Molded Case Circuit Breaker Trip Units, Types and Applications

Presented by Andrew Legro, P.E.
ABB Inc.

EasyPower
Webinar Series

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Power made easy.

Speaker Bio

Andrew Legro

Licensed professional engineer for 15 years. Over 20 years in the electrical industry including 8 years as a MEP design engineer.

Experienced in medium voltage and low voltage design and construction. Specialized in healthcare and industrial facilities. Provided electrical power system consulting and studies while working for major electrical equipment manufacturers.

Currently resides in Orlando, FL and provides application consulting for engineers throughout the state. Proficient in all ABB/GE medium and low voltage distribution products. Also proficient in system modeling and studies with EasyPower and EMTP.

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Overview

A fundamental element of all low voltage circuit breakers is the trip unit or ‘brain’ of the circuit breaker. Several different trip unit technologies are available, but which one is the best choice for my application?

This presentation provides an overview of each trip unit technology from thermal magnetic to multi-function digital. Cost versus function will be reviewed and as well as a walk-through of some example applications.

Introduction

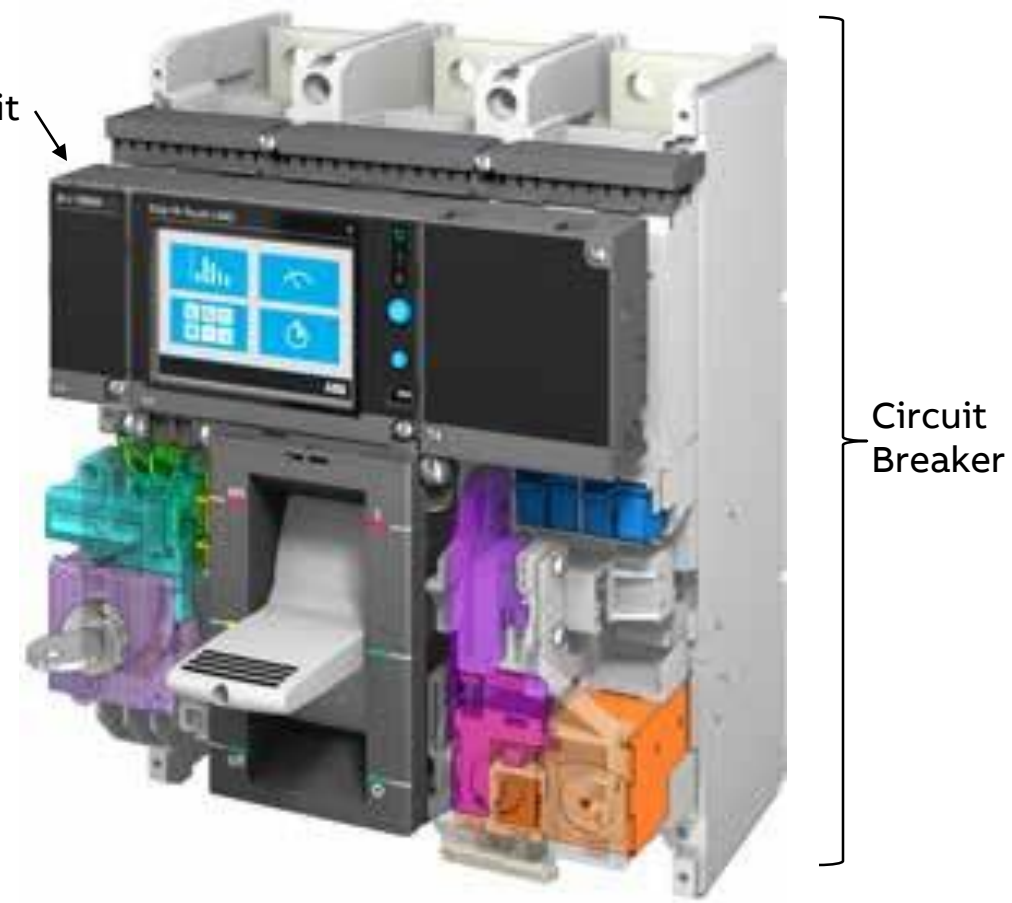
What is a trip unit?

What is a Trip Unit?

To understand the trip unit, we first need to define a circuit breaker.

A circuit breaker is an electrical switch designed to automatically detect and eliminate short circuits and overloads.

The trip unit is the “brain” of the circuit breaker. It measures physical parameters such as current and decides when to “trip” or rapidly open the circuit breaker. Trip units are built into the circuit breaker and may or may not be replaceable depending upon manufacturer / model.



What is a Trip Unit?

Types of circuit breakers that contain trip units

Molded Case (MCCB)

Panelboards & Switchboards

UL-489, 3 Cycle

15A to 1200A, 1, 2 or 3 pole

'Q' Line

Tmax XT4

Insulated Case (ICCB)

Switchboard

UL-489, 3 Cycle

800A to 4000A, 3 or 4 pole

PowerBreak II

Power Circuit Breaker (LVPCB)

Low Voltage Switchgear

UL-1066, 30 Cycle

800A to 6000A, 3 or 4 pole

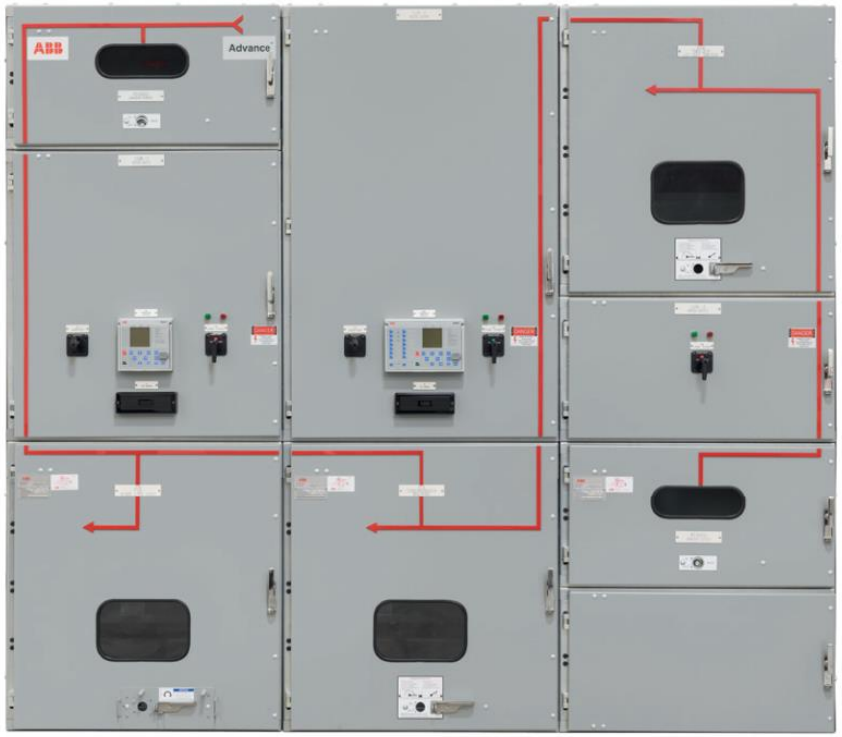
Instantaneous element optional

Emax2

What is a Trip Unit?

The term trip unit only applies to low voltage circuit breakers. Circuit breakers designed for medium and high voltage operation do not have trip units rather they use external protective relays as the “brains” of the circuit breaker.

MV circuit breakers in switchgear



Digital multifunction protective relay

Trip Unit Types

Technology Overview

Trip Unit Types

Currently technology

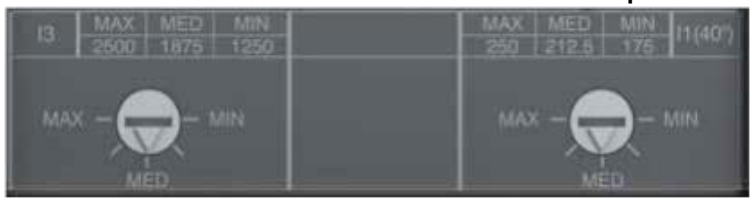
Thermal Magnetic

Most common type of trip unit in use. Uses a bi-metallic element to sense overloads and an electromagnet to sense short circuits. Available in fixed or very basic adjustable trip.

Pros:
- Low cost
- Simple to configure
- Tried & true solution

Cons:
- Very limited protection
- Low accuracy
- Ambient temperature sensitive
- Difficult to coordinate

Ekip TMA



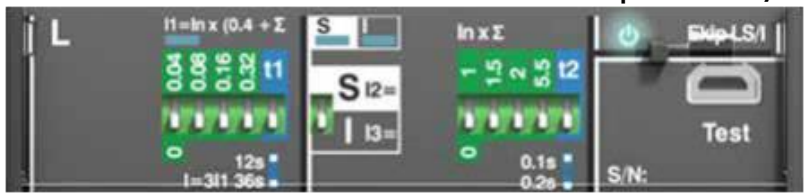
Solid State Limited Adjustability

Fully electronic and typically digital trip unit with true RMS sensing. Ground fault protection typically available. Adjustability is often limited to LI or “tracking”.

Pros:
- Enhanced protection with adjustability.
- Cost competitive
- Accurate
- Ambient insensitive

Cons:
- May not have full LSI/G adjustability
- Limited “advanced features” available

Ekip DIP LS/I



Solid State Microprocessor

Fully digital trip unit with numerous advanced protections and features available. Fully adjustable LSI/G

Pros:
- Too many to list here

Cons:
- Cost
- Complexity

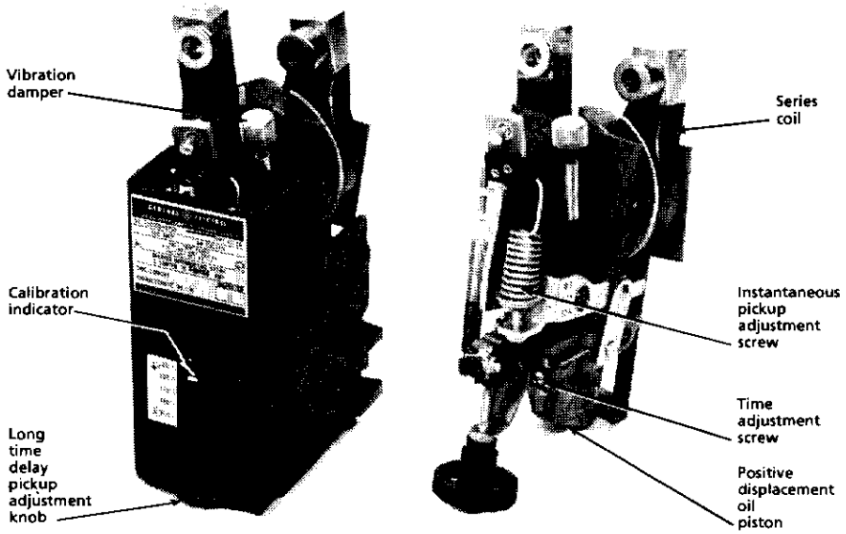
Ekip Hi-Touch

Trip Unit Types

Historical & obsolete but still a large installed base

Series Trip (A.K.A Dashpot Trip Unit)

Series trip units were the original device used in LV power circuit breakers. They were wired in series with the breaker contacts and used magnetics to actuate a piston slowed by oil “dashpot” this providing an “inverse time” trip response. Used from 1950s through 1970s and eventually replaced with solid state electronic.



GE EC-1 Trip Unit used in AKD switchgear

Electronic Peak Sensing

- The first generation of electronic trip units used analog circuitry and discrete semiconductor components such as diodes and transistors.
- Current transformers on each phase of the breaker provided both power and signal to the trip unit.
- Current was measured by the peak of the sinusoid where the peak value is equal to the RMS value * 1.41. This was acceptable for linear loads but could not measure non-linear (harmonic) loads accurately.
- Eventually replaced by “True RMS” trip units circa 1980’s through 1990’s.

Ekip DIP LS/I

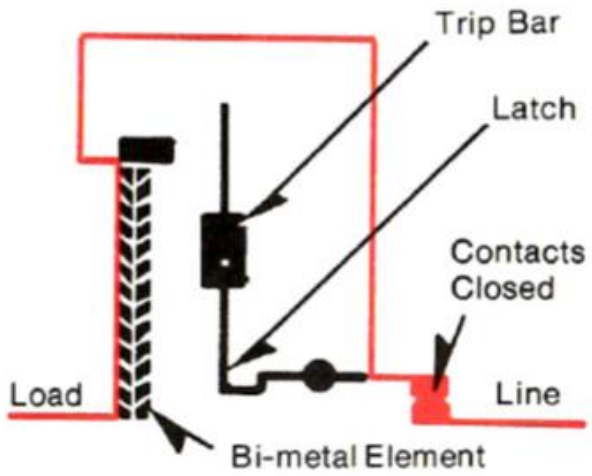
Thermal-Magnetic Trip Unit

Design and Operation

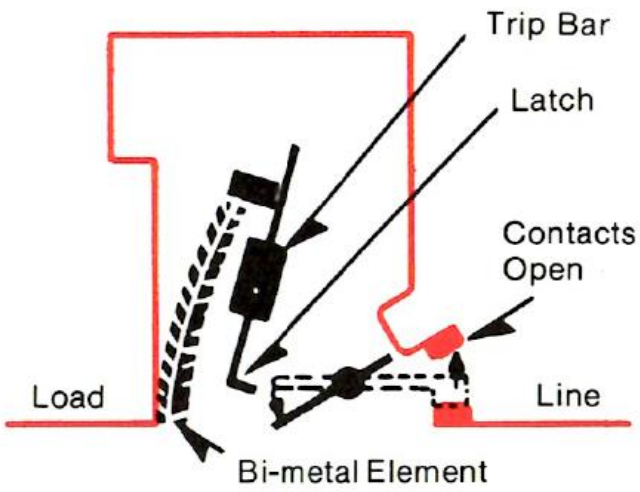
Thermal Magnetic Trip Unit – Thermal Element

Time Delayed Overload Protection

Closed



Tripped



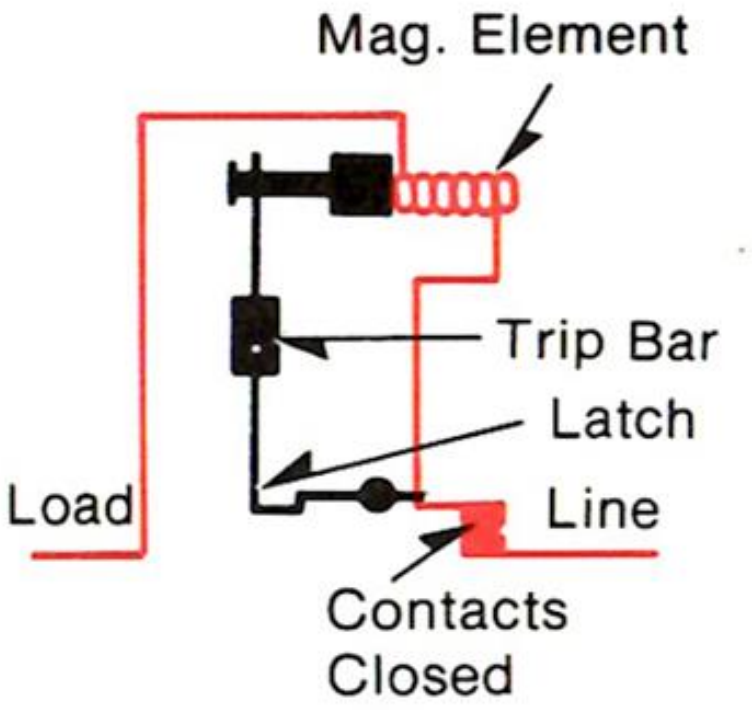
Operation

- The thermal element in a thermal magnetic trip breaker is a bi-metallic strip which bends in proportion to its temperature.
- When the temperature becomes high enough the bending strip will actuate a “trip bar” which releases the opening springs of the circuit breaker and opens the breaker contacts.

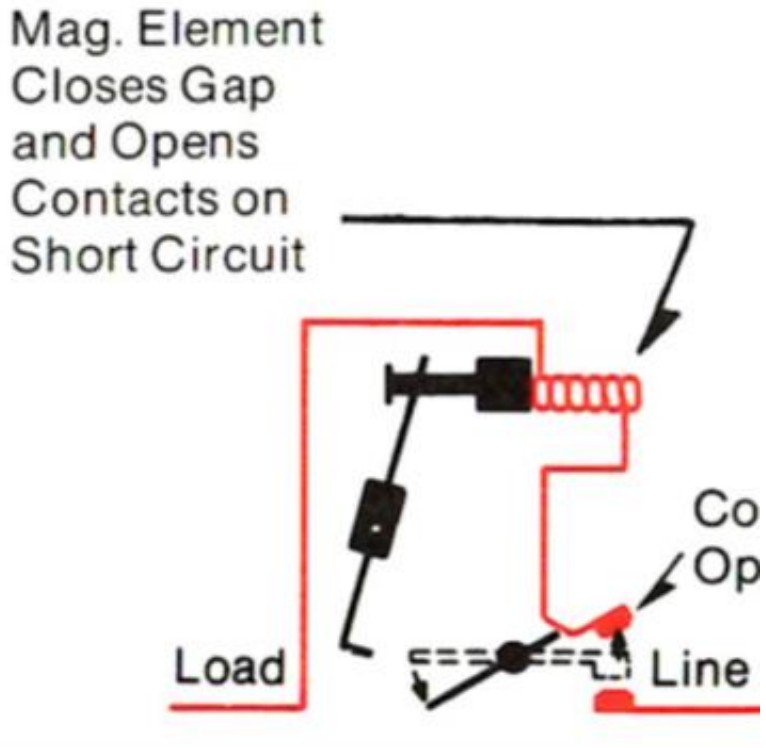
Thermal Magnetic Trip Unit – Magnetic Element

Instantaneous Short Circuit Protection

Closed



Tripped

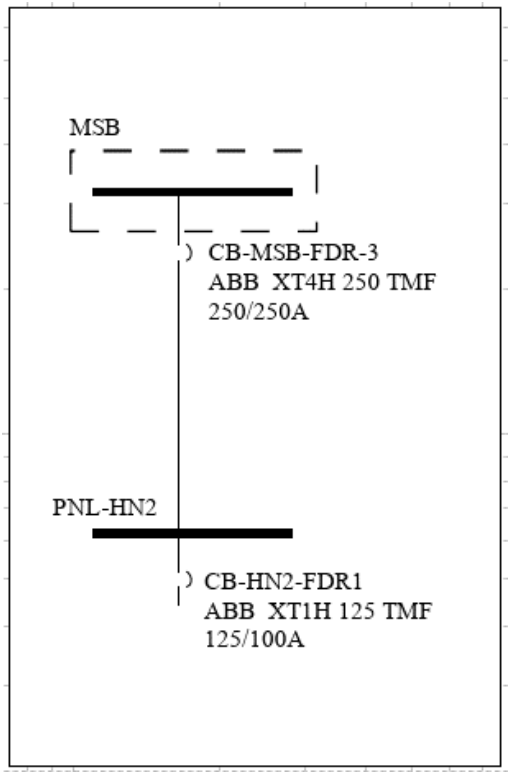


Operation

- The magnetic element of a thermal magnetic circuit breaker is a coil of wire wrapped around a plunger (solenoid).
- The magnitude of current through the coil causes the plunger to release the trip bar thus tripping the breaker. The magnetic element is an instantaneous trip element as it is not delayed and will only operate at a fixed level of current.

Thermal Magnetic Trip Unit

Time – Current Curve



XT4
250A

XT1
100A

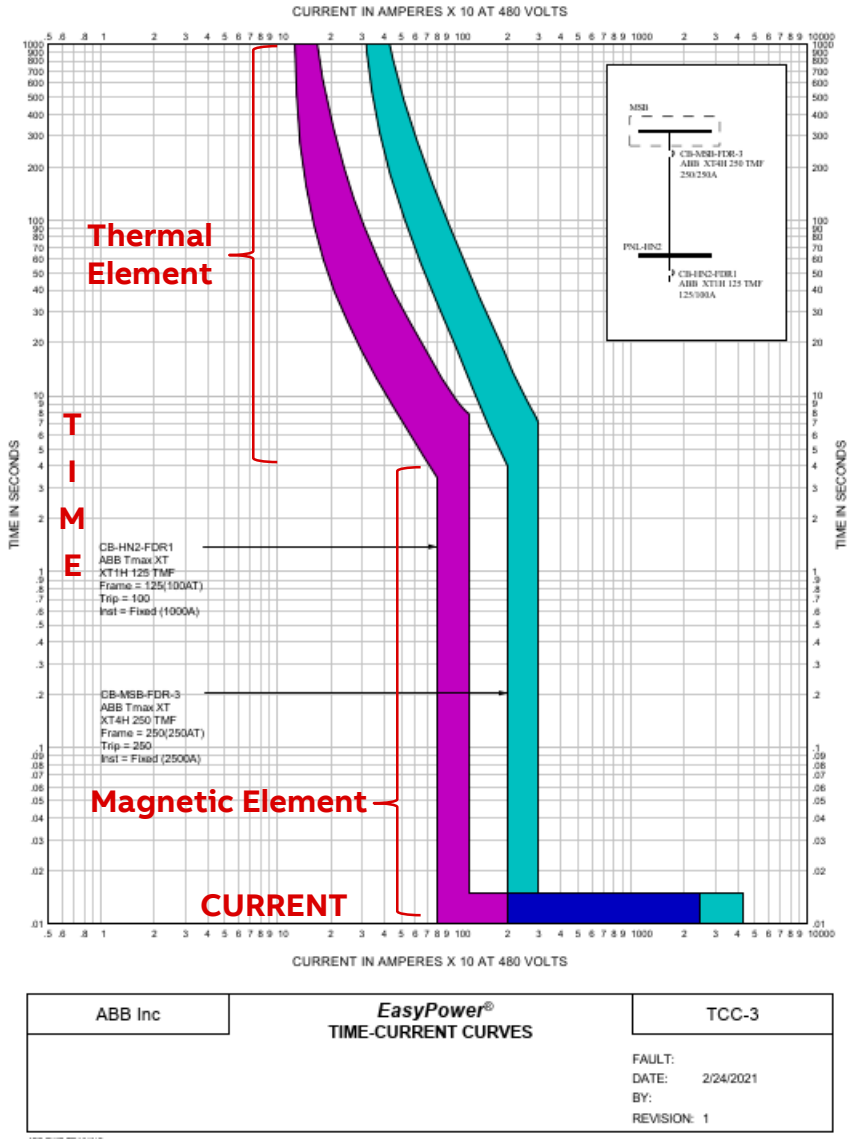


ABB Inc	*EasyPower*® TIME-CURRENT CURVES	TCC-3
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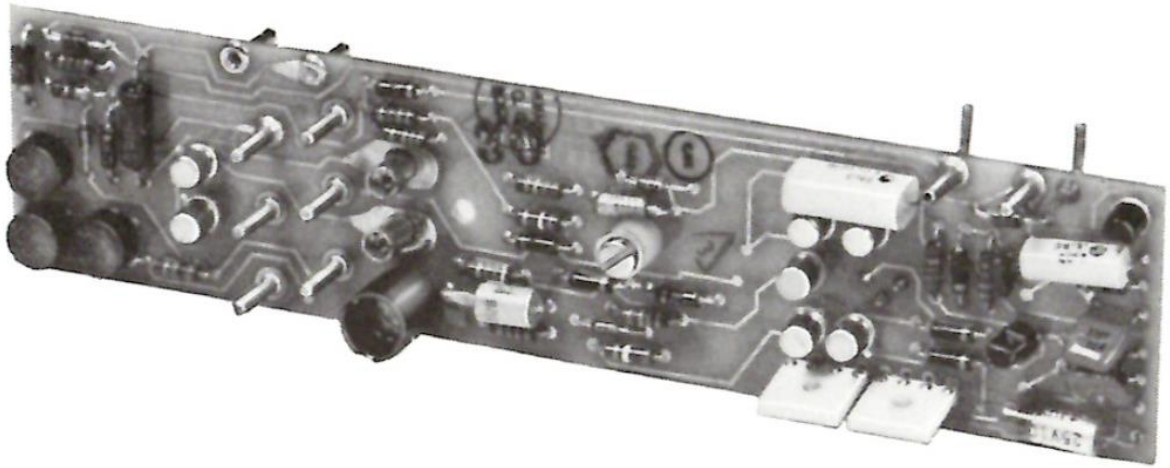
Solid-State Trip Unit

Design and Operation

Solid-State Trip Unit – Introduction

- Advances in electronics and the desire for increased accuracy, temperature stability, and advanced functions led to the development of the solid-state trip unit.
- The first solid-state trip units were analog circuits containing discrete components used to measure currents and make trip decisions. These were typically “peak sensing” units and lacked accuracy under harmonic load conditions. These analog trip units are mostly obsolete today.
- Modern solid-state trip units are digital devices using integrated circuits. These devices have improved accuracy, temperature stability, and measure true RMS values.



Typical first generation analog solid state trip unit

Solid State Trip Unit – Basic Components

Solid-State Trip

In a solid-state trip unit, the bi-metallic element is eliminated and replaced with electronic components.

Circuit Board(s) – The “brain” of the circuit breaker. Early designs used discrete analog components. Modern designs are based on integrated circuits and microprocessors.

Current Sensor – Built into the breaker, this sensor is typically an iron core current transformer. Recently, these traditional sensors have been replaced by Rogowski Coils that increase accuracy and dynamic range.

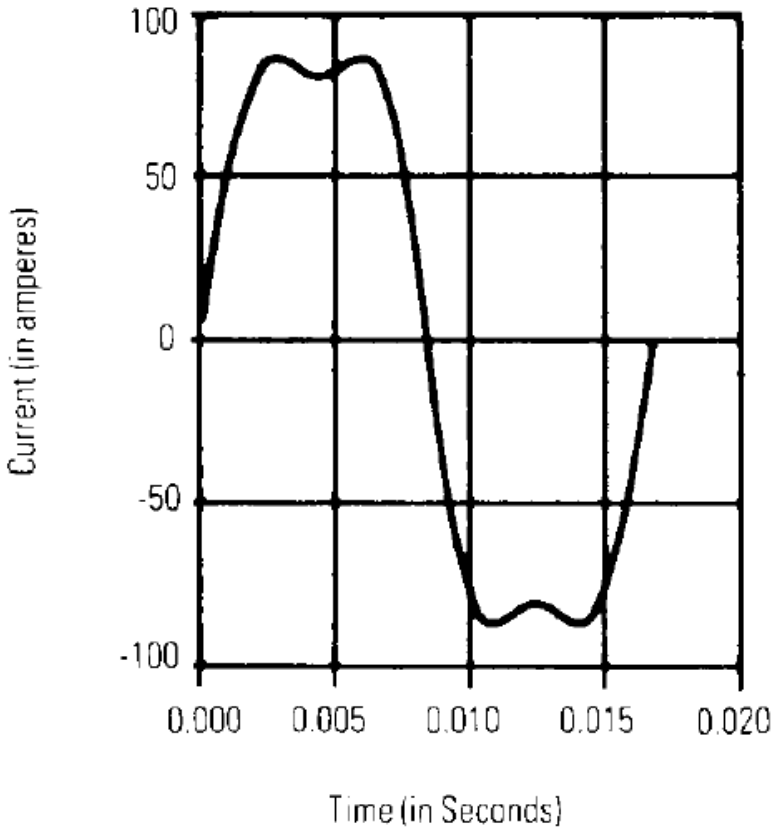
Rating Plug – Typically a component that establishes the breaker’s trip rating. Some breakers are equipped with interchangeable or adjustable rating plugs.

Setting Adjustment – Most solid-state trip units include some ability to adjust the trip response. Typical adjustment means are rotary dial, dip switch, or slider.

Solid State Trip Unit – Peak Sensing

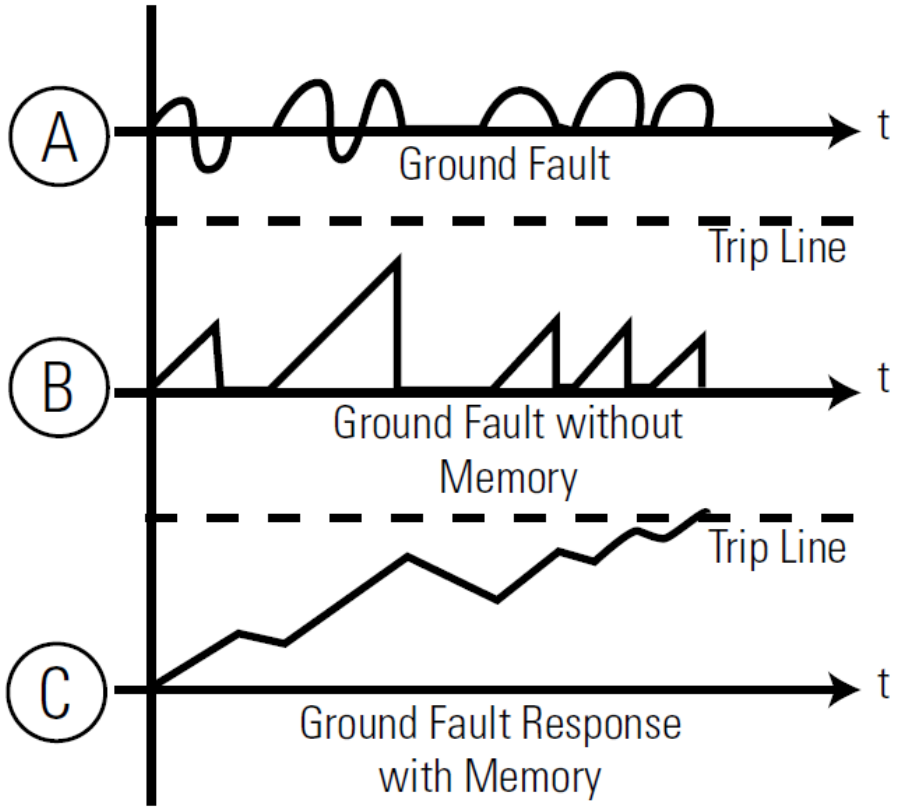
- The original solid state trip units were “peak sensing” and thus measured the load current at the peak of the sinusoid to determine the RMS value.
- Many modern electrical loads use static power converters that produce a high level of harmonic currents.
- Peak sensing may over or under protect the circuit based upon the waveform. These trip units have become largely obsolete being replaced by true RMS units.

Distorted current waveform with 20% 3rd harmonic. The peak current is 85A so the assumed RMS value is 60A. The true RMS value is 71A, a difference of more than 15%.



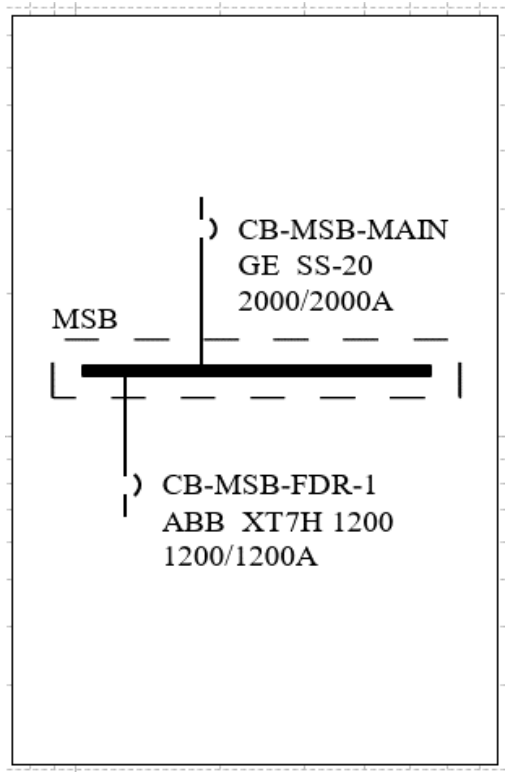
Solid State Trip Unit – Thermal Memory

- Due to the inherent nature of thermal trip elements, they “remember” the pervious over current energy due to the elements thermal time constant.
- Thermal memory allows the solid-state trip unit to replicate the performance of a thermal magnetic circuit breaker.
- UL-489 Requires that solid state trip units include a thermal memory function and that it meet a specific thermal memory retention test. UL-489 Sec 7.1.2.6.



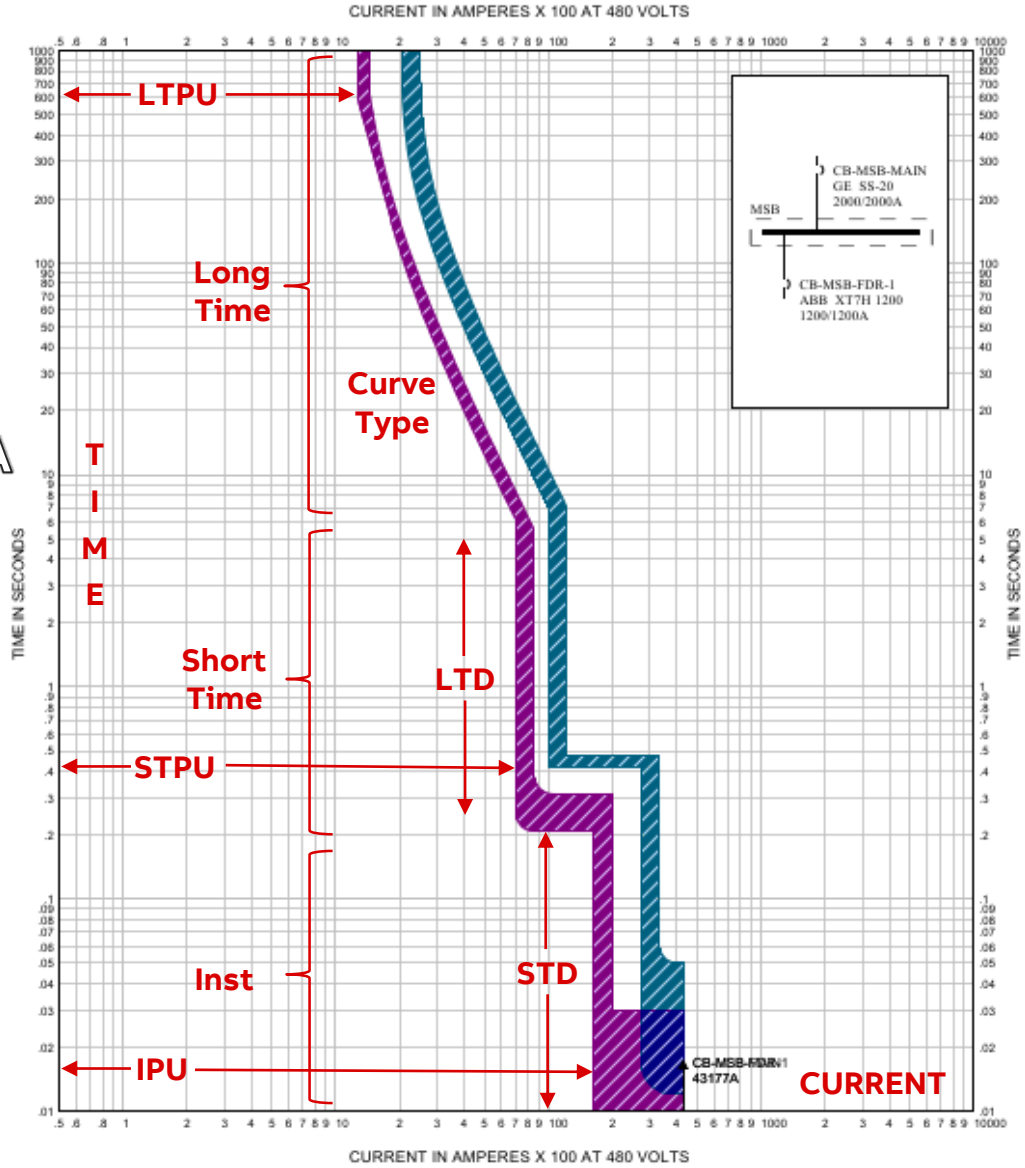
Solid State Trip Unit

Time – Current Curve



PBII
2000A

XT7
1200A



Advanced Solid-State Trip Unit

Design and Operation

Advanced Solid-State Trip Unit – Ekip Touch & Hi-Touch

Available Protective Functions

Voltage Protection

UV - Undervoltage
OV - Overvoltage
UV2 – 2nd Undervoltage
OV2 - 2nd Overvoltage
VU – Voltage Unbalance
Phase Sequence

Power Protection

RP – Rev. active power
Cos ϕ - Power factor
D – Directional Overcur.
RQ – Loss of field or reverse reactive power
OQ – Reac. overpower
OP – Active over power
UP – Active underpower
RQ – 2nd Loss of field or reverse reactive power

Frequency Protection

UF - Underfrequency
OF - Overfrequency
UF2 - 2nd Underfrequency
OF2 - 2nd Overfrequency

Adv. Voltage Protection

S(V) – Voltage controlled overcurrent
S(V) – 2nd Voltage controlled overcurrent
RV- Residual Voltage

ROCOF Protection

ROCOF – Rate of charge of frequency

Adaptive Protection

Set A-B – Dual Setting (Maintenance Mode)
Zone selectivity on: S, G, G-external
Directional zone selectivity

Advanced Solid-State Trip Unit – Ekip Touch & Hi-Touch

Relay and PLC functionality in a molded case breaker

Interface Protection

In order to check the Main Grid conditions and disconnect the User's plant whenever grid voltage and frequency are out of the ranges prescribed by the connection local standard

Load shedding

The embedded algorithm that is able to manage power system for the comprehensive micro grid energy management

ATS function

This unique integrated solution avoids the usage of other external control units, reducing equipment footprint, the number of connections and commissioning time.

Synchro reclosing

Logic that synchronizes the plant voltage and frequency to reconnect it. Making sure only to reconnect to power once it meets criteria prescribed and is in sync.

Power Controller

Algorithm to shave peaks and shift loads in order to optimize system performance and productivity

Touch Trip Unit

Measurement Capabilities

Measures

All the electrical parameters at your disposal without any additional components

Current, Voltage, Phase sequence, Frequency, Power factor, Peak factor, Power, Energy

Accuracy

Class 1 Accuracy

Current 0.5%, Voltage 0.5%, Power 1%, Energy 1%

Availability

Data available at any time

Instantaneous values

Historical measurement

Ekip Multimeter

The most precise molded case circuit breaker trip unit ever

Connectivity

Leading Edge Communications & Control

Local connection

Easy protection setting and information access

- Laptop connected with USB port
- Trip unit embedded Bluetooth (optional)
- Ekip Multimeter and Control Panel connectivity

Remote communication

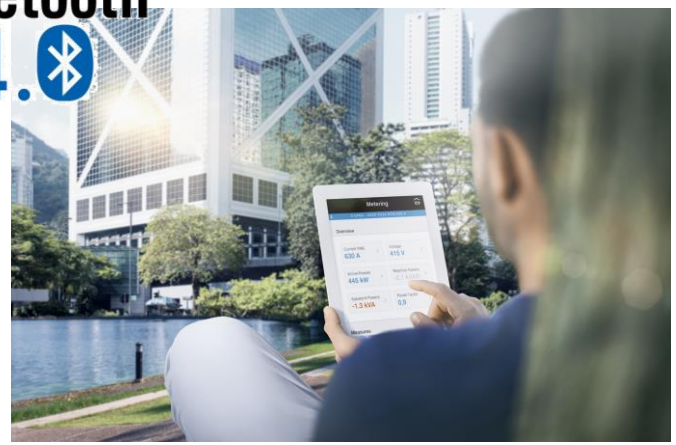
Connect Tmax XT to whatever supervision system

- 8 communication protocols
- The same maps for all the products makes communication easy

Cloud connectivity

Exploit the full service of ABB Ability™ EDCS platform

Ekip Com HUB gets Tmax XT Cloud connected



Protocols
Modbus RTU
Modbus TCP
Profibus-DP
Profinet
Ethernet / IP
DeviceNet
IEC 61850

Monitoring and control at any time from wherever you like

Functions Upgrade

Several downloadable firmware packages

- Available in all the Ekip Touch trip units
- Upgrade via Smartphone/Tablet over Bluetooth
- Upgrade via PC and USB
- Allow facilities to be “future ready” in the event of changes in the future
- Allows customization of functions to suit a particular customer’s needs

Application Summary

Best practices for choosing trip unit technology

Application Summary

Thermal-Magnetic

- Good overcurrent protection for branch circuits, panels, cables & LV transformers.
- High reliability
- Low cost
- Available in nearly all equipment
- Low accuracy
- Ambient sensitive
- Zero or limited adjustability
- Limited selective coordination. Min 3 to 1 selectivity ratio for 0.1 second (NEC 517) coordination.
- Almost no ability for full selective coordination unless current limiting.

Solid-State

- Enhanced overcurrent protection for critical loads and equipment.
- Ground fault (but not GFCI)
- High reliability
- Medium cost but can be competitive with thermal-magnetic in larger sizes.
- Not ambient sensitive
- Limited adjustable, full LSI, partial LI or “tracking”. Standard I2T curve.
- Good selectivity 2 to 1 or better
- Almost no ability for full selective coordination unless current limiting.

Advanced Solid-State

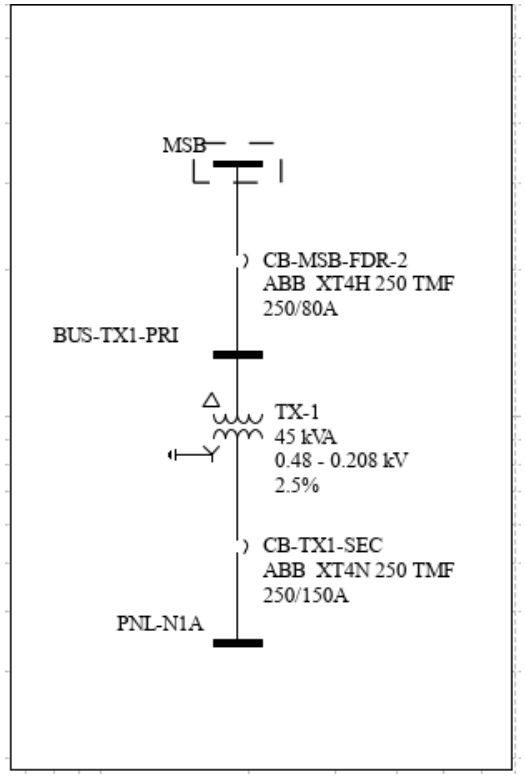
- Excellent comprehensive protection for critical loads and equipment.
- Multiple overcurrent curves available to match other protective devices.
- Many additional protection elements available for current, voltage, power, frequency.
- Arc flash protection available (various methods)
- Metering (accuracy varies)
- Network communications
- Built in logic for automation
- Full selective coordination using functions like zone selective interlocking.

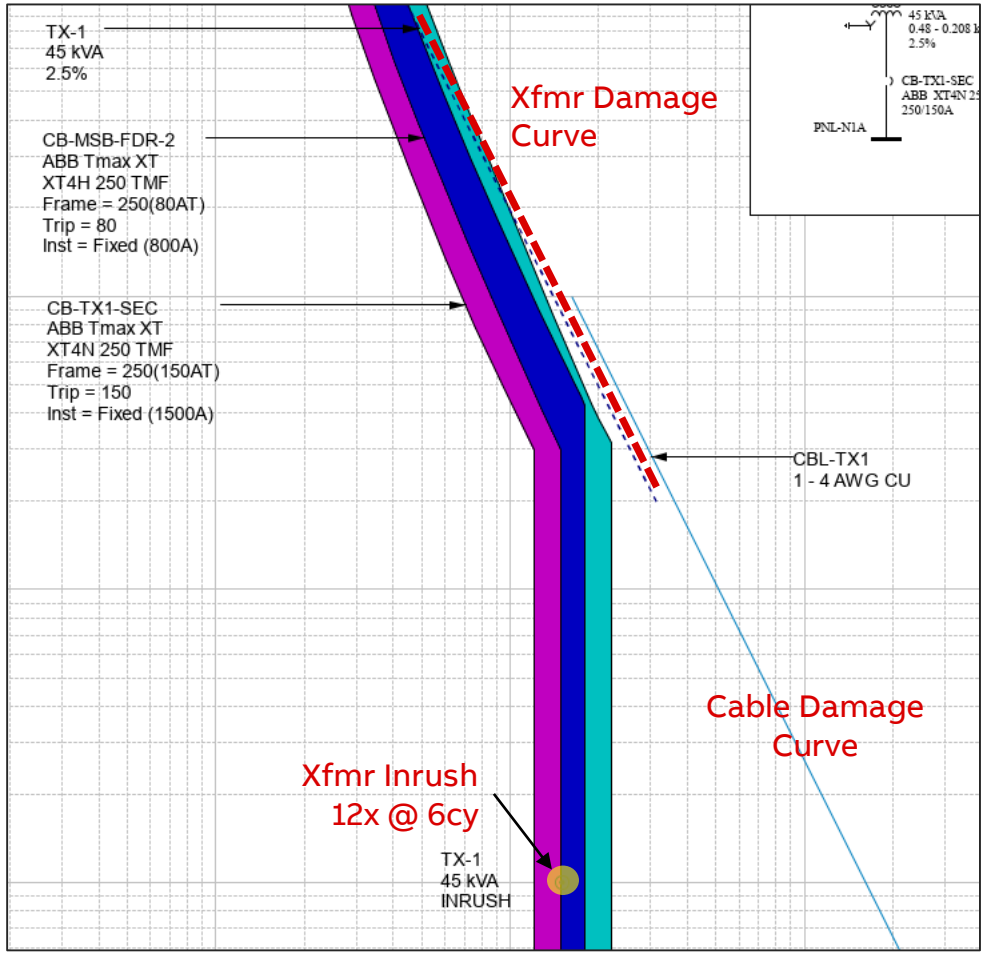
Application Examples

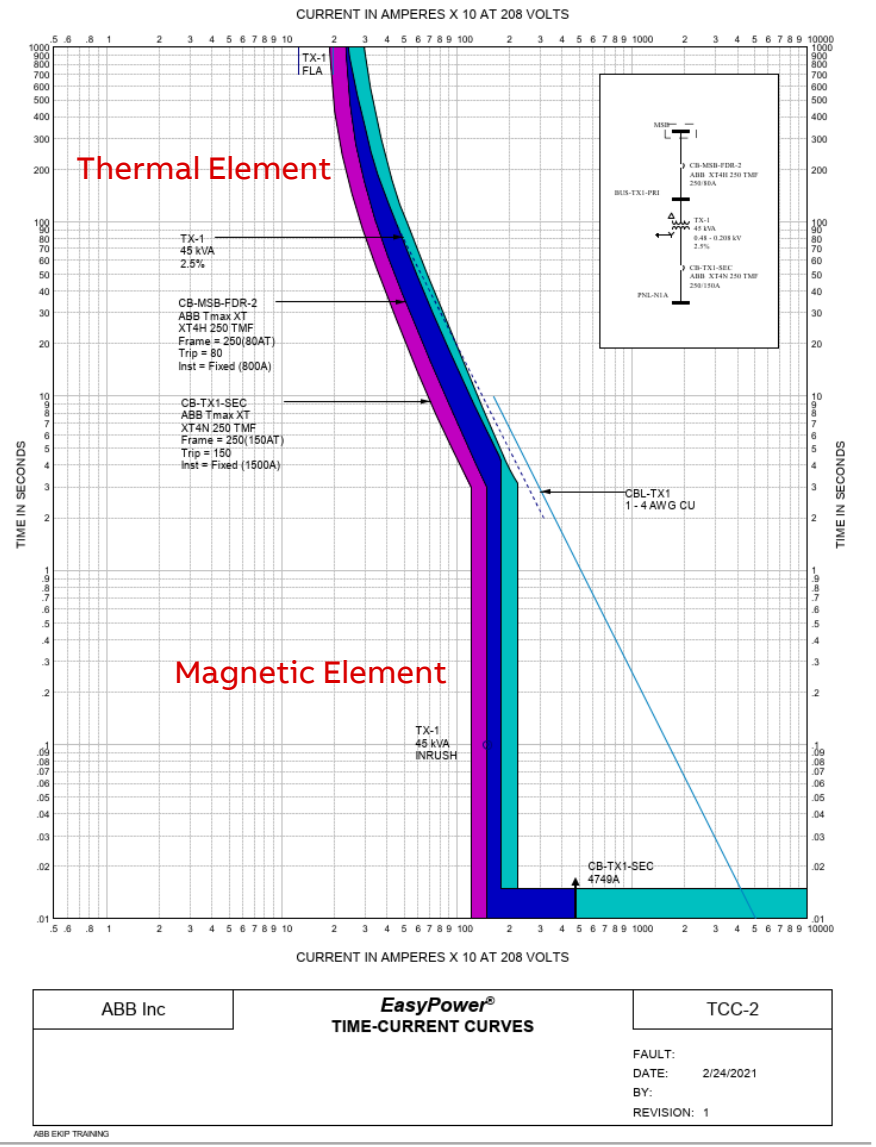
Real World Stuff

Thermal Magnetic Trip Unit

Basic protection for cables and transformers

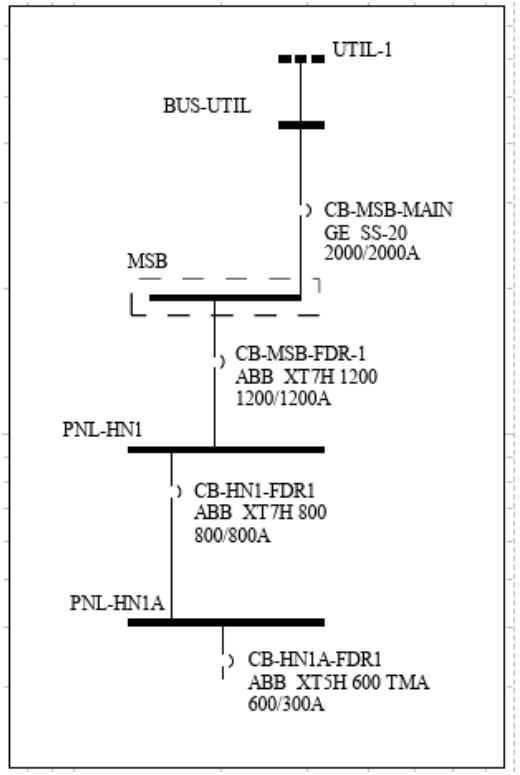


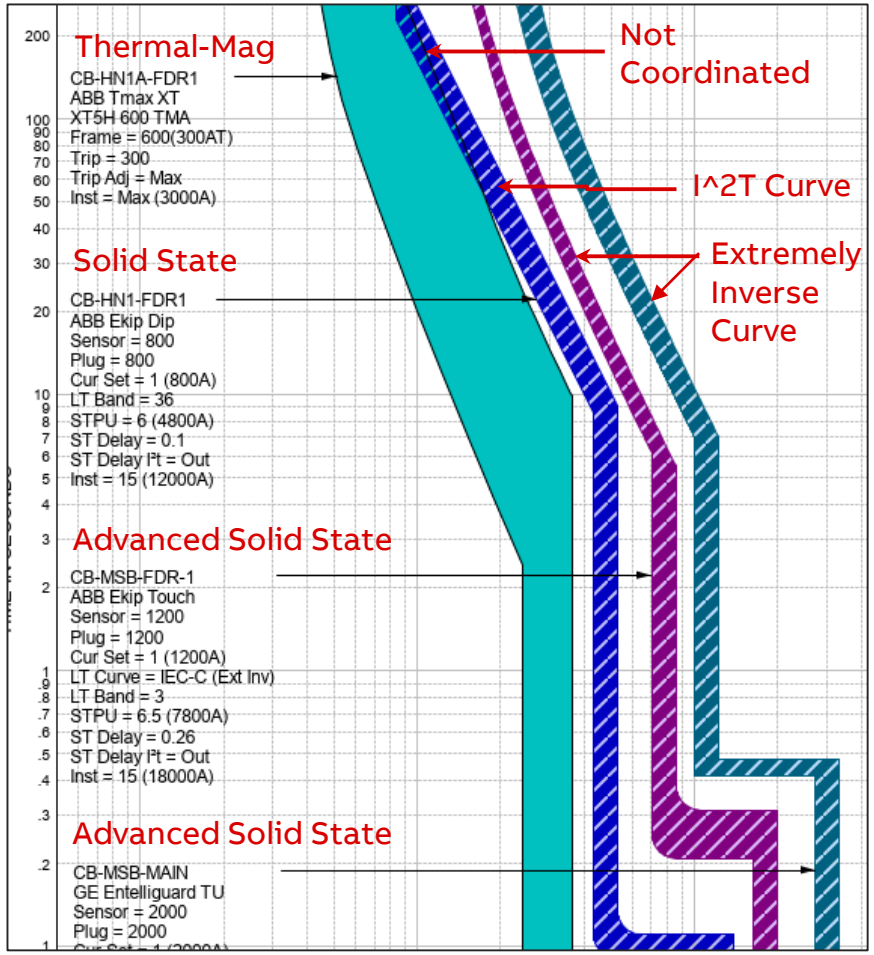


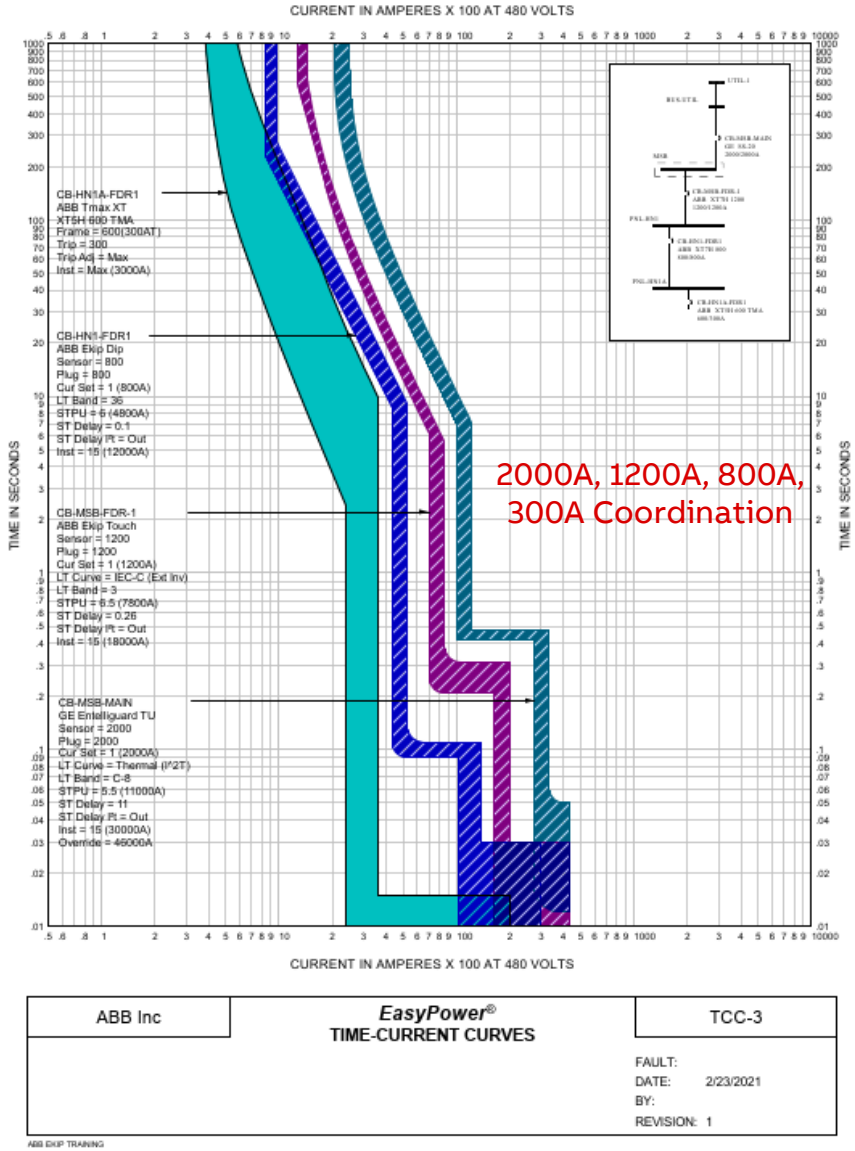


Solid State Trip Unit

Enhanced selectivity







Tmax XT – Next Generation UL489 MCCB

UL 489 Molded Case Circuit Breaker 125A to 1200A Frame

Thermal Magnetic to Advanced Microprocessor Protection

Tmax XT

A groundbreaking new molded case circuit breaker

The new product range

An MCCB family up to 600V, 1200A UL 489

- That ensures extreme performance and protection features, while maintaining cost effectiveness for customers
- Designed to maximize ease of use, integration and connectivity
- Built to deliver safety, reliability and quality
- Conceived to deliver value through the entire customer journey – with upgradeability in the field.

Tmax XT

AC Specifications

	XT1	XT2	XT4	XT5	XT6	XT7
Frame (A)	125	125	250	400/600	800	800/1000/1200
Min Trip (A)	15	15 TM 10 LSI	25 TM 40 LSI	300 TM 250 LSI	600	600
Poles	3,4	3,4	3,4	3,4	3,4	3,4
Max Voltage (V)	600/347	600V	600	600	600	600
Interrupting (kA @ 480V)	25/35/65	25/35/65 100/150 200	25/35/65 100/150 200	35/50/65 100/150 200	35/50/65	50/65 100
Mounting	Bolted/ Plug In	Fixed Plug In Drawout	Fixed Plug In Drawout	Fixed Plug In Drawout	Fixed Drawout	Fixed Drawout
Thermal Mag	■	■	■	■	■	
Electronic – DIP & Touch		■	■	■	DIP Only	■

Tmax XT Trip Unit Options

Standard Protection

Advanced Protection

Connectivity & Communication

Measurements

Embedded Advanced Functions

Online Upragradability

Thermal-magnetic

Ekip Dip LSI/G

Ekip Touch/Hi-Touch

Thank You

Questions?

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