APPLICATION NOTE

Power and Control Applications for Thermal Management Systems

Battery Energy Storage Systems (BESS)

Enhance the performance of your thermal management system with our control and power protection solutions. A complete product offering from a reliable supplier for safely starting and protecting thermal management systems in battery energy storage systems.

What is a Thermal Management System?
A thermal management system (TMS) allows for safe and efficient battery performance through temperature regulation. The system controls the operating temperature of a battery by dissipating heat when the battery is too hot or supplying heat when the battery becomes too cold. This functionality is critical as high temperatures can reduce battery life and cause safety hazards, such as fires, while low temperatures can decrease battery capacity and charging/discharging capabilities. Thermal management systems function through active, passive, or hybrid heat transfer solutions that preserve the battery to mitigate costs and optimize energy storage.

Why do you need Control and Power Protection for your Thermal Management System?
Continuous operation of the thermal management system is critical to ensuring a safe operating temperature for the battery energy storage system. ABB's control and power protection products help to reduce downtime and support continuity of service in any condition.

Main benefits

Continuous operation
Keep your thermal management system up and running in any condition thanks to reliable connections, reliable power, and a reliable partner.

Compact and easy to install
Save space in the control panel with our AF contactors and reduced-width electronic compact starters. Save time during the installation phase using our readymade starter connection kits to make compact and safe connections.

Safety and protection
Reduce the chance of a fire in your system and loss of valuable assets by using a complete range of surge protection devices (SPDs) to protect the entire electrical system from lightning and surges.

Energy-efficiency
Increase the energy efficiency of your TMS panel by incorporating AF contactor technology. This technology reduces contactor coil consumption, minimizes heat dissipation, lowers temperature rise, and enables higher installation density within the panel.

Battery Energy Storage Systems (BESS)

BESS overview

The battery energy storage system (BESS) market is forecasted to become a megatrend in upcoming years as there is a shifting focus towards decarbonization, decentralization, and digitalization. Fueled by federal incentives such as the Inflation Reduction Act (IRA) and lower overall costs, BESS are becoming more imperative for reliable, clean energy. These systems source and store energy for various applications such as peak shaving, transmission and distribution congestion relief, and energy arbitrage. As more dependence is placed on BESS, it is critical to optimize battery performance and durability through thermal stability.

Thermal Management Systems (TMS)

Temperature is one of the key factors that affect battery performance. The ambient temperature and heat generated during the battery's operation collectively impact the overall temperature of the battery energy storage system (BESS). Effective thermal management is essential to ensure the safe and efficient operation of the BESS.

This includes controlling and maintaining the temperature of the batteries and associated electrical components within a specified range. For lithium-ion batteries, the primary battery type used in BESS, optimal performance is achieved within the temperature range of 15 °C to 35 °C[1]. Proper thermal management not only helps to prevent safety hazards but also prolongs the lifespan of the batteries and enhances overall performance.

Safety
One of the primary safety considerations for battery energy storage systems is the prevention of fires and explosions. Uncontrolled heat generation within the battery cells can trigger a chain reaction known as thermal runaway. This occurrence begins when the heat produced within a battery exceeds its capacity to dissipate heat. Subsequently, a repetitive chemical reaction ensues. This reaction is fueled by the escalating temperature, ultimately leading to the potential occurrence of a fire or an explosion.

Performance and efficiency
Batteries utilize chemical reactions to convert stored chemical energy into electrical energy. The efficiency of these reactions is dependent on temperature. Exposure to both extremely high and low temperatures can significantly impact battery performance. Higher temperatures accelerate the chemical reactions within a battery, leading to increased electrical energy production. On the other hand, lower temperatures slow down these reactions, leading to a decrease in electrical energy production. In colder temperatures, the internal resistance of the battery rises, impeding the flow of current and consequently reducing the amount of energy that the battery can release.

Lifespan
While higher temperatures enhance battery capacity and performance, there is a trade-off. Exposure to extreme heat accelerates the degradation of the battery's components, leading to a reduced lifespan. Temperature uniformity among the battery packs and modules is also imperative to prolong the life of the battery. An uneven temperature distribution leads to a reduction in cycle life and performance. Proper thermal management is essential to maximize the longevity of the battery, ensuring a balance between improved performance and sustained durability.

Battery performance over temperature range

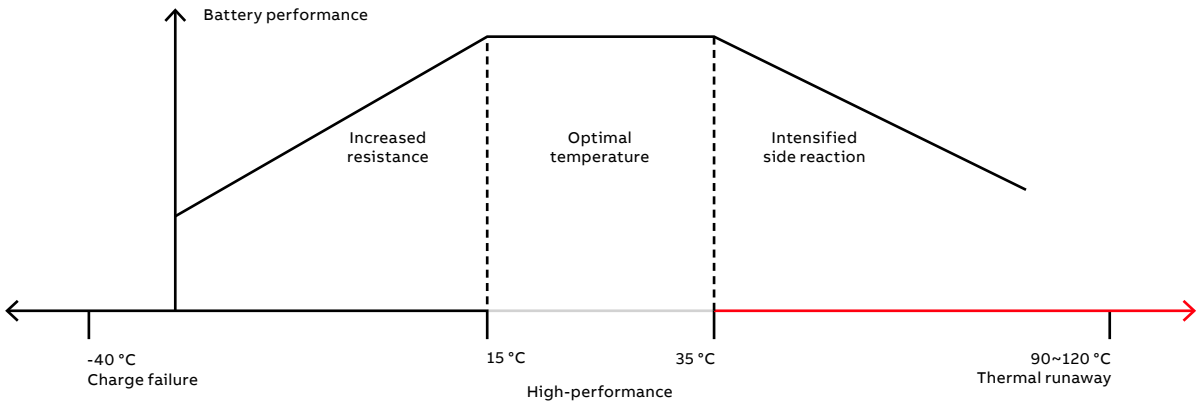


Fig. 1: Optimal temperature range for lithium-ion batteries [1]

Thermal Management Systems in BESS

Thermal management systems are categorized as active, passive, or hybrid. Active systems employ external devices such as fans, pumps, or compressors to control or disperse heat from the batteries. Alternatively, passive thermal management does not require additional energy input for heat dissipation. Instead, it relies on natural methods such as radiation and conduction for heat transfer. Hybrid systems integrate aspects of both active and passive methods to maintain an optimal temperature. Examples of active thermal management include forced air and liquid cooling, while phase change materials (PCMs) and heat pipes are examples of passive techniques.

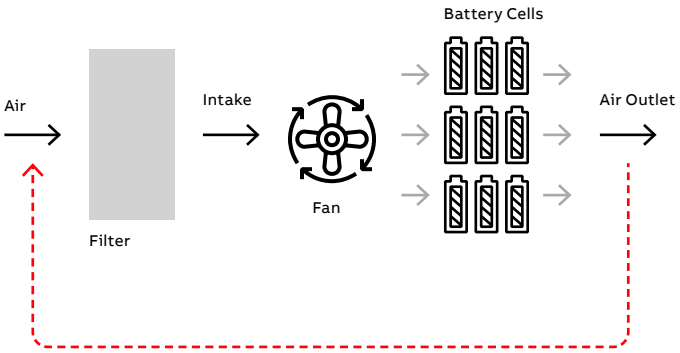
Active air and liquid cooling are the primary thermal management methods utilized in BESS[2]. Phase change materials and heat pipe cooling are still in the R&D stages for BESS.

Forced air cooling uses fans or blowers to generate airflow, facilitating the dissipation of heat from the BESS enclosure and battery's components. Its main advantages are its simple design, low cost, and ease of maintenance. However, its primary disadvantage is that it transfers heat less efficiently in comparison to alternative cooling methods due to its low heat capacity and small thermal conductivity[3].

Liquid cooling uses a liquid coolant such as water or ethylene glycol to absorb heat and consequently lower the temperature of the batteries. Pumps or other mechanical devices move the liquid coolant through tubes or channels that are in contact with the battery's cells. The heat is then removed from the coolant via equipment such as a heat exchanger or radiator. Liquid cooling boosts better efficiency, enhanced heat transfer, and uniform temperature distribution. Complexity and cost are its key disadvantages.

Cooling load, environmental conditions, cost constraints, and scalability requirements are factors to consider when choosing the optimal system.

Air cooling



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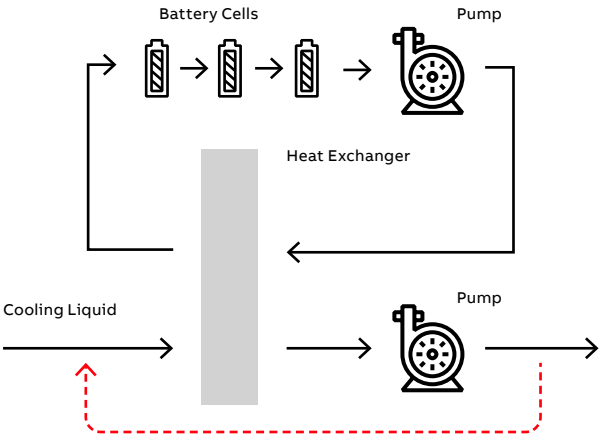
Basic schematic of an air-cooling system

Liquid cooling



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Basic schematic of a liquid cooling system

Thermal Management Systems in BESS
Core mechanical components for BESS thermal management systems

Different types of air and liquid-based thermal management systems are available. Each system comes with its own set of advantages, and the choice is typically based on meeting the specific requirements of the energy storage system. Key components in these systems require a motor for operation including compressors, fans, and pumps.

Compressors
An integral part of air-cooling systems, the compressor plays a vital role in circulating liquid refrigerant. Its function involves compressing the refrigerant, enabling it to extract heat from the air.

Fans
Employed in both air and liquid cooling setups, fans contribute to air circulation within the battery energy storage system. This enhances the heat exchange process, promoting more effective thermal management.

Pumps
A critical component in liquid cooling systems, pumps are responsible for circulating the coolant throughout the system. Their role is to ensure a continuous flow of coolant across components that require cooling, facilitating efficient temperature regulation.

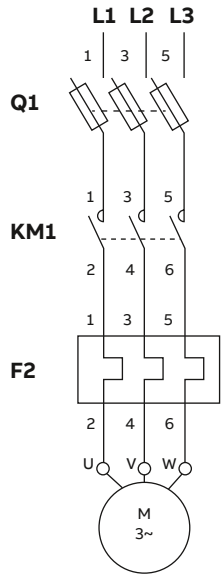
Thermal Management Systems in BESS
Recommended starter for compressor, fan, and pump control

ABB's scalable motor starting solutions provide complete flexibility in choosing the right starter for full-speed motor control.

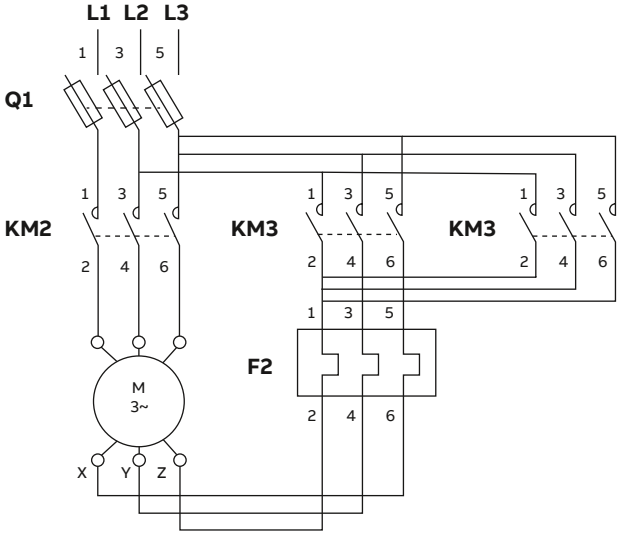
The three most common starter types are Direct-on-line (DOL), Star-Delta (Wye-Delta), and Softstarter. Each starter type has its own unique advantages such as:

1. DOL is the simplest and most common motor starter type, it offers the fewest number of components and has a low cost.
2. Star-Delta (Wye-Delta) is a slightly more complex starter type but starts the motor with less shock (torque) to the system and has a lower starting current.
3. A softstarter is a more advanced starting solution and gives a controlled start with a programmable ramp up or ramp down of the motor.

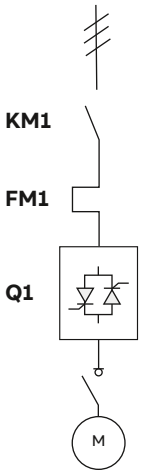
1 Direct-on-line starter



2 Star-Delta starter



3 Softstarter starter



Thermal Management Systems in BESS
Design data requirements for compressors, fans, and pumps

Primary requirements

- Short-circuit protection
- Overload protection (with the adjustable current setting)
- Voltage level monitoring
- Phase loss & phase sequence – for correct management of motor operation
- Ground fault protection

Optional requirements

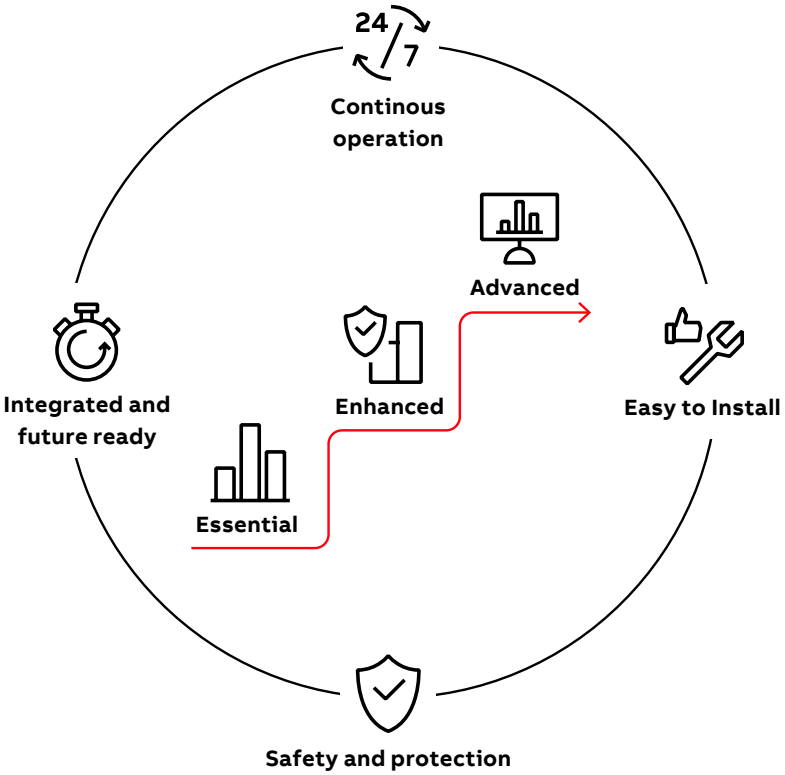
- Thermistor protection relay for monitoring winding temperature
- Digital connectivity (control, energy measurements, etc.)
- Locked rotor protection – in the case of a jammed motor
- Safety relays (if required, based on design)
- Temperature monitoring relay (if required, based on design)

Starter panel design parameters

- Motor rated voltage
- Motor rated current
- Maximum operating current
- Number of switching cycles (ON/OFF)
- Starting torque depending on motor load
- Acceleration time (starting time)
- Control voltage
- Ambient temperature
- Altitude
- Enclosure type
- Starter type
- Operations – auto/manual & local/remote
- Digital connectivity (control/monitor)

Power and Control Applications for Thermal Management Systems in Battery Energy Storage Solutions

Discover our Power and Control solutions designed for thermal management systems. These solutions help to maintain optimal temperatures for BESS, ensuring efficient and reliable performance.



Solution level	Basic protection functions	Monitoring of additional protection functions	Digital connectivity and cloud monitoring
Essential	●		
Enhanced	●	●	
Advanced	●	●	●

This table provides an overview of the possible functions in our different solution offerings for thermal management systems in BESS.

Essential Solution

Get the essentials right with fast and reliable installations
The Essential Solution helps to ensure that combinations of core power devices function in a coordinated way, thereby enabling continuous operation and ease of installation. In addition, the Essential Solution typically covers the requirements of stand-alone machinery like fans, pumps, compressors, etc.

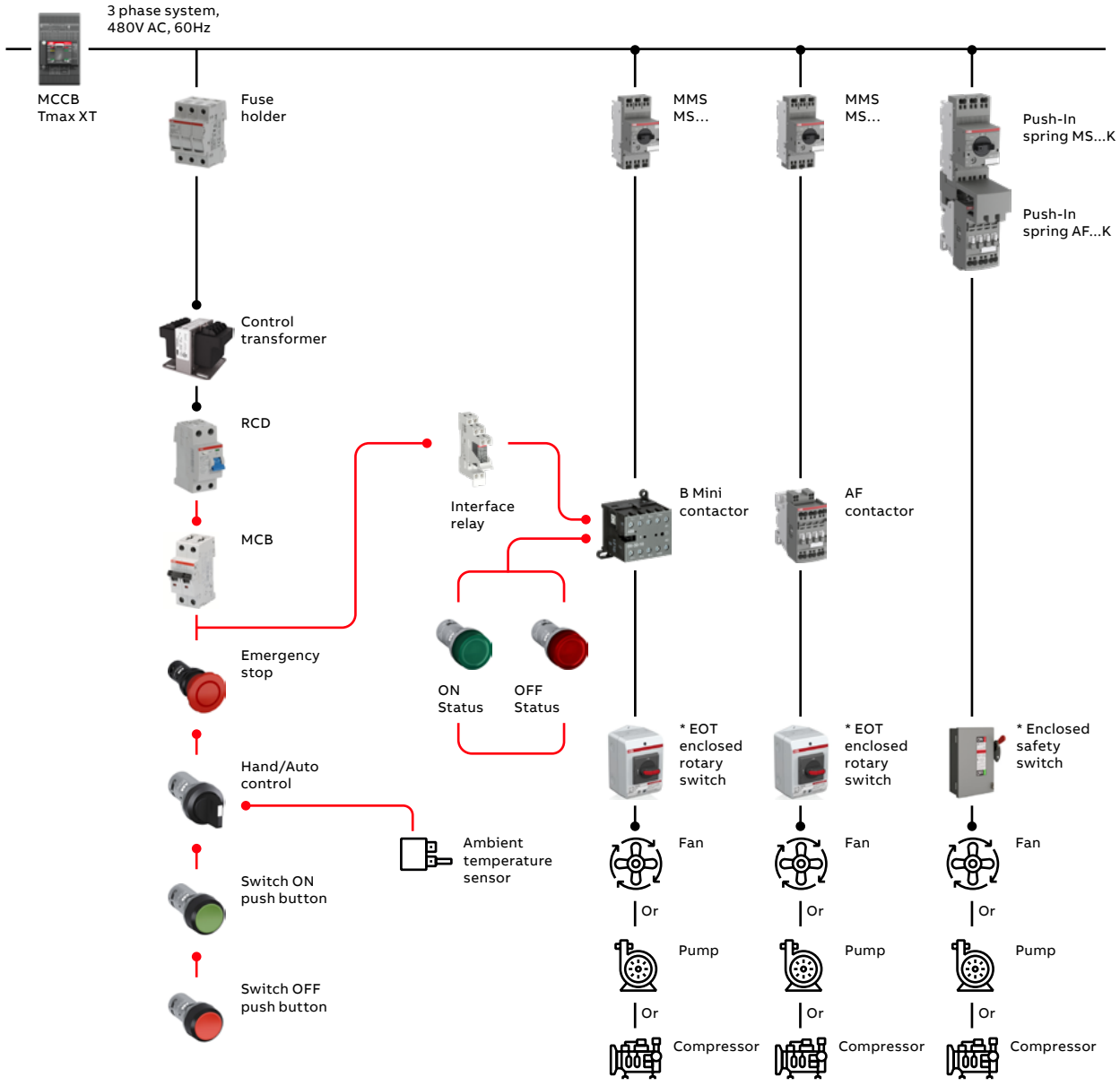
Enhanced Solution

Get going with our robust protection offering featuring enhanced safety, control and monitoring functions
The Enhanced Solution provides enhanced control, safety and monitoring functions for applications in the discrete automation field. The Enhanced Solution for thermal management systems in battery energy storage systems includes additional protection functions such as temperature monitoring, voltage monitoring relay, safety relays, and more. We can address any other requirements to suit end-user requests.

Advanced Solution

Get ahead with smart data and predictive applications to keep your thermal management system running
The Advanced Solution for thermal management systems includes integrated and future-ready motor protection, flexible motor control, fault diagnostics, maintenance schedules, and supports all major communication protocols.

ABB’s Essential Solution



The table below provides an overview of the difference between the combination of products offered in the Essential Solution for thermal management systems in battery energy storage systems.

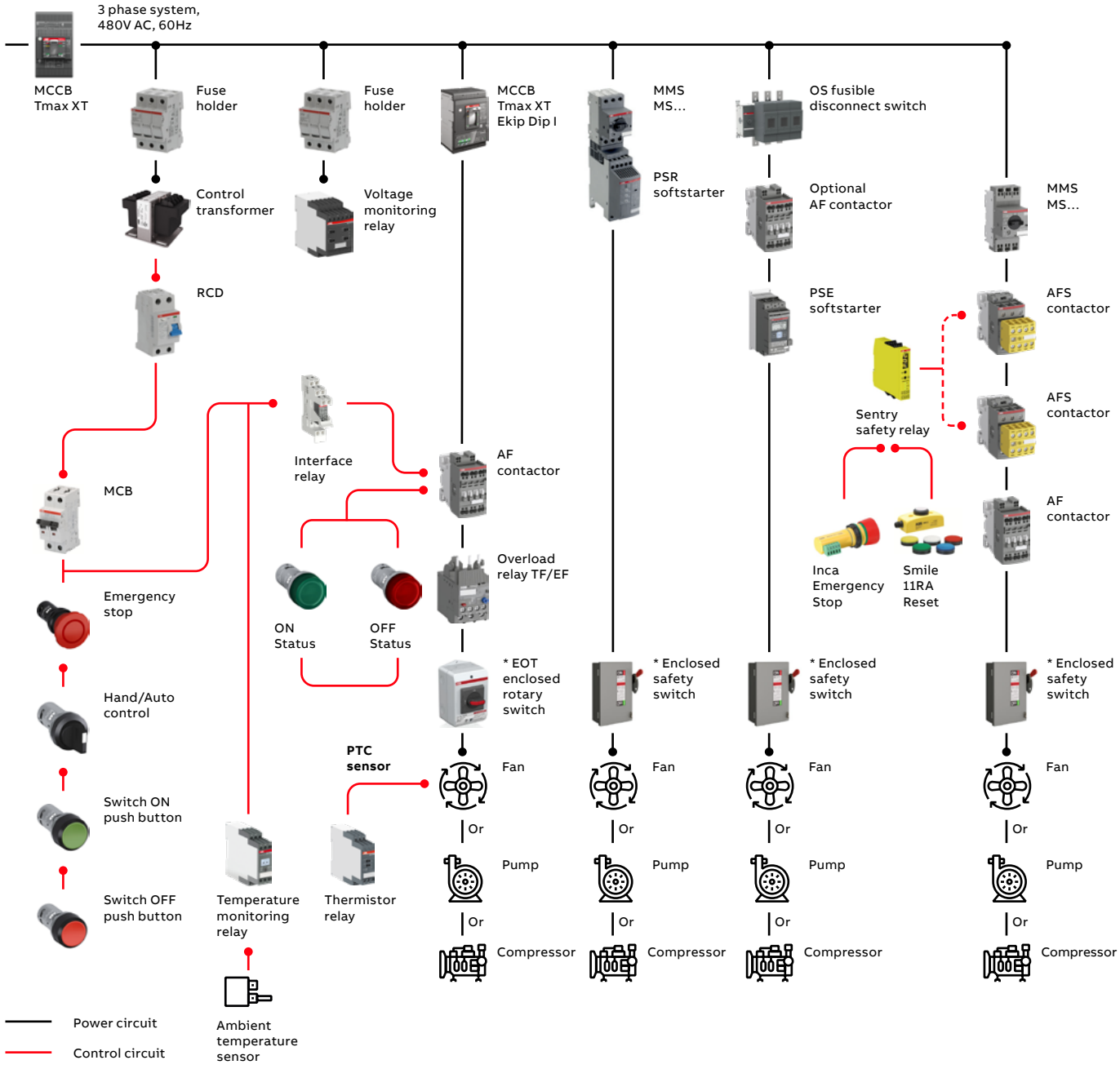
Product combination	Key Differentiator
B Mini contactor	For efficiency and space savings
Contactor + MMS (Screw version)	For standard offerings
Contactor + MMS (Push-In Spring)	For reliable connections, faster/easier wiring, and vibration protection

Notes:
MMS – manual motor starter

* The enclosed safety switch will be close to the motor in case it needs maintenance to isolate the power supply and help to ensure safety for a person working close to the motor.

The type of enclosed switch used depends on the application and environment.

ABB’s Enhanced Solution



The table below provides an overview of the difference between the combination of products offered in the Enhanced Solution for thermal management systems in battery energy storage systems.

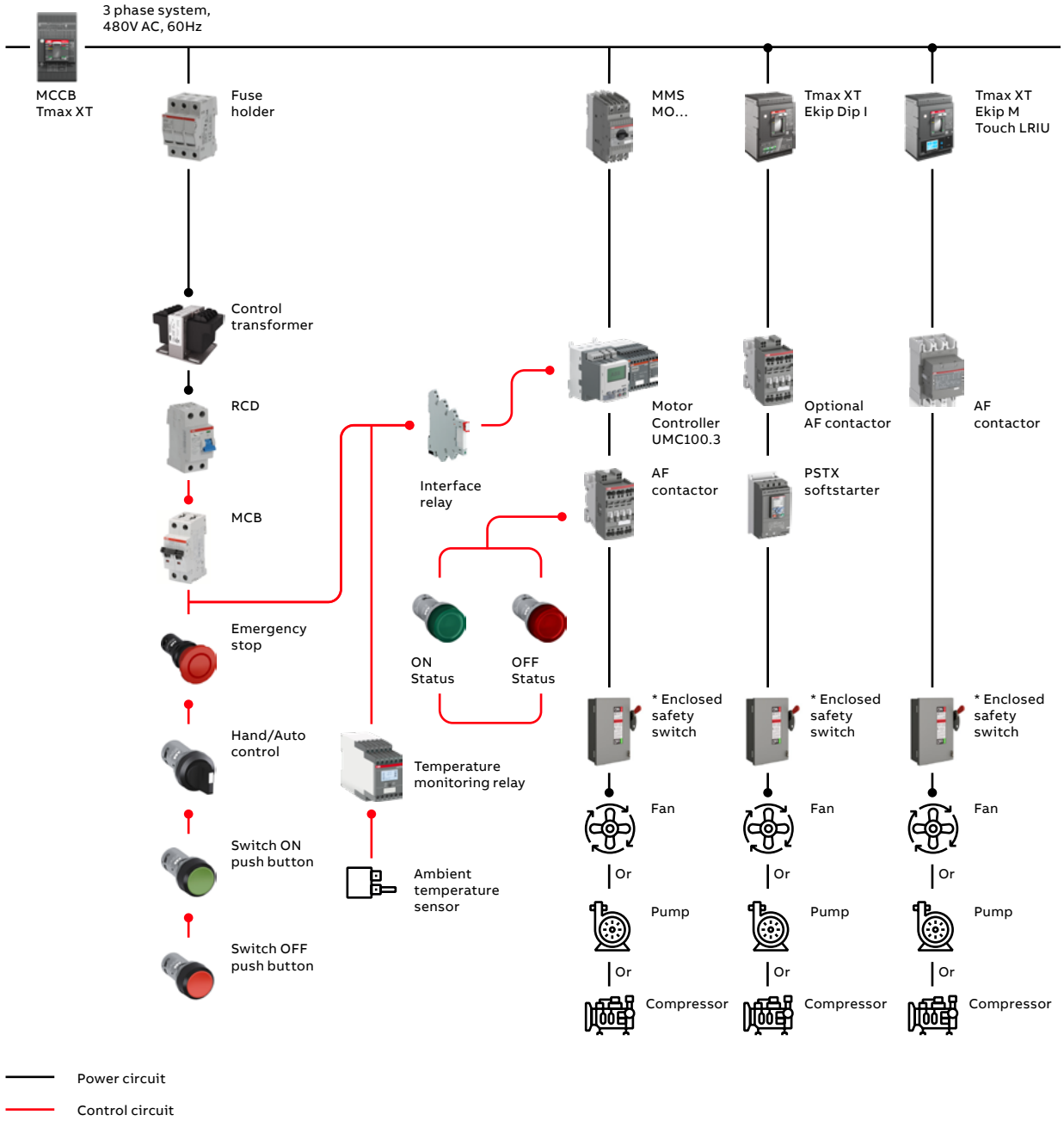
Product combination	Key Differentiator
AF contactor + TF/EF overload relay	For efficiency and space savings
PSR + MMS (Softstarter)	For smooth start and stop
OS switch + PSE (Softstarter)	For smooth start and stop
MMS MS... + AFS contactor	For machine safety offerings

Notes:
MMS – manual motor starter

* The enclosed safety switch will be close to the motor in case it needs maintenance to isolate the power supply and help to ensure safety for a person working close to the motor.

The type of enclosed switch used depends on the application and environment.

ABB’s Advanced Solution



The table below provides an overview of the difference between the combination of products offered in the Advanced Solution for thermal management systems in battery energy storage systems.

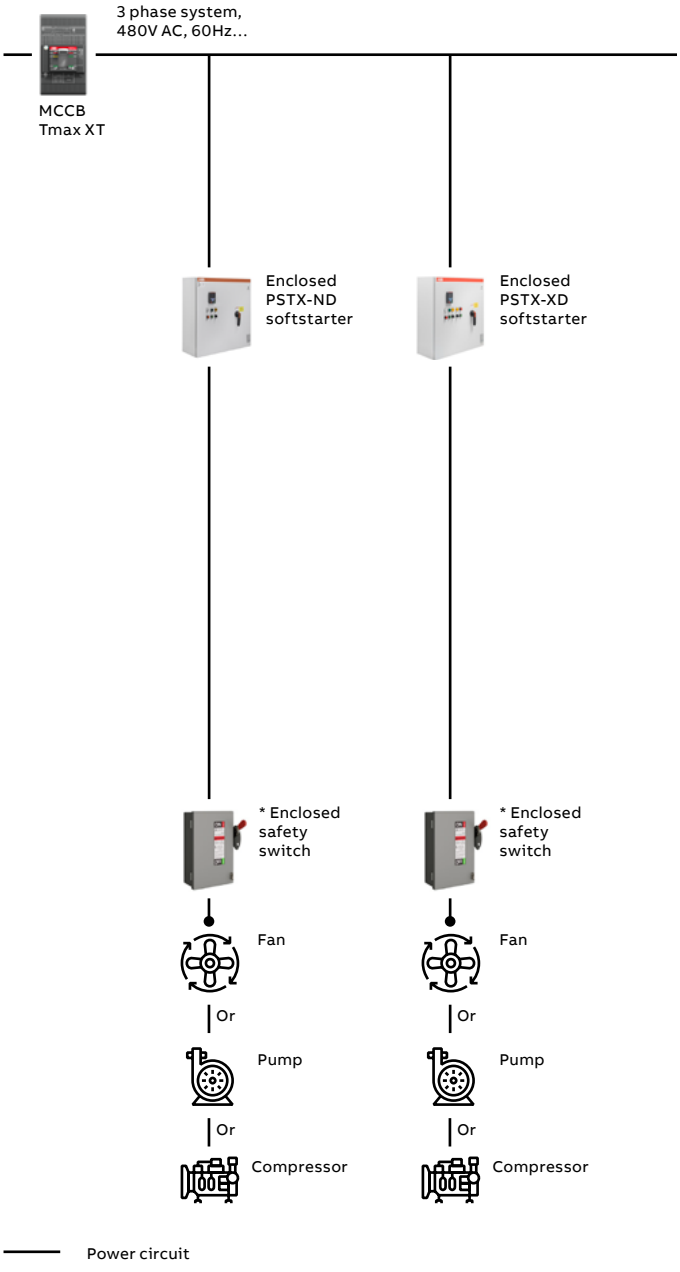
Product combination	Key Differentiator
MMS MO... + UMC100 + AF contactor	For efficiency and space savings
Tmax XT MCCB + PSTX (Softstarter)	For smooth start and stops
Tmax XT MCCB + AF contactor	For efficiency and space savings

Notes:
MMS – manual motor starter
MCCB – molded case circuit breaker

* The enclosed safety switch will be close to the motor in case it needs maintenance to isolate the power supply and help to ensure safety for a person working close to the motor.

The type of enclosed switch used depends on the application and environment.

ABB’s Advanced Solution



The table below provides an overview of the difference between the combination of products offered in the Advanced Solution for thermal management systems in battery energy storage systems.

Product combination	Key Differentiator
Enclosed PSTX-ND (Softstarter)	For normal duty
Enclosed PSTX-XD (Softstarter)	For normal and extreme duty

* The enclosed safety switch will be close to the motor in case it needs maintenance to isolate the power supply and help to ensure safety for a person working close to the motor.

The type of enclosed switch used depends on the application and environment.

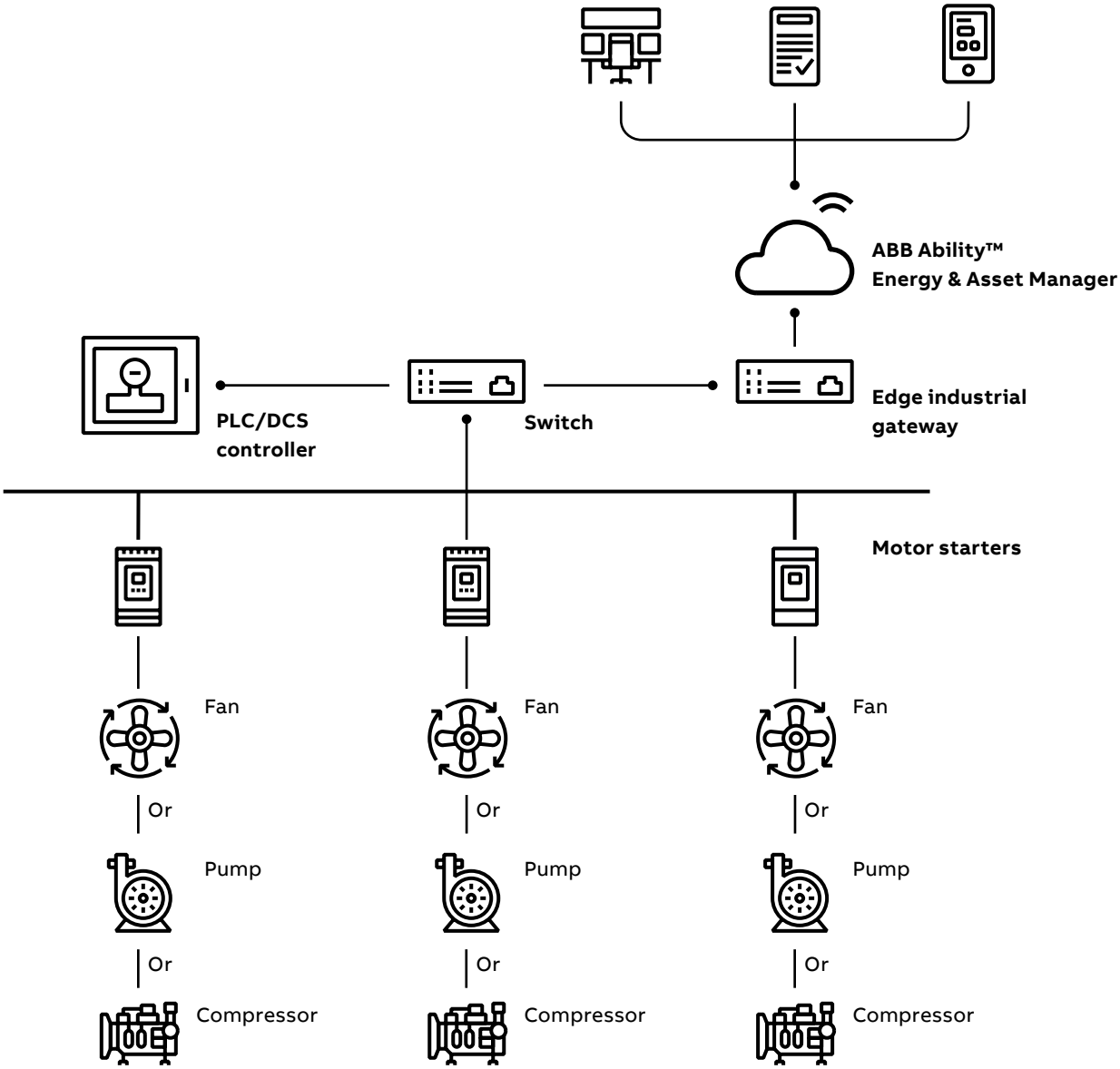
Digital offering

Our digital offering for Advanced motor starting solutions will help you digitally connect your thermal management system and monitor it with 100% data availability.

Digitalization allows flexible remote control of the thermal management system

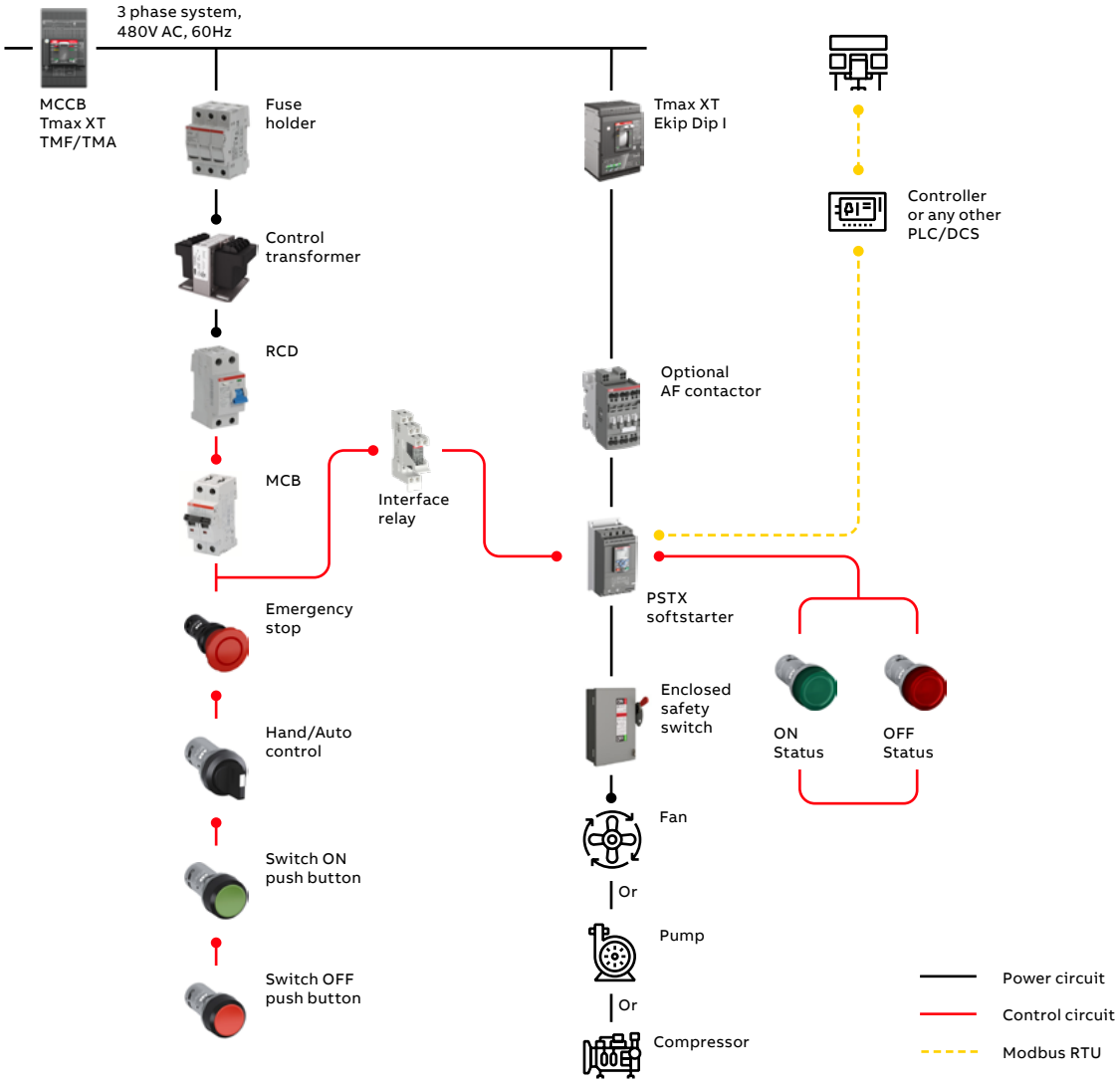
100% availability of motor measurement data as an aid to predictive maintenance

Cloud connectivity through ABB Ability™ Energy and Asset Manager, with data always quickly available on the web applications



1st scenario:

Digital offering with softstarter for motor control and monitoring.



Supporting communication protocols

Fieldbus networks

- Modbus RTU
- Profibus DP
- DeviceNet™

Ethernet networks

- Modbus TCP
- Profinet
- Ethernet/IP™
- IEC 61850

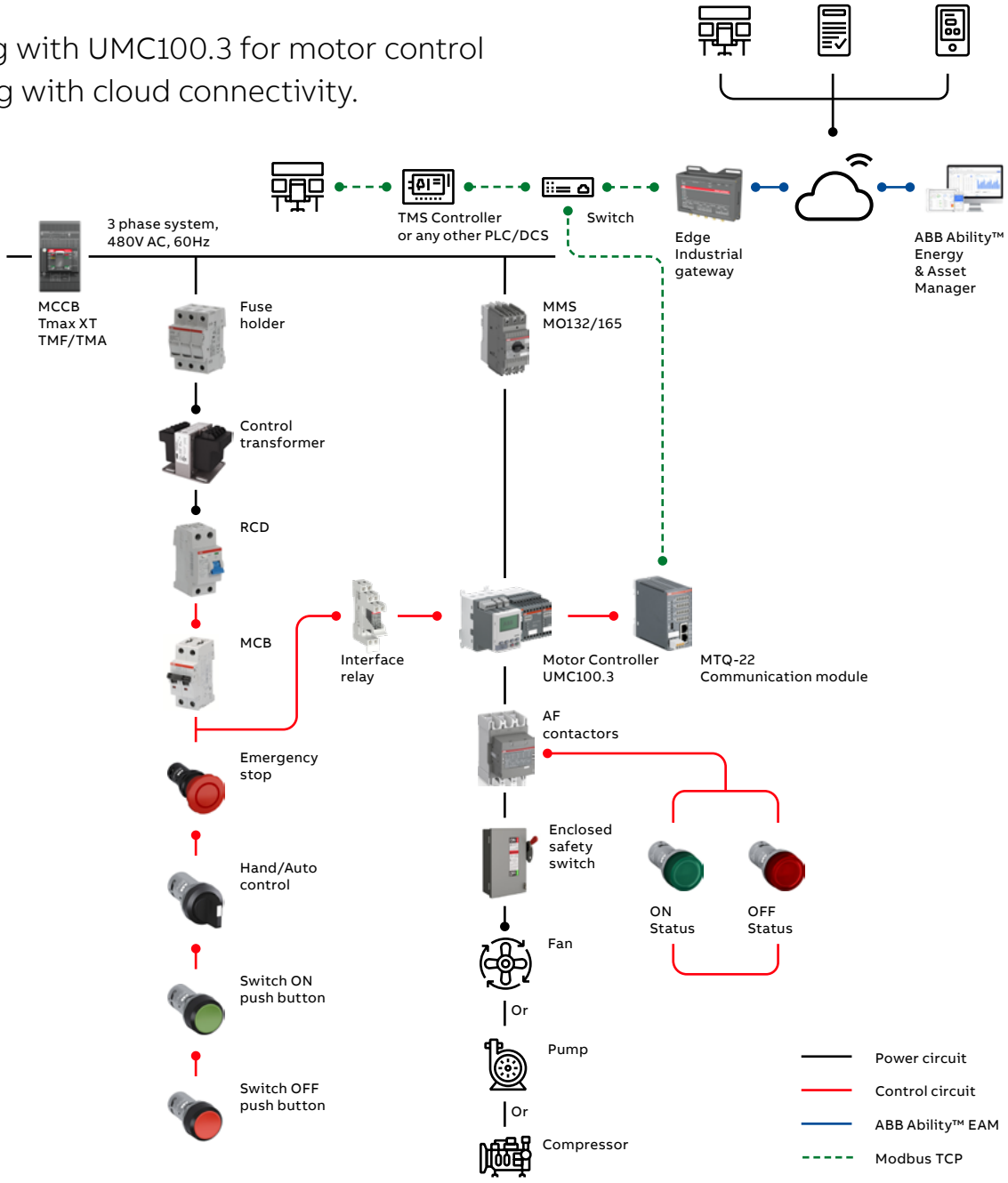
Features

- Flexible motor control (remote or local)*
- Advanced protection functions
- Status and fault diagnosis
- Monitoring of all electrical parameters
  - Voltage (V)
  - Current (A)
  - Power factor (Cos phi)
  - Active power (kW)
  - Reactive power (KVAR)
  - Apparent power (kVArh)
  - Main frequency (Hz)
  - Total harmonics distortion (THD)
  - Consumed Energy in kWh
  - Motor temperature

Notes:
* Motor (pump, fan, compressor) control is coming from the BESS controller

2nd scenario:

Digital offering with UMC100.3 for motor control and monitoring with cloud connectivity.



Supporting communication protocols

Fieldbus networks

- Modbus RTU
- Profibus DP
- DeviceNet™

Ethernet networks

- Modbus TCP
- Profinet
- Ethernet/IP™
- IEC 61850

Features

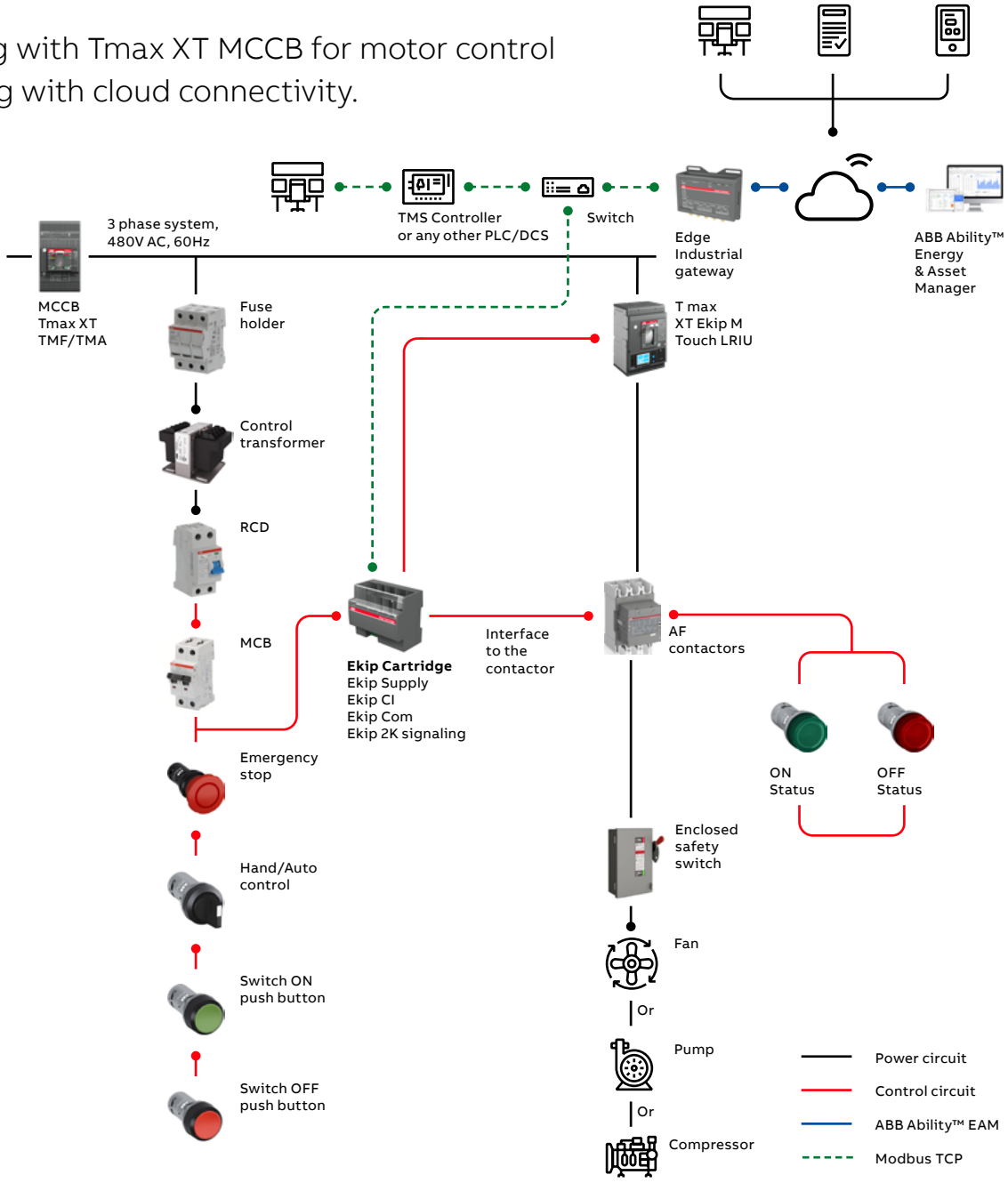
- Flexible motor control (remote or local)*
- Advanced protection functions
- Status and fault diagnosis
- Monitoring of all electrical parameters
  - Voltage (V)
  - Current (A)
  - Power factor (Cos phi)
  - Active power (kW)
  - Reactive power (KVAR)
  - Total harmonics distortion (THD)
  - Active energy (kWh)
  - Temperature
- Cloud connectivity – ABB Ability™ Energy & Asset Manager

Notes:

* Motor (pump, fan, compressor) control is coming from the BESS controller

3rd scenario:

Digital offering with Tmax XT MCCB for motor control and monitoring with cloud connectivity.



Supporting communication protocols

Fieldbus networks

- Modbus RTU
- Profibus DP
- DeviceNet™

Ethernet networks

- Modbus TCP
- Profinet
- Ethernet/IP™
- IEC 61850

Features

- Flexible motor control (remote or local)*
- Advanced protection functions
- Status and fault diagnosis
- Monitoring of all electrical parameters
  - Voltage (V)
  - Current (A)
  - Power factor (Cos phi)
  - Active power (kW)
  - Apparent power (kVA)
  - Reactive power (KVAR)
  - Total harmonics distortion (THD)
  - Active energy (kWh)
  - Reactive energy (kVARh)
  - Temperature (with Ekip 3T)
- Cloud connectivity – ABB Ability™ Energy & Asset Manager

Notes:
* Motor (pump, fan, compressor) control is coming from the BESS controller

Product offering

Contactors

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WEB PAGE

Manual motor starters

CATALOG LINK

WEB PAGE

Push-In Spring Motor Starting solution

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WEB PAGE

Softstarters

CATALOG LINK

WEB PAGE

Control power transformers

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Intelligent motor controller UMC100.3

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Three phase monitoring relays

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WEB PAGE

Interface relays & optocouplers

CATALOG LINK

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Power supplies

CATALOG LINK

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Thermistor relays

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Temperature monitoring relays

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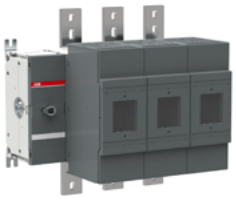
Tmax XT MCCBs

CATALOG LINK

WEB PAGE

Fusible disconnect switches



CATALOG LINK

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Safety relays

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System pro M compact – MCBs

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Pilot devices

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Enclosed safety switches

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Enclosed rotary switches (EOT series)

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Enclosed softstarters

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Fuse holders

CATALOG LINK

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ABB Ability™ Energy and Asset Manager

is a state of the art cloud solution that integrates energy and asset management in a single intuitive dashboard.

BROCHURE LINK

WEB PAGE

References

(1) Q.L. Yue, C.X. He, M.C. Wu, T.S. Zhao, “Advances in thermal management systems for next-generation power batteries,” International Journal of Heat and Mass Transfer, vol. 181, 2021.

(2) A.G. Olabi et al., “Battery thermal management systems: Recent progress and challenges,” International Journal of Thermofluids,
vol. 15, 2022.

(3) M. Shahjalal et al., “A review of thermal management for Li-ion batteries: Prospects, challenges, and issues,” Journal of Energy Storage, vol. 39, 2021.

CONTACT US

Do you have a similar project and are you searching for the right Application configuration?
Contact us and talk to our experts!

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