



#### Intelligent Molded Case Circuit Breakers – MCCB





ATOM Switch

C OFN

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### Agenda

- History of MCCB
- Overcurrent and Overloads
- Codes and Standards
- Overcurrent Protective Devices
- Time Current Curves
- Overcurrent Device Construction
- Intelligent Molded Case Breakers
- Solid Sate Breakers
- Closing Remarks





#### **Types of Overcurrent Protective Devices**



• The primary function of an overcurrent protective device is to protect the conductor from overheating





### **Overcurrent Protective Devices - Types**

#### Circuit Breaker

#### (NEC Article 100 Definition)

"A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating."

"FPN: The automatic opening means can be integral, direct acting with the circuit breaker, or remote from the circuit breaker."



Molded Case Circuit Breakers





### **Different Types And Sizes**

Molded Case Circuit Breaker (MCCB)

"A circuit breaker that is assembled as an integral unit in a supporting and enclosing housing of insulating material."

Insulated Case Circuit Breaker (ICCB)

"A circuit breaker that is assembled as an integral unit in a supporting and enclosing housing of insulating material and with a stored energy mechanism."

#### Low Voltage Power Circuit Breaker (LVPCB)

"A mechanical switching device, capable of making, carrying, and breaking currents under normal circuit conditions and making and carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit. Rated 1000 V ac or below, or 300 V dc and below, but not including molded-case circuit breakers."

Ref: IEEE Std 1015 - 2006 "IEEE Blue Book - Applying Low Voltage Circuit Breakers Used in Industrial and Commercial Power Systems"





### **Insulated Case Circuit Breakers**

- Typically 800A 6000A Frame Range
- Interrupting Duty 35 200kA
- Found In Enclosures, Switchboards and Switchgear









#### **Power Circuit Breakers**



- Interrupting Duty from 42kA to 100kA and Current-Limiting Up To 200kA
- 800A to 6000A Frame
- Found in Enclosures, Switchboards, and Switchgear





### **MCCB** Technology Evolution







### **Overcurrents and Overloads**







#### **Overcurrent Protective Devices**

#### **Overcurrent** (NEC Definition)

"Any current in excess of the rated current of equipment or the Ampacity of a conductor. It may result from overload, short circuit, or ground fault."

FPN: A current in excess of rating may be accommodated by certain equipment and conductors for a given set of conditions. Therefore, the rules for overcurrent protection are specific for particular situations.







#### **Overcurrent Protective Devices Protect From**

#### Overload. (NEC Definition)

"Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload."

An Overload Is NOT A

Short Circuit, or Ground Faults





#### **Overcurrent Protective Devices Protect From**

#### Short Circuit Current.

- Not Defined In NFPA, IEEE or other similar organization documents
- An overcurrent, typically many times larger than normal operating current

#### • Short-Circuit Current Rating (NEC Definition)

• Short Circuit Current Rating (SCCR) is a rating on components and assemblies representing the maximum level of *short-circuit current* that a component or assembly can withstand. This *rating* is used to determine compliance with NEC 110.10. "SCCR" labeling is required on all panels and assemblies.

A Short Circuit Is An Overcurrent But Not An Overload





#### Example – Overload



#### Within the normal path





#### Example – Short Circuit

$$I_{load} = V_S I R_T$$



 $\label{eq:Voltage} \begin{array}{l} \mbox{Voltage (V) = 480} \\ \mbox{Load Resistance (R) = 24 ohms} \\ \mbox{Wire Resistance (R) = 0.01 ohms = 8*0.01 = 0.08Ohms} \\ \mbox{I}_{load} = (480) \mbox{/} (0.08 + 24) = 19.93 \mbox{ Amps} \end{array}$ 





#### Class Example – Short Circuit







### Effects Of Overcurrents – Ground Fault

 People and Equipment Protection Levels



**Ground Faults Are Overcurrents** 





### **Effects Of Overcurrents**

- Conductor insulation damage
- Equipment damage
- Fires
- Arc Flash Energy









# The Overcurrent Protective Device Works **To Prevent The Hazardous Consequences Of Dangerous Overcurrents**





#### **Codes and Standards**







### **Codes And Standards**

- NFPA National Fire Protection Association
  - <u>NFPA 70</u>: "National Electrical Code"
  - <u>NFPA 70E</u>: "Standard for Electrical Safety In the Workplace"
  - NFPA 99: "Health Care Facilities"
  - NFPA 70B: "Recommended Practice







### **Codes And Standards**

- UL Underwriter's Laboratories
  - <u>UL 489</u>: "Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures"
  - <u>UL 1087</u>: "Molded Case Switches"
  - <u>UL 1699</u>: "Arc-Fault Circuit Interrupters"
  - <u>UL 943</u>: "Ground-Fault Circuit Interrupters"
  - <u>UL 1077</u>: "Supplementary Protectors for Use In Electrical Equipment"
  - UL 1053: "Ground-Fault Sensing & Relaying Equipment"





#### **Codes And Standards**



- <u>AB 1</u>: "Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures" (Now = UL 489)
- <u>AB 3</u>: "Molded-Case Circuit Breakers and Their Application"
- <u>AB 4</u>: "Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications"

ree Downloads @ www.nema.or





#### **Overcurrent Protective Devices**







### Time Current Curves (TCC)

Trip Curve Describes Device Operation

- Designed To Trip On Overcurrents
- Designed To Protect The Conductor From Thermal Damage
- Device Needs Time & Current To Trip



Understanding How An Overcurrent Protective Device Operates Is Important





### Time Current Characteristic (TCC) Curves

The Trip Curve

- A Trip Curve Is Plotted Time Vs. Current
- The Curve Tells The Trip Times For Various Levels Of Current
- Minimum and Maximum Clearing Times



Understanding How An Overcurrent Protective Device Operates Is Important





### **Circuit Breaker Components**

- Major Components
  - Molded Case Frame
  - Operating Mechanism
  - Arc Extinguishing And Contacts
  - Trip Units
- Tripping Conditions
  - Overload
  - Short-Circuit
  - Ground Fault







### **Thermal Protection**

- Bimetal In Series With Connected Cable
- Bimetallic Element Is Heated By The Load Current
- Sustained Overload Will Cause Bimetal To Deflect
- Deflection Trips The Breaker







#### Thermal Magnetic Time Current Characteristic Curve







### Labels and Ratings







### **Overcurrent Device Ratings**

- Amp Rating
- Interrupting Rating
- Withstand Rating





#### **Circuit Breaker Labels**







#### The Electronic Era







### **Electronic Trip Units**

- 1973 Saw The Introduction of The Seltronic<sup>™</sup> Circuit Breaker
- The First Electronic Circuit Breaker On The Market







#### **Integration With The Breaker**







### **Time-Current Characteristic**



Depicts the time required for an overcurrent protective device to open automatically

- Three Regions
- Long-time: Opening in minutes
- <u>Short-time</u>: Opening in seconds or tenths of seconds.
- <u>Instantaneous</u>: Opening with no intentional delay - milliseconds





### Communications

- Remote Data Collection
  - Energy / Voltage / Current
  - Cause Of Trip And Other Alarm Information







### Zone Selective Interlocking

- Communication Between Breakers
  - Reduces Trip Time When Possible
  - Helps With Arc Flash Energy Reduction

Case 1:

- Both Breakers See Fault
- Upstream Breaker Waits As Designed
- Case 2:
  - Only Upstream Breaker Sees
    Fault
    - No Input From
      - Downstream Breaker
    - Trip As Fast As Possible





### Arc Flash Reduction Switch

#### ALWAYS WORK DE-ENERGIZED

- Manually or Automatically enables analog instantaneous pickup
- Protects all downstream equipment / personnel
- Limits energy available during maintenance





**Door Mounted Hardware** 





### **Electromechanical Intelligent Breakers**







### **Product Attributes!**

- Globally rated breakers— UL, CSA, CCC & IEC
- 1, 2, 3 & 4 pole frames
- Smaller number of frames (15A 2500A)
- Up to 100kAIC/480V & 65kAIC/600V
- Field installable thermal-magnetic
   & electronic trip units
- Through-cover accessories and improvements galore







### **Intelligent Breaker Features**

- Software Configurations
- Breaker Health
- Arc flash Mitigation
- Enhanced Ground Fault
- Metering Accuracy
- Programmable Relays
- Communications
- Testing and Commissioning





### **Software Protection Manager**

**BEFORE**: Set points manually, hand held test kits with different connections by platform, manual transcribing for test reports, temporary meters for troubleshooting and attempting to capture events

**AFTER**: USB-equipped trip units and PC-based software to configure, test, and troubleshoot trip units in the field



\*

**Set point Configuration**: Allows direct-to-trip unit or offline set up, including duplication of settings between units

Control Mode: Capture waveforms, reset TU, or set date/time



Test Mode: Run secondary injection & create test reports



*Real Time Data*: Provides information regarding all status and metered data direction from the trip unit



*Event Summaries*: Stores up to 200 events, detailed information on most recent (10) trip and (10) alarm events, and time adjustments to the real time clock

Reports: Allows printing of real time data & events from trip unit





#### **Test Report**

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### **Introducing Breaker Health**

**BEFORE:** Operational condition and wear of breaker is unknown, no warning that breaker is near end of life

**AFTER: Breaker Health** algorithm provides real-time evaluation of breaker condition by tracking and analyzing diagnostic details including:

Breaker operations Short circuit fault levels Operational time Internal temperature Overloads

- Communicates breaker status at 25% Health to prompt for breaker maintenance or inspection
- Also optional to configure a programmable relay







WILLING

### Standardizing ARMS Functionality

**BEFORE**: ARMS differed in functionality between breakers trip units

**AFTER**: Maintain industry-leading solution with added consistency amongst frames and enhanced functions:

- OFF/Remote-ON switch and blue LED trip unit, selfpowered with current above ~20%
- Remote switch wiring and remote indication capability via programmable relay
- Remote switching via communications
- Adjustable ARMS levels via screen or PC Based Software

**White Paper** published to provide thought leadership on 240.87 approved methods for arc energy reduction, advantages and disadvantages



#### **Typical ARMS Wiring**

#### Adjustable Levels









### Added ZSI Testing and Indication

WHITE PAPER

**BEFORE:** No way to verify Zone Selective Interlock activation or test functionality

**AFTER:** Comprehensive system test capabilities and advanced ZSI functionality

- ON / OFF capability
- On screen visual indication, and remotely by programmable relay
- Indication appears during testing and in service (TU Reset removes signal mark)
- Can be used to detect integrity of wiring connections between devices
- TCCs will be noted w/ ZSI response time
- Common between MCCB and ACB







### **Enhanced GF Protection & Coordination**

**BEFORE:** Ground fault protection limited up to 300ms flat response and no ability to turn off (must swap breaker/TU)

**AFTER:** Expanded protection of ground fault increases coordination capabilities and provides ability to turn protection off

- ON/OFF feature simplifies system testing
- GF switch combines functionality of LSIG, LSIA, & OFF
- Expanded GF delays
  - Flat and I<sup>2</sup>t profiles in all GF units
  - Flat: 100ms to 1 sec / l<sup>2</sup>t: 0.67ms to 300 ms







### **Metering Accuracy**

#### **Metering Accuracy**

Trip Units meet ANSI c12.1 delivering **1.0 Accuracy Class** energy readings\*



\* from 20% to 120% of the breaker ampacity







#### Introducing Programmable Relays

**BEFORE**: Single, pre-programmed relay provided with ARMS, GFA, or High Load Alarm **AFTER**: Multiple relays that can be programmed for breaker and trip unit visibility

Programmable Relay Features				
	Indications	<ul> <li>Breaker status (ON, OFF, TRIP)</li> <li>Trip events: any trip, Long Delay, Short Delay, Instantaneous, Short Circuit, Ground Fault, Neutral, or Maintenance Mode</li> </ul>		
ø	Alarms	<ul> <li>High load, overload, ground, ground pre-alarm</li> <li>High temperature, thermal memory</li> <li>Breaker health</li> </ul>		
(:-	Communications	Open/Close breaker pulsed, Output 1, Output		
	Safety	<ul> <li>ARMS indication</li> <li>ZSI signal received, ZSI signal sent, ZSI Active</li> </ul>		
<b>/</b> *	Trip Unit Status	Low battery, internal faults, set point error, comms error		
Ð	Motor Protection	<ul><li>Available on MPCB</li><li>Phase loss, phase unbalance</li><li>Under voltage, over voltage</li></ul>		





### **Versatile Communications Options**

**BEFORE:** Modbus RTU or proprietary communications were only options for MCCB. Had to sacrifice space, technology or expense

**AFTER:** Multiple options in MCCB from 15A to 2500A and compatible with ACB electronics; imbedded option in breaker with a possibility of dual communications from a single device

- Modbus RTU: Imbedded in trip unit; standard offering
- CAM Communications: Breaker includes communications capability; protocol determined by CAM module connected; 1 CAM per Breaker

#### ECAM

 Modbus TCP and http ...and ultimately... SNTP (time sync), BACnet, ProfiNet, IEC 61850, SMTP (email protocol)

#### РСАМ

Profibus DP





ECAM

PCAM





### PC Software Breaker Testing

#### **BEFORE:**

#### Functional Test – Simulated Injection

- · PC Software sends message to the TU test driver code through USB
- Protection routines respond per the settings to trip the breaker





#### Functional Test – Secondary Injection

- Separate code in the trip unit creates a signal which is injected in parallel with the output of the Ct's mimicking the sensor's output
- Protection routines respond per the settings to trip the breaker
- Unique offering to intelligent breakers and the 'best' test method offered via a test kit

#### **Current Sensor Test**

- Separate code in the trip unit creates a signal which is directed through the CT's to verify continuity
- Unique offering to intelligent breakers and when coupled with Secondary Injection offers complete testing of the functionality of an eT/U









### Accessories

- UVRs/Shunt trips
- Aux/Alarm switches
- Rotary handles
- Plug in blocks and withdrawable cassettes





#### Accessories – Aux and Alarm Switches



#### Dedicated right pocket, snap-in accessories

- Removable secondary cover for easy install
- Shared styles between different Frames

#### **Features and Options**

- Same switch used for both Aux and Alarm positions
- Snap-in design for a secure fit
- Wire channels available for lead termination
- Available in NO, NC, and OC options
- Termination options include pigtail (3.0m or 0.75m), screw terminal, and NEW push-in-clamp





#### Accessories – Shunt Trips and UVRs



#### Dedicated left pocket, snap-in accessories

- Removable secondary cover for easy install
- Available on all the Frames

#### **Features and Options**

- New design with reduced power consumption
- Styles available in all standard voltages
- Snap-in design for a secure fit
- Wire channels available for lead termination
- Termination options include pigtail (3.0m or 0.75m), screw terminal, and NEW push-in-clamp





#### Accessories – Rotary Handle Mechanisms



#### **Close-coupled and Variable Depth Handles**

- · Easy installation with hardware
- Available on all intelligent breakers frames

#### **Features and Options**

- Standard design (Black & Grey)
- Emergency design (Red & Yellow)
- Standard handle locks
- Optional mechanism padlock
- Optional door interlock
- Optional cylinder key lock (IEC)

NFPA79 compliant handle for variable depth assemblies







### Product Configurator QR Code







### **Asset Management**

Serialized QR codes will enable an enhanced ownership experience for Market by providing a portal to product support resources, improved transactional efficiency, product tracking, authenticity verification, warranty claims processing, and more.

Scanning the QR code brings user content specific to that product through Asset Management (AM) App on iOS and Android

#### **Delivered AM Content**

- Product authentication
- Access to technical content
- Warranty registration
- Animated or video instructions

#### Near Term AM Content

Downloadable test reports



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### Wrap-up

- Customer Value Props
- Better than Before





### **Intelligent Breakers Delivers!**

**Delivering Power Distribution Solutions that Deliver Business Outcomes** 







### **Intelligent Breakers Delivers!**

### **Better than Before**

- Easily installed accessories with commonality
- Replaceable trip unit
- Modular comms & relays
- Manufacturing test report availability
- Improved product traceability
- ZSI with On/Off, testable, indication
- Common MCCB & ACB ARMS design
- USB port / secondary injection testing







# Emergence of solid state overcurrent protective devices





#### There are different architectures for solid state devices in the industry each with its advantages and disadvantages

Hybrid Circuit Breaker (HCB)



- Isolation Relay required to meet the product standard
- Either small or no arcing
- Fast interruption (e.g. ≤ 1 msec)
- Remote on/off
- · Fast by-pass relay can be expensive

Solid State Circuit Breaker (SSCB)



- Isolation Relay required to meet the product standard
- No arcing
- Fast interruption (e.g. ≤ 200 µsec)
- Remote on/off
- Higher loss in normal operating condition





### Power Electronic Breakers

Emerging technology enabling significant benefits







#### Circuit Breaker technology comparison Power electronic breaker vs Traditional breaker

	Mechanical Breaker	Power Electronic Breaker
Breaker Costs	+	Up to 10-20X today
Speed of Interruption	-	+
Power Efficiency / Losses	+	-
Remote Management	-	+
Remote Actuation (open / close)	-	+
Direct Current Interruption	-	+
Software Defined Solution	-	+





#### The Ecosystem



#### Atom Panel ™

A simple, intuitive, and intelligent distribution panel. The Atom Panel houses all of the Atom Switch circuit breakers and networks everything together. Simply plug in the Atom Switches and it works instantly.

#### Atom OS ™ Software User Interface

Control and even change the characteristics of your electrical infrastructure. Digitally open and close circuits, breakers change their time-current characteristics, rename panels, and even enable artificial intelligent decision-making for your electrical infrastructure. This all can now happen through one of the simplest apps ever developed, accessible from any device, anywhere.





#### ABB reinvents the circuit breaker

Solid State DC Circuit Breaker



Presented at the Hannover Fair, April 1-5, 2019 Breakthrough features

- Nominal current from 1000 to 5000 A
- Voltage up to 1500 VDC
- Air and water (not deionized) cooling
- Fixed and plug-in versions
- Target applications
- DC ships
- DC microgrids
- Battery storage
- Arc-safe solutions

- ...





# Thank You

## **Questions?**