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# Implementing Type 2 Coordination to Improve the Performance of the Motor Control Center (MCC)

*By*

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## *Abstract:*

This paper explains the criteria of selection and coordination between the motor control centers (MCCs) components to meet the need of motor service continuity in the most of industrial processes. The aim behind this study is to obtain high level of coordination between the MCC components which is denoted by Type 2 coordination. The requirements of Type 2 coordination are illustrated in this research; this is according to IEC 947-4-1, where illustrates different methods of meeting these requirements. Also, this research proposed an algorithm to compare between implementing either fuses or circuit breakers (CBs) as short circuit protection device (SCPDs) in the MCC.

## *Keywords:*

Three phase induction motors, Motor starters and protection, Coordination of motor circuits; Motor control centers (MCCs)

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## 1. Introduction:

With the tremendous progress of the micro and mega industries, the three phase induction motors are the most important electromechanical devices that perform most of stages in the industrial processes. Selection and coordination between the MCC components that operate and protect these motors properly is an important issue to guarantee high level of process dependability. The dependability means that the process should be reliable, available, maintainable, and safe [1].

Motor Control Centers (MCCs) form a substantial part of any commercial or industrial installation. With greater emphasis being placed on reduced downtime and increased productivity, so with a large number of induction motors in use, the protection system for them has become an important aspect in order to have:

- Efficient operation of the motor process.
- Minimum downtime of the plants.
- Increasing the safety degree of these plants.

MCC designers have a lot to think about in selecting the MCC components to achieve isolation, control and protection.

To achieve proper selection, the designers begin to install motor starters in MCCs which lead users to size motor feeder cables economically. When a short-circuit fault occurs, the Short Circuit Protective Device (SCPD) takes a finite time to interrupt the fault. During this time, the current rises rapidly and certain energy is let through which is higher than the withstand capacity of the downstream equipment; it can cause damage to the equipment. So, MCC coordination means matching the characteristics of SCPD and the downstream equipment including cables to ensure that the let-through energy and peak cut-off current do not rise above the levels that the circuit can withstand [1].

## 2. Coordination Types:

The IEC 947-4-1: 1990 and IS 13947 (Part 4/Section 1): 1993 standards on starters and contactors define two types of co-ordination: Type 1 and Type 2.

Type 1 co-ordination requires that, under short-circuit conditions; the contactor or the starter shall cause no danger to persons or installations and may not be suitable for further service without repair and replacement of parts [1].

Type 1 co-ordination is easy to achieve but in the event of a short circuit, the user has to check all the starter components and replace them if found necessary. This works out to be very expensive.

Type 2 co-ordination requires that under short-circuit conditions; the contactor or starter shall cause no danger to persons or installations and shall be suitable for further use. The risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken in regards to the maintenance of the equipment [1].

Essentially it means that the starter will not be damaged, and can be returned to service after the cause of the short circuit has been determined and corrected.
In terms of motor branch circuit components, it means that the fuses are protecting the starter (see fig.1).

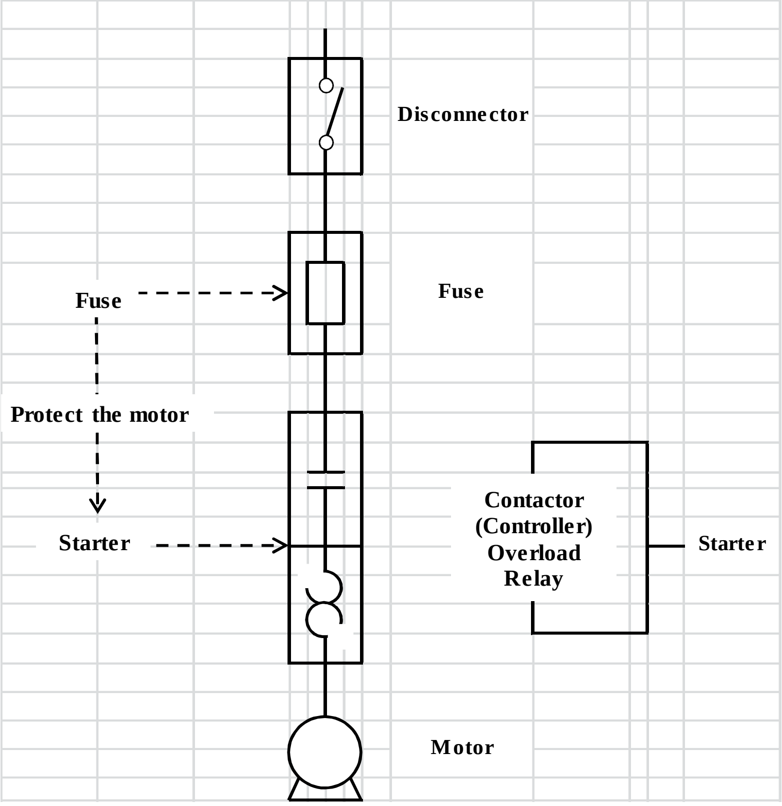
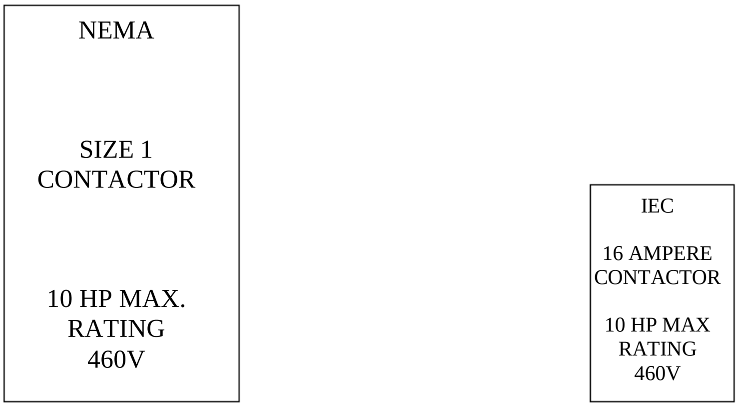


***Figure (1):*** *Motor branch circuit*

Type 2 co-ordination has a major advantage, after the fault is cleared, the user needs just to reset the breaker or replace the blown fuse and check for contact welding.
Type 1 co-ordination is cheaper during installation but Type 2 will prove to be economical in the long run, there are two primary reasons why Type 2 coordination became a requirement in Europe.
First, because starters were designed to be utilized at or very near their maximum capacity (minimizing the amount of materials required), they are smaller in physical size than traditional NEMA starters used in North America, Fig.2 shows the different sizes of the motor starter according to both NEMA (National Electrical Manufacturers Association) and IEC (International Electro-technical Committee) standards [2].



HEIGHT = 6.00 "
WIDTH = 3.56 "
DEPTH = 4.47 "
PANEL AREA = 21.36 $IN^2$

HEIGHT = 3.26 "
WIDTH = 2.17 "
DEPTH = 3.62 "
PANEL AREA = 7.07 $IN^2$

***Figure (2):*** *Size of MCCs*

In general, the smaller the starter, the lower it's short circuit withstand rating and the more susceptible it is to being damaged from a short circuit fault current.

Second, the relevant IEC standards for short circuit protective devices (SCPD) do not specify maximum allowable let-through currents and let-through energies. The performance, thus the level of protection provided by any given SCPD was left to the discretion of the SCPD manufacturer. In terms of an SCPD protecting a motor starter against short circuit faults, the lower the let-through current and energy, the less damage that is likely to occur to the starter. The small size of the starter and the unregulated let-through characteristics of SCPDs put users and motor starters in a precarious situation. If an SCPD with high let-through current and energy was used to protect a starter, the likelihood that the starter could be damaged or even totally destroyed by a short circuit is great. This is obviously undesirable as it raises a safetyconcern, increases costs (component replacement and associated labor), and can reduce manufacturing productivity [2].

National Electrical Code (NEC) has established guidelines for the selection and application of motor branch circuit components to provide protection against fires. Underwriters Laboratories (UL) has developed product safety standards to ensure that people are not injured as a result of damage that may occur to a motor starter “The applicable standard for motor starters is UL 508 [3] [9]”. Neither the NEC nor the UL safety standard or NEMA standards specifically addresses damage levels of equipment following a short circuit fault. IEC 947-4-1 offers the most precise definitions of allowable damage to a motor controller, namely Type 1 and Type 2 coordination. For this reason, many users in North America are now referencing to IEC standards because they offer guidance in evaluating the level of damage likely to occur to the motor starter in the event of a short circuit fault [3] [6].

## ***2.1How Short Circuits Damage Motor Starter:***

There are two things that cause short circuit damage; one is electro dynamic forces and the second is excessive heat. Both of these are functions of the current.

Magnetic forces are a function of the instantaneous peak let-through current ($I_{peak}$) passed by the SCPD. This is the current that flows in the circuit before the SCPD can respond to the current and open the circuit. Magnetic forces put physical stress on the starter. The forces cause the contacts of the starter to "blow apart" and can cause the housing of the starter to fracture.

Excessive heat is a function of let-through energy ($i^2t$ ), As Heat is proportional to the let-through energy ($i^2t$ ) passed by the short circuit protective device during opening. Excessive heating energy may cause the starter contacts to weld after magnetically blowing apart and may also cause thermal unit burnout, during the clearing of the short circuit fault current by the SCPD [2] [10].

## ***2.2 How to Minimize Short Circuit Damage to Motor Starter:***

There are a number of ways that the damage can be minimized including: using physically larger, more rugged starters, reducing available short circuit fault currents, and using better protecting short circuit protective devices.

Damage to a starter caused by magnetic forces can be minimized by increasing the electrical clearances between current paths and supporting the current carrying parts with more insulating material.

Damage caused by excessive heat can be minimized by incorporating larger current carrying parts with higher contact mass in the starter. Larger parts can absorb more heat, reducing the possibility of the parts welding.

The disadvantage of trying to minimize damage with this approach is that it increases the size of starter, which in turn increases the size of the control panel and ultimately the facility. In addition, more material equates to higher costs. These are quite contradictory to trends in industry to downsize everything and keep costs to a minimum [2].

A second way to minimize damage to a motor starter is to limit the available fault current. As fault current is a function of the circuit impedance and the upstream short circuit protective devices, and is generally determined during the construction of the facility or plant, short circuit damage can be minimized by using better short circuit protective devices (faster acting, more current limiting). Since short circuit damage is a function of the current passed by the SCPD, limiting this current will minimize the

$I_{peak}$ damage to the starter. Fuses of this type are described by UL as "current limiting" which is defined in UL 198C [6]. To be classified as current limiting, the protection device must interrupt fault currents within the first half cycle of the current wave, Figure 3 show the difference in let-through energy in circuits with and without current limiting when applied to current-limiting, a current-limiting device is one that opens and clears the current in less than ½ of an AC cycle (0.01 sec.), the maximum instantaneous peak current during the first ½ cycle after initiation of a fault. Depending on the power factor and when the fault occurs, the maximum possible instantaneous peak current () without current limitation can be as high as 2.3 times the available RMS fault current when the fault occurs. As shown, if a current-limiting protection device is used, the maximum instantaneous peak current is limited to a small fraction of the peak current that could possibly flow if the fuse were not used. The current-limiting fuse link melts and clears the circuit in less than 0.01 second. The area under the curve is known as the $I^2t$ let-through energy. The lower the $I^2t$ the lower the destructive thermal energy is that passes through the circuit before it is interrupted [4] [7].

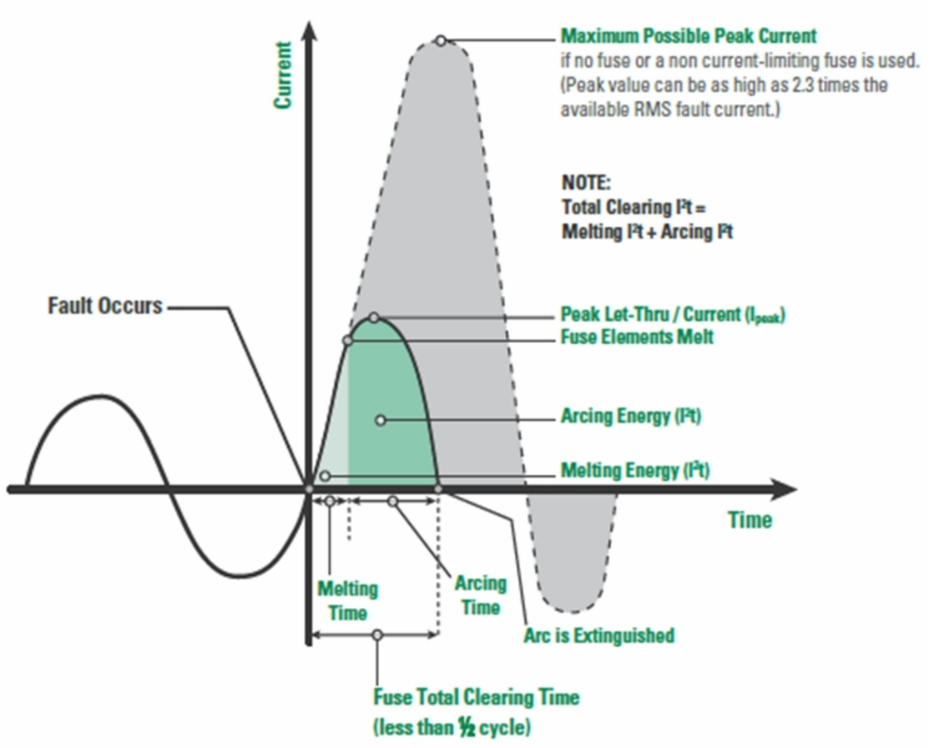


***Figure (3):***Let-through energy in circuits with and without current limiting

## 3. Protective Devices in the MCCs:

### 3.1 Fuses as SCPD:

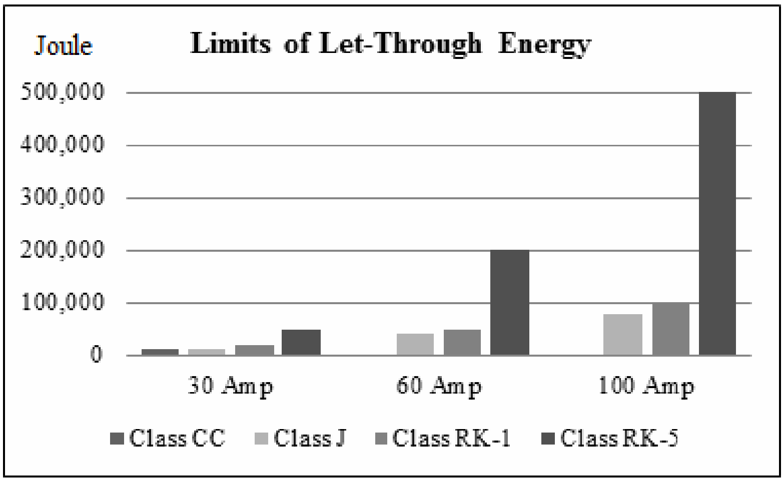
Fuses are traditionally used as SCPDs because of their desirable characteristics of noiseless interruption, no expulsion violence, current-limiting action, very high current-interrupting capability, low initial capital cost and their capability to interrupt faults faster. Fuses have excellent current limiting characteristics and can be applied safely on systems having high fault levels. Using fuses for short-circuit protection is found to be the easiest and its contribution to achieve type of coordination is tested in this research compared to the molded case circuit breakers (MCCBs) as SCPDs.

The principal strength of a fuse is its ability to reduce energy let-through at high fault levels. At high currents, the fuse element gets hot and melts (pre-arcing period, if the fuse dimensions are available it is possible to calculate from Eq. (1) the pre-arcing $i^2t$ for current-limiting fuses by:

$$i^2t = 2.\,88 \times 10^{10} A^2 \quad (1)$$

Where A is the area in square inches of the minimum cross-section of any portion of the fusible element (6. 03 x $10^8 A^2$ with A in square centimeters), considering with silver contacts [5]. This is followed by arcing which persists until the resistance across the fuse builds up to a sufficiently high value to reduce the current to zero (arcing period). Both actions take place very quickly - about 2 msec for pre-arcing period and 4 msec for arcing period - making the total operating time of about 6 msec in the event of short circuit. The combination and high speed operation and high arc resistance limits the peak fault current and reduces the let-through energy.

There are different degrees of current limitation, in other words some fuses limit the let-through energy more than others. Figure 4 shows the UL limits of let-through energy for the most commonly used classes of fuses in motor branch circuit applications. The best fuses for protecting typical electromechanical starters in motor branch circuits are UL Class CC, J and RKl because they are the most current limiting commonly used fuses and they minimize the let-through energy in the circuit to levels that most starters can withstand without being damaged [2].



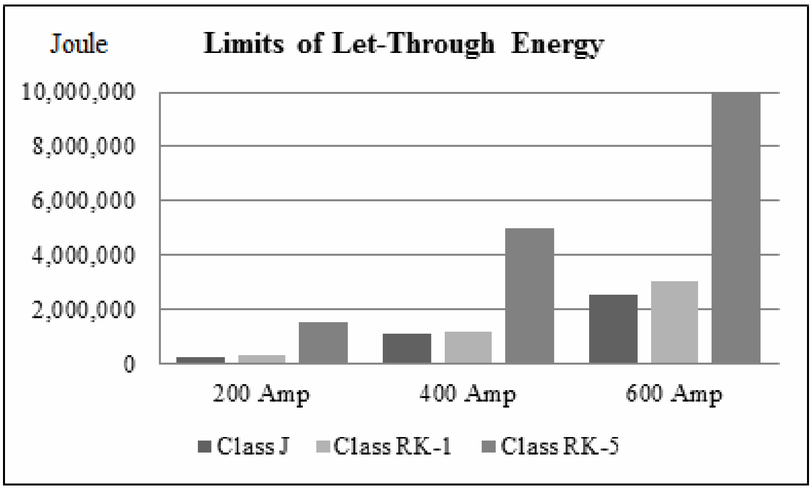


***Figure (4):** Limiting of fault energy by different fuse categories*

## 3.2 MCCBs as SCPD:

### 3.2.1 Conventional MCCBs:

MCCBs as SCPDs have been compared, with the fuses. The first generation of MCCBs had low short-circuit breaking capacity and high operating time.

The operating time of 15-20 msec. The traditional MCCB is also a zero-point device, in the event of a short circuit; the device is unable to clear the fault till it completed the first half-cycle. During this half-cycle, the entire circuit would undergo tremendous stress, at times resulting in damage to the downstream equipment [5].

### 3.2.2 Current limiting MCCBs:

Introduction of current limiting MCCBs has resulted in a big break-through in the reduction of let-through energy in a system and getting very high breaking capacity. Current limiting MCCBs can reduce both the peak fault current and energy that reach downstream equipment to a tolerable level. Thus, motors and cables connected to the system will not be exposed to high Let-through energy. With this, the current limiting MCCB helps in using lower size devices and cables, resulting in cost efficient control system [5].

To meet these stipulated requirements, the current limiting MCCB must respond quickly in case of a fault. To achieve high speed contact separation, closely spaced contact fingers carrying current in opposite directions create a strong magnetic repulsion between the conductors. High speed contact separation is actually produced by electromagnetic repulsion forces generated by the fault current itself. The higher the current, the greater is the force pushing the contacts apart. Although rapid contact opening is important, just opening the contact quickly is not enough. The next concern is to control the arc voltage across the contacts to ensure proper arc extinction. This is accomplished by forcing the arc into the arc chute and stretching the arc. The elongated arc is cooled and broken into segments in the arc chute until it is de-ionized and ceases to conduct current, thus being extinguished [5].

Final requirement for current limiting operation is that the trip mechanism must operate quickly enough to co-ordinate with the rapidly moving contacts [5].

## *4. Proposed Model to Compare Between Fuses and MCCBs:*

Consider a motor connected to a part of industrial low voltage distribution network that is responsible to feed Low Voltage (LV) motor with the data sheet illustrated in Table 1.

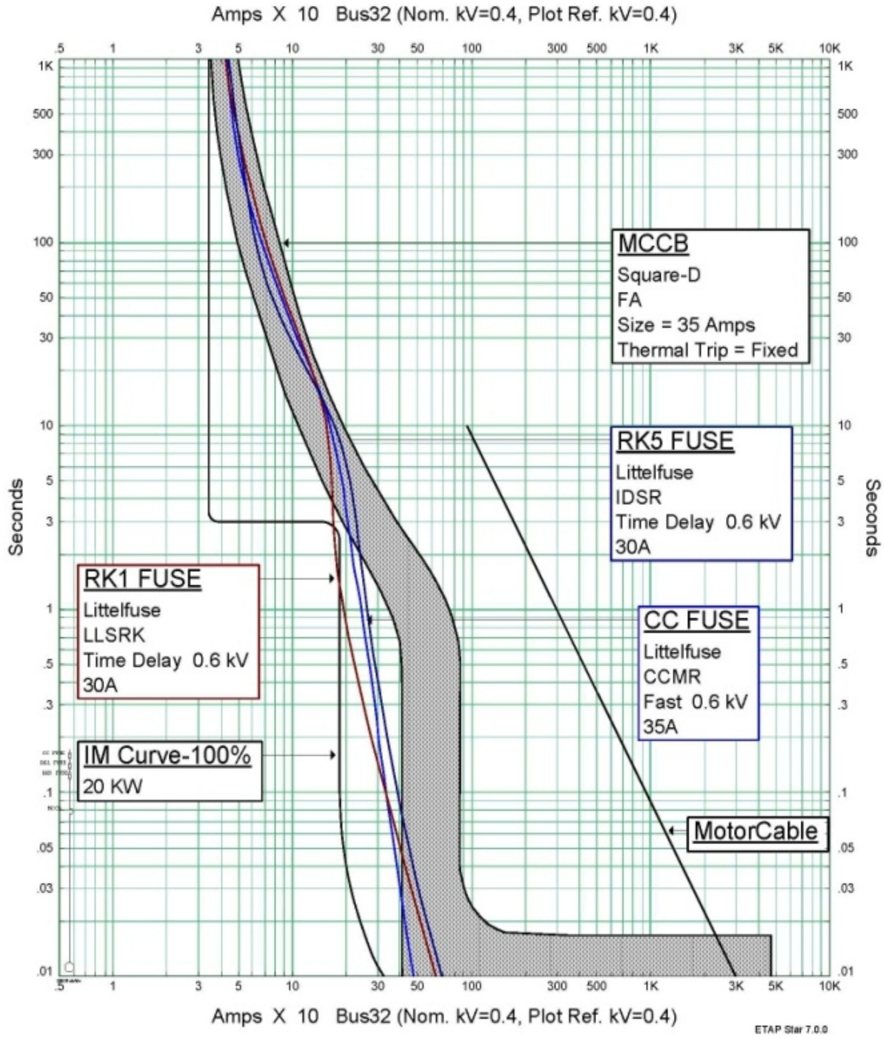
***Table (1):*** *Motor data sheet*

| **Motor Name Plate** | | |
|---|---|---|
| Power | (KW) | 20 |
| Voltage | (KV) | 0.38 |
| FLA | (Amp) | 38.96 |
| Poles | | 4 |
| RPM | | 1460 |
| P.F @ 100% | (%) | 88.9 |
| Slip | (%) | 2.6 |
| Eff | (%) | 87.73 |

ETAP software is implemented to simulate the LV distribution network with motor and MCC, the fault study based on achieving coordination Type 2. It is optional to choose either fuses or MCCBs to protect this motor against short circuit fault, the protection curves (IT curves) of the protection elements are chosen as shown in Fig. 5.

One constraint against the acceptance of MCCB is the initial cost when compared to the cost of the fuse. But for more complete comparison of costs, one must also consider the other aspects like ease of maintenance, downtime, simplicity of operation, recurring costs, etc. To sum up, the advantages offered by fuses like low initial cost, very high breaking capacity, very low peak cut-off current and let-through energy, etc.

While comparing fuses with MCCBs, it is essential to compare the systems. MCCB results in a higher let-through than a fuse, so it is usually necessary to use a bigger size of contactor and/or a CT operated relay. This occupies larger panel space resulting in increased costs.



***Figure(5):****IT Curves of the fuse and MCCB under study*

## 4.1 Algorithm:

Figure 6 shows the methodology of analyzing the MCC performance for a LV motors.