chance of a failure happening, with 1 representing the lowest occurrence and 10 representing the highest occurrence. For example, a score of 1 may be assigned to a failure that happens once in every 5 years, while a score of 10 may be assigned to a failure that occurs once per hour, once per minute, etc.
- c. Detection — Assesses the chance of a failure being detected, with 1 representing the highest chance of detection and 10 representing the lowest chance of detection.

d.RPN — Risk priority number = severity X occurrence X detection. By rule of thumb, any RPN value exceeding 80 requires a corrective action. The corrective action ideally leads to a lower RPN number.

According to the above procedure, witnessing and analyzing our MCCB shop floor process we came up to following scorings of the PFMEA that may be noticed in the below image.

Owner & Team Members:						RISK Prioritization				ACTION RESULTS					
Item (Hardware or Software) and its Function(s)	Potential Failure Mode(s)	Potential Failure Effects	SEV	Potential Causes	OCC	DET	SEV	RPN	DEPI A G O C T I O N	Actions Recommended	Action Owner	Target Date	Actual Date		
Function															
Magnetic Tripping According to the production test plan for types of BZMI below and including 40A. (Special focus on BZMI 1p 20A)	Trip to quick, before 200 ms at the defined current (magnetic low)	Fail the magnetic tripping test and need to repair the device	4	Force of the Ankerfeder is to weak (out of tolerance)	2	No control	10	4	80	P					
			4	Force of the Mechanism is to low (Greasing applied in wrong areas)	7	Control according to PA BZM 24	7	4	28	136	P	Work instruction review.	Moldovan Horatiu	31-Jul-15	
			4	Bimetal operation during magnetic test related to the bimetal adjustment	4	No control	10	4	16	160	D	Concept definition and testing of possible solution to separate magnetic from thermic trip unit	Pop Mihai	31-Jul-15	
	Not trip within 200 ms at the defined current (magnetic high)	Fail the magnetic tripping test and need to repair the device	4	Bending of the ankerfeder during assembly (especially for single pole devices)	7	No control	10	4	28	280	P	Work instruction review and operator retraining	Moldovan Horatiu	31-Jul-15	
			4	Bimetal operation during magnetic test related to the bimetal adjustment	7	No control	10	4	28	280	D	Statistic of repaired failures	Moldovan Horatiu	31Jul15	
			4	Magnetic field generated is not strong enough	10	Studies of the magnetic tripping capability	5	4	40	200	D	Concept definition and testing of possible solution to increase magnetic field generated in the device	Pop Mihai	31-Aug-15	
			3	The travel of the machine for switching on is to short, there is no holding time at the end of the travel	8	No control	10	3	24	240	P	Statistic implementation to gauge the type of affected and occurrence of the problem	Tuturan David	31-Jul-15	
			3	The positioning jig is not precise enough											
			3	The positioning jig is not precise enough											
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Figure 1. PFMEA scoring sheet

As outcome of these analysis are the major steps of the process having a high RPN which need to be addressed first in terms of improving MCCB performance:

- Welding process improvement and control
- Riveting process improvement and control
- Assembly process improvement and control
- Adjustment process improvement and control(hot adjustment concept)
- Testing process improvement and control (check if currents applied for magnetic and thermic testing are according to spec and requirements)

### 3.2. P-Diagram

Parameter Diagram (or P-Diagram) takes the inputs from a system/customer and relates those inputs to desired outputs of a design that the engineer is creating, while also considering non-controllable outside influences. It is a useful tool in brainstorming and documenting input signals, noise factors, control factors, error states and the ideal response of the system.

P-Diagram is most useful when the item under analysis is a complex system with many system interactions, operating conditions and design parameters, and the team will benefit from seeing these elements visually.

Using above concept we identified the following step semi-automatic hot adjustment stand is one of the most important factor that can increase the functionality of the MCCB product.

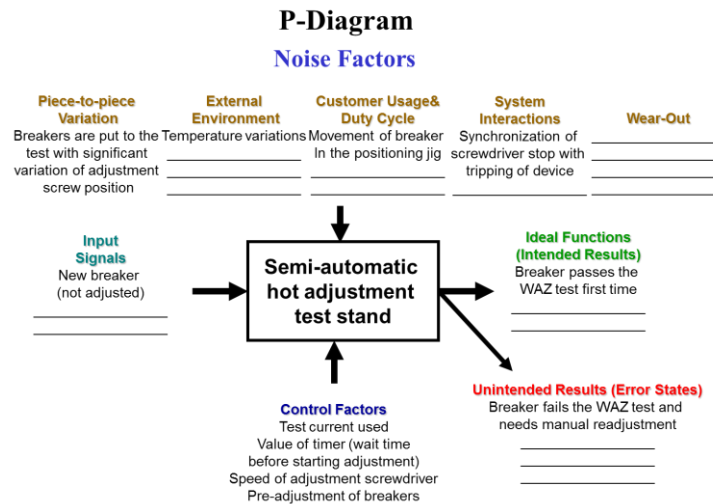


Figure 2. P-Diagram

### 3.3. Capability study

The input of a process usually has at least one or more measurable characteristics that are used to specify outputs. These can be analysed statistically; where the output data shows a normal distribution the process can be described by the process mean (average) and the standard deviation.

A process needs to be established with appropriate process controls in place. A control chart analysis is used to determine whether the process is "in statistical control". If the process is not in statistical control then capability has no meaning. Therefore, the process capability involves only common cause variation and not special cause variation.

The output of a process is expected to meet customer requirements, specifications, or engineering tolerances. Engineers can conduct a process capability study to determine the extent to which the process can meet these expectations. Willing to evaluate the product and process implemented we have applied the study and gathered the following results.

According to the expectation the final result revealed was quite low and as an improvement we decided to develop and implement the below concept of warm adjustment.

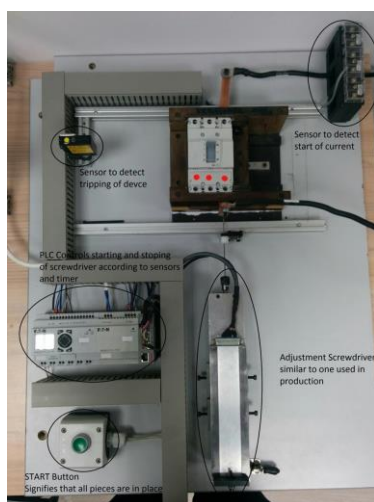


Figure 3. Warm adjustment stand short capture

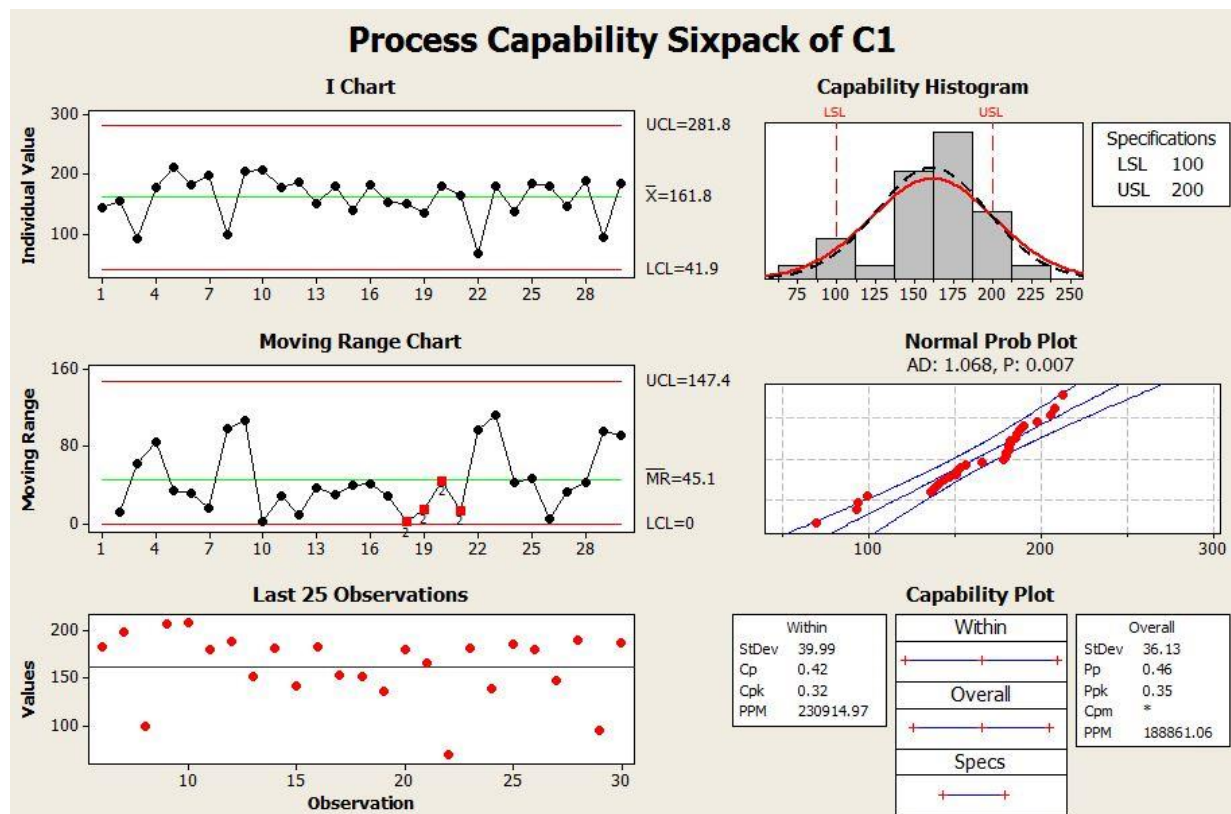


Figure 4. Capability study

#### 4. Results and conclusions

In manufacturing terms, First Time Quality (FTQ) has been defined as "a lean metric that indicates to what extent parts are manufactured correctly the first time without need for inspection, rework, or replacement." FTQ is an important tool in any Quality Management System toolbox to deliver a high quality product— built right, the first time. This is a key element in the effort to exceed the expectations of both internal and external customers.

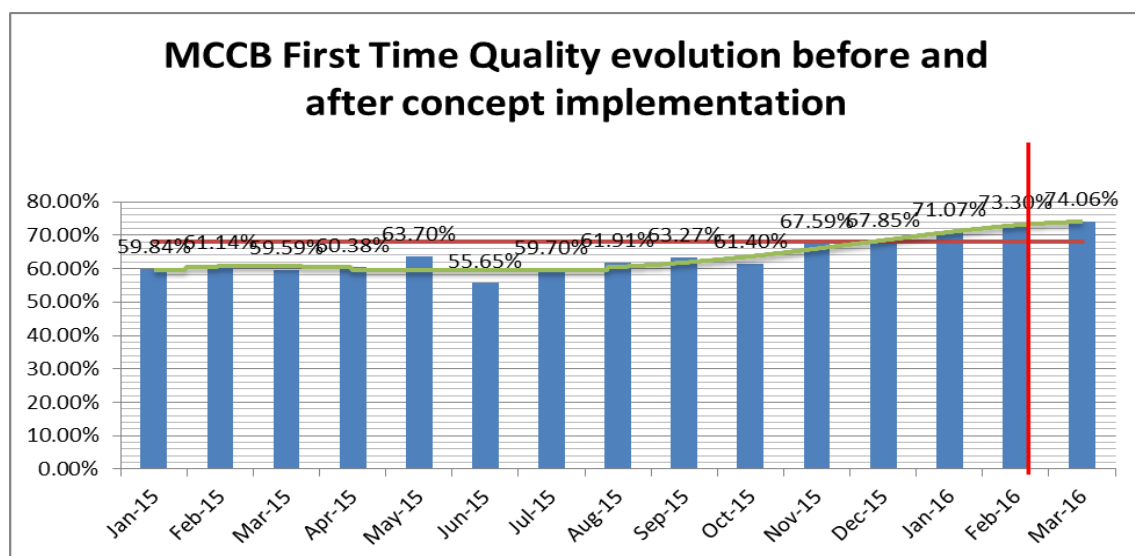


Figure 5. MCCB FTQ evolution

For our particular case FTQ were used as metric to follow progress and evaluate the success of actions taken. Test results showed a significantly improve of the tripping time into the tripping window. The difference between the tested results regular production procedure and warm adjustment was up to 20% percent, higher using the warm adjustment station and having more constant values.

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