Solving the LV vs MV Dilemma When Optimizing Costs for Motor Management

A Guide to Large Pump Applications in Mining
5 reasons why you should read this document, and (re)consider motor management

1. Motors directly impact industrial electrical distribution and equipment.
2. Motors are the foundation of all industrial processes.
3. Motors are the largest consumer of energy (90%) in heavy industry.
4. Motors are critical assets for predictive and preventive maintenance.
5. Motors can be the opportunity to make a strategic choice between LV and MV.
Introduction ...............................................................p. 4
The LV or MV Dilemma - A Lever for Optimizing the Cost of Motor Management ..........p. 4
What Are the Challenges When Optimizing Motor Management? ................................. p. 5
The Decision Triangle - End Users, Design Engineers, and Equipment Manufacturers ...... p. 6
Scope of the Motor Management Solution ................................................................. p. 7

Large Pump Applications in Mining ......................... p. 9
Where are large pumps typically found in open pit mining operations? .......................p. 10
Pump Characteristics ........................................................................................................... p. 12
Two Major Families of Pumps ................................................................................................. p. 13

Motor Management Equipment ........................................ p. 15
Electric Motors - The Interface Between the Application and the Electrical System ........ p. 16
LV and MV - Relative Comparison of Asynchronous Motors ............................................. p. 17
Motor Starting and Control - An Adequate Solution ............................................................ p. 18
Starting Method - Arrangements and Performance Comparison ........................................ p. 19
Motor Starter Sharing - An Economic Option for Multiple Pumps in Parallel ..................... p. 20
Variable Speed Drives - Operational Control and Energy Savings .................................... p. 21
Motor Protection and Control - Keeping the Process Up and Running ......................... p. 22
Process Control - For Consistent, Economical and Safe Operation ................................. p. 24
Power Quality - Making the System Sustainable ................................................................. p. 25
Motor Asset Management - Increasing Motor and Process Availability ........................... p. 26
EcoStruxure - IoT-Enabled Architecture for Motor Control and Monitoring .................... p. 27

LV or MV for Large Pumps? ................................................. p. 28
A Holistic Motor Management Approach Will Help Make a Better Choice ...................... p. 29

Three Case Studies .......................................................... p. 30
LV/MV Cost Comparison ................................................................................................. p. 32
Case Study Context - Open Pit Mine Electrical Distribution Overview .......................... p. 33
DIRECT ON LINE Application Case .................................................................................. p. 34
SOFT STARTER Application Case ....................................................................................... p. 38
VARIABLE SPEED DRIVE Application Case ............................................................... p. 42
Introduction

The LV or MV Dilemma - A Lever for Optimizing the Cost of Motor Management

Motors consume more than 90% of the electrical energy in heavy industries and are the major loads defining the electrical distribution system and architecture design. Depending on their rated power, motors can be connected to low voltage (LV) or medium voltage (MV) electrical distribution systems. In the 100-800 kW range both connection levels are feasible and the decision is subject to technical, economic, and people-related criteria. Established practices and habits are just as important as the technical and economic arguments.

Motor technology and design are related to the voltage level. The choice of LV or MV can impact starting current, mechanical torque, inertia, and reactive power consumption. The voltage selection for large motors entails a different motor management design for the same application and motor power in LV and MV.

The following aspects need to be considered:

- Electrical distribution architecture
- Capital expenditure (CAPEX) related to the necessary investment in equipment, software, etc.
- Operation expenditure (OPEX) related to operational performance, maintenance costs, and energy efficiency
- Total cost of ownership (TCO) of the installation

This diagram compares generally established practices for voltage level selection and their reasonable limits. It shows that switching to MV often occurs much earlier than necessary while there might be a hidden cost minimizing optimization potential.
What Are the Challenges When Optimizing Motor Management?

Electrical motors are an asset in electrical installations. Motor management optimization deals with the design of an adequate, yet simple solution, for integrating motors in industrial processes and electrical systems, while addressing several challenges:

- Optimizing investment
- Increasing uptime
- Reducing operating and maintenance costs
- Improving energy efficiency
- Minimizing the impact on the industrial process and the electrical system

Purpose of This Guide...

To explain the technological differences between LV and MV motor management and the impact on installation design, motor control and protection selection, power quality, etc.

To describe the Motor Management approach as a key to optimizing investment and operating costs.

To provide multiple guidelines and resources to help in decision making.

To allow end users to make the most of their installation by selecting the most suitable and consistent solutions for Motor Management.

Note: Although this guide focuses on pumping applications in mining, the guidance and conclusions presented are also valid for the Oil & Gas and Water & Wastewater industries.
Introduction

The Decision Triangle - End Users, Design Engineers, and Equipment Manufacturers

Choosing LV or MV connection voltage is a dilemma for end users and especially for design engineers. Often, for convenience or to minimize change and reduce risks, engineers prefer to repeat previous systems to avoid dealing with the fundamental questions around design.

At the same time, the optimal voltage selection could have an important impact on project profitability. This is where equipment manufacturers can play a significant role in overall optimization.

End users
Objectives:
• Optimize CAPEX, OPEX, and TCO
Expectations:
• Reliable and safe equipment
• Easy to maintain by personnel on site
• Lowest possible investment cost
• Lowest energy consumption
• Lowest footprint
• Large number of suppliers
• Simple in principle
• Fit for purpose
• …

Design engineers
Objectives:
• Minimize design process time
• Minimize CAPEX
• Meet application needs
• Cover eventual evolutions
• Guarantee performance
• Use approved solutions

Values:
• In-depth knowledge of products and solutions
• Awareness on range effects
• Ability to help with overall optimization

Equipment manufacturers
Objectives:
• Respond to the request
• Be selected as supplier

Values:
• In-depth knowledge of products and solutions
• Awareness on range effects
• Ability to help with overall optimization

Key points to remember
• Voltage level selection is a compromise between end users, design engineers and equipment manufacturers.
• It is part of the entire feeder design and requires a case-by-case approach.
Motor management is part of a complete industrial installation with 3 levels:

1. **Circuit breakers and fused contactors** associated with protection relays are typically used to connect, protect and start motors.
2. **Soft starters** or variable speed drives are used to start and operate motors by adapting the electrical and mechanical characteristics to the load and the network.
3. **Cables** are mainly sized according to installation requirements. Their conductive cross-section is defined by normal and fault currents. The control mode selection can influence cable sizing and bring optimization benefits.
4. **Motors** are essentially defined by application requirements. In high power ranges, their optimization can bring overall cost savings in terms of reactive power consumption, heat losses, upstream transformers and generator sizing.
5. **Power quality** concerns extra power consumption and financial penalties from utility or equipment malfunctioning. Motors act on power quality through their control mode.
Large Pump Applications in Mining
Where are large pumps typically found in open pit mining operations?

Large pumps are used in multiple applications in the mining industry, including slurry pumping, dewatering, drainage, and jetting.

More than 70% of them will be connected and controlled via contactors.

30% will use a variable speed drive.

<table>
<thead>
<tr>
<th>Process</th>
<th>Exploration &amp; Extraction</th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications</td>
<td>Mine dewatering</td>
<td>Material grinding and classifying</td>
</tr>
<tr>
<td>Fluid</td>
<td>Water and non-settling slurry</td>
<td>Cyclone feed and fresh water</td>
</tr>
<tr>
<td>Pump technology</td>
<td>Centrifugal</td>
<td>Centrifugal</td>
</tr>
<tr>
<td>Motor power range</td>
<td>Up to 400 kW</td>
<td>Up to 1000 kW</td>
</tr>
<tr>
<td>Typical connection voltage</td>
<td>LV and MV</td>
<td>LV and MV</td>
</tr>
<tr>
<td>Flow</td>
<td>Constant</td>
<td>Constant</td>
</tr>
<tr>
<td>Operating mode</td>
<td>Intermittent</td>
<td>Intermittent</td>
</tr>
</tbody>
</table>
## Large Pump Applications in Mining

**Material Handling**
- Comminution
- Process water
- Centrifugal
- Up to 400 kW
- LV and MV
- Variable
- Continuous

**Process Exploration & Extraction Processing**
- Material handling
  - Slurry pumping
  - Concentrating and refining
- Applications
  - Mine dewatering
  - Material grinding and classifying
  - Comminution
  - Slurry pumping
  - Concentrating and refining
- Fluid
  - Water and non-settling slurry
  - Cyclone feed and fresh water
  - Process water
  - Settling slurry or tailings
  - Process water and leach acids
  - Settling slurry transportation

**Pump technology**
- Centrifugal
- Positive displacement
- Motor power range
  - Up to 400 kW
  - Up to 1000 kW
  - Up to 1500 kW
  - 110 – 300 kW
  - 300 – 2500 kW

**Typical connection voltage**
- LV and MV

**Flow**
- Constant
- Variable

**Operating mode**
- Intermittent
- Continuous

**Material handling**
- Transportation
- Settling slurry transportation

### Table

<table>
<thead>
<tr>
<th>Comminution</th>
<th>Slurry pumping</th>
<th>Concentrating and refining</th>
<th>Material handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process water</td>
<td>Settling slurry or tailings</td>
<td>Process water and leach acids</td>
<td>Transportation</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>Positive displacement</td>
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<tr>
<td>Up to 400 kW</td>
<td>Up to 1500 kW</td>
<td>110 – 300 kW</td>
<td>300 – 2500 kW</td>
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<tr>
<td>LV and MV</td>
<td>LV and MV</td>
<td>LV</td>
<td>LV and MV</td>
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<td>Variable</td>
<td>Variable</td>
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<td>Continuous</td>
<td>Continuous</td>
<td>Continuous</td>
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</tr>
</tbody>
</table>
Large Pump Applications in Mining

Pump Characteristics

Pumped liquids can be divided into three main categories, depending on their viscosity and content:

- clear liquids: clear water
- non-settling slurry: usually in drainage, concentrating, and dewatering
- settling slurry: formed by raw material diluted with water for pipeline transportation

A global overview of this classification is illustrated below:

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**Definitions:**

Head and flow are two of the main characteristics of a pump.

- **The head** measures the vertical height that the pump can lift the liquid and is given in meters.
- **The flow** measures the volume of liquid, usually in m³/h. The flow varies with the head and vice-versa.
- **Best efficiency point**, or BEP*, is defined as the head and flow combination giving the highest efficiency and lowest wear on the pump.

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* Specific to centrifugal pumps.

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**Key points to remember**

- The type of liquid being pumped determines the kind of pump technology to be used.
- For financial reasons, most pumps in mining are centrifugal.
- Slurry pumping applications often use positive displacement pumps, typically rated up to 1500 kW.
Two Major Families of Pumps

Centrifugal pumps are the more economical and widely used technology. These pumps are adapted for clear and non-settling liquids. They can be associated with variable speed drives for energy savings through variable loading.

Proper centrifugal pump operation is dependent on the pressure and viscosity of the liquid at the suction end and maintaining this is achieved through adequate upstream material processing.

Positive displacement pumps are better adapted to the constraints of slurry pumping and slurry pipelines. These pumps operate at constant speed and can reach significant head. They are often driven with variable speed drives.

Positive displacement pumps are operated at constant flow and high efficiency, independent of the pressure or viscosity of the pumped material.

Head/Flow capacities*

Head/Flow comparison at fixed speed

Load torque comparison

Note: Slurry pumping implies dealing with variations in viscosity. Centrifugal pumps often operate at less than best efficiency point. This increases pump wear and maintenance. Centrifugal pumps are preferred to positive displacement pumps for higher flow levels and can have higher rated power.
Motor Management Equipment
Electric Motors - The Interface Between the Application and the Electrical System

There are two major motor technologies: asynchronous and synchronous.

In pumping applications asynchronous motors prevail by far, hence our focus on this technology in this guide.

Asynchronous motors have a simple and robust construction and are much more economical than synchronous motors. They are designed for a high starting current because it is necessary to obtain sufficient torque and stability during operation. As a consequence, starting high-power motors is always an open question.

Asynchronous motors also have a non-unity power factor and require capacitor banks for reactive power compensation. They are frequently used with centrifugal pumps. Robustness and relative ease of maintenance are important decision factors for these motors. LV and MV motors are both standardized according to IEC 60034.

Key point to remember
Asynchronous motors are the predominant motor technology used for pumps in mining.
LV and MV - Relative Comparison of Asynchronous Motors

<table>
<thead>
<tr>
<th>Comparison Characteristics</th>
<th>LV Motors</th>
<th>MV Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic benefit</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Footprint</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Efficiency</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Power factor</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Low starting current</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>High starting torque</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Repair</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
<tr>
<td>Service life</td>
<td>★★★★★★</td>
<td>★★★★★★</td>
</tr>
</tbody>
</table>

Motors under 100 kW are usually LV whereas motors above 800 kW are usually MV. It is the range between 100 kW and 800 kW that poses the dilemma of selecting LV or MV.

Key point to remember
The electromechanical behavior of LV and MV motors is different due to different motor design.
Direct On Line
Direct On Line is a common starting method for its simplicity and low cost. It may impose significant stress, however, on both the network and the mechanical load.

Advanced Starting Modes
Advanced starting modes modify motor behavior through voltage and/or frequency modulation and help to reduce:
- starting current and voltage drop
- initial starting torque and mechanical stress, particularly water hammer effect with pumps
- sizing constraints on transformers or generators

Variable Speed Drives
Variable speed drives provide the following additional benefits:
- starting with higher than rated torque required by positive displacement pumps
- minimized motor heating during starting
- increased number of starts per hour

Optimal motor starting and operational control are fundamental to the industrial process and electrical installation sustainability. Options to consider:

Advanced starting modes are beneficial in the long term since they avoid oversizing and the need for frequent maintenance on the electrical and mechanical equipment.
Starting Method - Arrangements and Performance Comparison

<table>
<thead>
<tr>
<th>Starting Equipment</th>
<th>Standard DOL</th>
<th>Soft Starter</th>
<th>VSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Initial cost benefit</td>
<td>●●●</td>
<td>●●</td>
<td>●</td>
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<tr>
<td>Footprint saving</td>
<td>●●●</td>
<td>●●</td>
<td>●</td>
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<tr>
<td>Weight reduction</td>
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<td>●●</td>
<td>●</td>
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<td>Engineering simplicity</td>
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<td>●●</td>
<td>●</td>
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<tr>
<td>OPEX</td>
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<td></td>
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<tr>
<td>Ease of equipment</td>
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<td>●●</td>
<td>●</td>
</tr>
<tr>
<td>maintenance</td>
<td></td>
<td></td>
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<tr>
<td>Pump energy and</td>
<td>●</td>
<td>●●●</td>
<td>●●●</td>
</tr>
<tr>
<td>maintenance savings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control flexibility</td>
<td>●</td>
<td>●●●</td>
<td>●●●</td>
</tr>
<tr>
<td>Motor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting current control</td>
<td>●</td>
<td>●●</td>
<td>●●●</td>
</tr>
<tr>
<td>Starting torque control</td>
<td>●</td>
<td>●●</td>
<td>●●●</td>
</tr>
<tr>
<td>Pump adequacy</td>
<td></td>
<td></td>
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<tr>
<td>Centrifugal</td>
<td>●</td>
<td>●●</td>
<td>●●●</td>
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<tr>
<td>Positive displacement</td>
<td>●</td>
<td>●●</td>
<td>●●●</td>
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</tbody>
</table>
Motor Management Equipment

Motor Starter Sharing - An Economic Option for Multiple Pumps in Parallel

In MV applications, a single soft starter or drive is often used to start several pumps sequentially, saving on equipment cost and footprint. A redundant soft starter or drive can be added in order to increase availability. The cost of LV soft starters is lower and labor savings make preferable individual installations.

Key points to remember

The main criteria for selecting optimal motor control are:

- **Process requirements**: flow variation, pressure, dynamics. Slurry pumps do not have the same constraints in terms of torque, pressure, and viscosity as water pumps.
- **Necessary torque for starting**: Centrifugal pumps will have quadratic torque, increasing with speed, while positive displacement pumps will exhibit almost constant torque from zero to rated speed. Starting methods will differ for each.
- **Frequency of starts**: Intermittent starting will wear the motor bearings more rapidly, as well as the pump itself.
- **Size of the pump**: Higher power pumps will require starting methods that avoid voltage drops and parallel load disconnection.
- **Motor voltage**: Low voltage motors may need a soft starter to reduce their high starting torque. Medium voltage motors may need a VSD to increase their overall torque.

KEY SOLUTIONS FOR ADVANCED MOTOR CONTROL

- Autotransformer starter Motorpact RVAT
- LV soft starter ATS48
- MV soft starter Motorpact RVSS

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Variable Speed Drives - Operational Control and Energy Savings

Not only appropriate for starting, variable speed drives are also used during operation to:

- Adapt the motor speed and torque to the application needs
- Save energy in some applications such as pumping
- Maintain operation at the best efficiency point

Energy costs represent 40% of the TCO of a typical pump operated at rated speed with flow control through mechanical valves. With VSDs, optimized motor control can bring up to 30% savings on energy consumption.

VSDs can easily operate the pump at their optimal efficiency point and reduce wear and maintenance.

The fault current contribution of any motor with VSD is significantly lower than when operated in direct on line. In some cases the reduced motor short-circuit current contribution can also optimize busbar sizing.

**Selection of VSD voltage levels is highly impacted by cable technology and distance to the motor.**

In LV applications, shielded cables will reduce the effect of EMC but will increase capacitances to earth and limit the length to several hundred meters. Adding a wave-smoothing sinus filter will increase maximum length, but will also increase the cost and footprint of the overall solution.

In MV applications, multi-level inverter technologies greatly improve the voltage waveform provided to the motor and allow operation over several kilometers without specific constraints on cables or the sinus filter.

Modern variable speed drives go far beyond motor speed and torque control. Embedded functions allow multiple advanced services to manage power, energy, process, and protection.
Large Pump Applications in Mining - Technical Guide

Motor Management Equipment

Motor Protection and Control - Keeping the Process Up and Running

Motor and feeder protection is part of a global concern for safety, security, and process availability. It includes protection of:

- Personnel (operators and maintenance staff)
- The process
- The electrical network feeding the motor
- The motor

Protection is achieved by switchgear design and intelligent electronic devices.

Switchgear is an enclosure consisting of current switching equipment, measuring devices, intelligent electronic devices, etc. This is all housed in a protective cabinet that allows personnel to work safely on the electrical installation.

The design of LV and MV switchgear must be compliant with electrical standards that meet internal arc and compartmentalization requirements, etc.

The main switchgear standard for LV equipment is IEC 61439-1/2 and for MV IEC 62271-200.

Switchgear can be a deciding factor regarding the footprint and weight of the overall solution.

In MV, circuit breakers and contactors are installed individually in cubicles, with typical footprints with fuse contactors around 0.35 - 0.6 m².

For higher power motors when only circuit breakers are used, this footprint is around 0.88 - 0.91 m².

In LV switchgear, several motor feeders are integrated in a panel. The number depends on the size of the motors and the diversity factor, related to the expected operation.

For 400 V, this can be up to 4 x 110 kW, or 3 x 160 kW, or 2 x 250 kW, which is a surface gain. For long distances, more cables will be required per phase. This cable-related constraint may impose the need for installation in more panels, thus canceling out the footprint advantage.

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Intelligent electronic devices (IED) are protection relays that are associated with circuit breakers or contactors. The difference between LV and MV relays can be in:

<table>
<thead>
<tr>
<th>Number of inputs</th>
<th>Number of outputs</th>
<th>HMI</th>
<th>Communication protocols</th>
<th>Number of integrated protection functions</th>
</tr>
</thead>
</table>

Main protection functions common to LV and MV relays:

<table>
<thead>
<tr>
<th>Protection type</th>
<th>Typical functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current-based</td>
<td>Earth fault and short-circuit, Current unbalance, Thermal overload, Number of starts per hour, Long start or excessive starting time, Phase undercurrent</td>
</tr>
<tr>
<td>Voltage-based</td>
<td>Voltage unbalance, Voltage phase loss, Voltage phase reversal, Undervoltage, Overvoltage</td>
</tr>
</tbody>
</table>

In MV relays there are specific machine protection functions:
- Machine differential
- Stator windings and/or frame temperature
- Pole slip (for synchronous motors)

Consequences of motor failure

When a motor fails, it means the process itself is no longer available, and results in:
- loss of production
- Increased maintenance costs
- unacceptable risks in any critical process

Key points to remember
- Motor protection is adapted to the customer need and depends on how critical the motor is to the operation.
- MV or LV relays offer similar protection.
- MV installations will require more cabling and space as current transformers are not integrated in the relay.
Process Control - For Consistent, Economical, and Safe Operation

Process control systems (PCS) enable automatic control, monitoring, and remote diagnostics of the mining process.

Process Control System

Connected products consist of advanced motor protection and control products, sensors, and Intelligent Motor Control Centers (IMCC). These products also provide feedback and diagnostics for edge control and process automation, bringing intelligence and increased process availability.

Edge control and process automation consists of a distributed control system (DCS) with integrated cyber security and:
- Programmable logic controller (PLC)
- Supervisory control and data acquisition (SCADA) system
- Remote I/O system.

To ensure good interoperability, featured data is transmitted via network protocols commonly used in industrial automation such as Modbus TCP/IP, Modbus Serial, EtherNet IP, or Profibus DP in LV applications and IEC 61850 in MV.

LV and MV installations will have similar features for process control. Except for a slightly higher amount of cabling of LV devices, there is no particular constraint for the selection of the motor connection voltage from this aspect.

Key Solutions for Process Control System

- PLC Modicon M580
- EcoStruxure Hybrid DCS
- Remote I/O

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Capacitor banks, harmonic mitigation systems, and transformers ensure the correct operation of motors in the process with minimal impact on the power system.

As a rule of thumb, LV motors may have a slightly lower power factor and require a slightly higher reactive power compensation. The power factor difference depends on the motor manufacturer.

**Capacitor banks** are used for power factor correction (PFC). They are usually installed on the same busbar as the motors. In MV, there are also individual capacitors per motor.

**LV drive technology** often has standard variable speed drives, generating high harmonic currents. **Active or passive harmonic filters** are generally suitable for installations where several LV drives are connected to the same busbar. Specific low harmonic LV drives for large motors are an efficient means of reducing harmonic levels without increasing the switchboard size.

**MV drive technology** - The most popular MV drives, such as multi-level inverters with embedded multi-pulse transformers, have the advantage of being almost a linear load with a high power factor. No harmonic reduction equipment is required.

**Transformer** power and short-circuit voltage define the voltage drop, especially during motor starting, and the impact of harmonic currents on busbar voltage. Large motor starting is a constraint for the system and requires careful analyses for the sizing of the transformer. Up to 800 kW, DOL starting is generally not an issue in MV installations.

**WHAT IS THE IMPACT OF POOR POWER QUALITY?**
Inadequate power quality or equipment sizing may lead to overheating or vibration in the motors and accelerate their aging and replacement. It can also cause parallel load disconnection and production losses.
Motor Management Equipment

Motor Asset Management - Increasing Motor and Process Availability

Condition assessment and predictive technologies help to avoid motor and application failures in the early stages, with remote or local monitoring services.

Asset management services consist of the continuous monitoring of critical LV and MV motors and their related loads. A service bureau platform is used by experts on the premises of the equipment manufacturer. Experts use analytics to diagnose potential problems and they provide event reports and notifications of any necessary action that can help to:

- Prevent downtime, increase system continuity, ensure safety, and optimize asset lifetime
- Determine maintenance adjustments for cost optimization and risk mitigation.

Asset Management Services

Local monitoring of assets is achieved through the installation of dedicated monitoring devices, known as “edge analytics,” and realized in the process control layer of the industrial installation. Asset management solutions are mostly defined by the criticality of the motor for the industrial process and do not influence voltage level selection.

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KEY ASSESSMENTS

- Portfolio management
- Operational performance
- Motor condition
- Maintenance workspace

EcoStruxure Maintenance Advisor
EcoStruxure Asset Advisor
EcoStruxure - IoT-Enabled Architecture for Motor Control and Monitoring

In Heavy Industries
Motor Management Approach

In Motor Applications
EcoStruxure Architecture

Apps, Analytics & Services

Edge Control/Process Automation

Connected Products

ONLINE CONDITION MONITORING
ALARMING + EMBEDDED HISTORIAN
ACQUISITION METERING

MOTOR APPLICATION ANALYSES
CUSTOMER NEEDS

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LV or MV for Large Pumps?
A Holistic Motor Management Approach Will Help Make a Better Choice

The holistic Motor Management approach, developed by Schneider Electric, is based on our high level of expertise and proven solutions. It ensures that all decisions are made only after careful analysis of the application and the industrial power system.

**MOTOR MANAGEMENT APPROACH**

**"ANALYZING" STEPS**

- **CUSTOMER NEEDS**
  - Key analyses
  - Motor application
  - Electrical installation
  - Economical objectives
  - Maintenance practices
  - Operational requirements

- **EXPERT SERVICES FOR MOTOR APPLICATIONS**
  - Key analyses
  - Voltage level
  - Power supply characteristics
  - Short-circuit currents
  - Mechanical and thermal stress
  - Cable sizing
  - Footprint optimization

**"DEFINITION/PROPOSITION" STEPS**

- **ADVANCED MOTOR CONTROL**
  - Key factors
  - Process compliance
  - Motor and load torque for starting
  - Frequency of starting
  - Voltage stability

- **MOTOR PROTECTION & CONTROL**
  - Key factors
  - Power supply
  - Motor control type
  - Motor operating mode
  - Motor criticality
  - Communication requirements

- **POWER QUALITY**
  - Key assessments
  - Power factor
  - Harmonics
  - Energy efficiency

- **MOTOR ASSET MANAGEMENT**
  - Key assessments
  - Operational performance
  - Motor condition monitoring
  - Scalability of the application

**Customer Objectives**

<table>
<thead>
<tr>
<th>Customer Objectives</th>
<th>Starting and Operation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DOL</td>
</tr>
<tr>
<td>Solution simplicity</td>
<td>●</td>
</tr>
<tr>
<td>Frequent starting</td>
<td>-</td>
</tr>
<tr>
<td>High starting torque</td>
<td>●</td>
</tr>
<tr>
<td>Limited voltage drop</td>
<td>-</td>
</tr>
<tr>
<td>Reduced mechanical stress</td>
<td>●</td>
</tr>
<tr>
<td>Lower heating</td>
<td>●</td>
</tr>
<tr>
<td>Harsh environment</td>
<td>●</td>
</tr>
<tr>
<td>Variable speed</td>
<td>-</td>
</tr>
<tr>
<td>Energy saving</td>
<td>-</td>
</tr>
<tr>
<td>Footprint optimization</td>
<td>●</td>
</tr>
</tbody>
</table>
Motor Management Approach - Three Case Studies
Three typical mining applications illustrate how the motor management solution is developed for LV and MV connections and the related advantages and drawbacks of each.

The main factors to consider are:
- Application requirements
- Motor feeder main components
- LV/MV cost comparison
- Schneider Electric solution overview for each voltage level

1. Three typical applications

2. Technical feasibility

3. Decision key points
Case Studies

LV/MV Cost Comparison

Typical Feeder Composition

Equipment costs are compared.
The costs of the LV and MV versions of a complete single feeder are compared for a given motor power.
All feeder elements are sized according to motor power and short-circuit current.

The result of the comparison is given as a LV to MV cost ratio. It limits the effect of option-related variation and allows the results to be generalized.

LV/MV ratio < 1 - Benefit is for LV solution
LV/MV ratio > 1 - Benefit is for MV solution

Non-technical factors such as habits, available voltage levels, and need for personnel competency improvement can influence the choice.
Even if a solution is more expensive, it may be preferred on the basis of such contextual reasons, but this may also be the case when the difference in equipment cost between the two voltage levels is negligible.

A margin, noted as context-dependent, is also considered to illustrate these variabilities.
Case Studies

Case Study Context - Open Pit Mine Electrical Distribution Overview

One of the most common electrical distribution architectures used for open pit mines is the double radial system. This consists of a main MV switchboard with two incomers and a normally open bus section.

Each half-busbar is supplied by a transformer loaded to 50% of its capacity but sized to supply the total load. If one transformer fails, the associated incomer circuit breaker trips and the bus section closes to transfer the total load to the other transformer. Double radial architectures offer a good compromise between energy availability, equipment redundancy, and overall cost.

The three examples concern:

- Clear water pump in comminution
- Non-settling slurry pump in mine dewatering
- Slurry pump for material transportation

The pump feeders are sized in the following typical environment:

- Altitude < 1000 m
- Ambient temperature -5°C to 35°C
- Relative Humidity < 90%
- Ambient air not significantly polluted
- Protection IP31
- No seismic risk
- Insignificant vibrations

Motor power considered for each motor starting method:

<table>
<thead>
<tr>
<th>Motor Power</th>
<th>Direct On Line</th>
<th>Soft Starter</th>
<th>Variable Speed Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 kW</td>
<td>315 kW</td>
<td>400 kW</td>
<td></td>
</tr>
</tbody>
</table>
Processing/Communion

Motor
- Motor power: 200 kW
- Frequency of starting: 2/week

Pump
- Type of pump: centrifugal
- Fluid: clear water

Electrical network
- Short-circuit power: high

Pumping clear water with a centrifugal pump can be achieved with Direct On Line starting when not frequent and not subject to water hammer.

MOTOR MANAGEMENT APPROACH

"ANALYZING" STEPS

<table>
<thead>
<tr>
<th>CUSTOMER NEEDS</th>
<th>EXPERT SERVICES FOR MOTOR APPLICATIONS</th>
<th>&quot;DEFINITION/PROPOSITION&quot; STEPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze objectives</td>
<td>LV/MV cost ratio</td>
<td>Control solution</td>
</tr>
<tr>
<td>Simplicity</td>
<td>DOL</td>
<td>LV contactor</td>
</tr>
<tr>
<td>Frequent starting</td>
<td>RVAT</td>
<td>Circuit breaker + relay</td>
</tr>
<tr>
<td>High starting torque</td>
<td>VSS</td>
<td>MV contactor</td>
</tr>
<tr>
<td>Limited voltage drop</td>
<td>PO</td>
<td>Contact + fuse + relay</td>
</tr>
<tr>
<td>Reduced mech. stress</td>
<td>Protection</td>
<td>Individual power factor correction</td>
</tr>
<tr>
<td>Lower heating</td>
<td>Asset management</td>
<td>Asset Advisor</td>
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<tr>
<td>Footprint optimization</td>
<td></td>
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</tr>
</tbody>
</table>

"ANALYZING" STEPS

Control solution
- LV solution
  - LV contactor
  - Circuit breaker + relay
- MV solution
  - MV contactor
  - Contact + fuse + relay

"DEFINITION/PROPOSITION" STEPS

PRIORITY #1
- Advanced Motor Control
- Motor Protection & Control

PRIORITY #2
- Power Quality
- Asset Management

PRIORITY #3
- Protection
- Power Quality
- Asset Management

COMMENTS

In the 400 V variant the economic benefit from the equipment cost is visible for a cable length around 100 m. Longer cables require changing to 690 V or switching to MV.

For 690 V the cable length has a much smaller impact. The LV or MV choice will be mainly defined by additional technical or personnel-related factors.
DIRECT ON LINE Application Case

Direct on line is the basic and most frequent architecture for motor control. This is why the LV and MV variants are very similar.

In LV, the capacitor bank used for power factor improvement is separated from the motors on a dedicated feeder on the main busbar.

In MV, this solution exists but the capacitor bank can also be integrated in the cubicle containing the motor feeder. In this case, the capacitor is sized individually for the motor and operates only when the motor is connected.
General Recommendation

The case study analysis is extended in motor power. Context-dependent areas are defined around the LV/MV equivalence limits, based on the same tolerance as before.

The choice of MV or LV is recommended above and below these areas respectively.

Three zones are distinguished in the comparison graphs:

- **“LV”** where LV connection is recommended
- **“MV”** where MV connection is recommended
- **“Context-dependent”** where the connection is subject to the abovementioned cost variation factors

**KEY TAKEAWAYS**

The use of 400 V for large pumps is rapidly limited by cable length. This voltage level is suitable for lower power and numerous motors, where the supplying switchboard will be close to the pumps.

At 690 V, motors can reach much higher power. The context-dependent zone is larger as the decision to go to MV may impose the need to review the electrical distribution architecture. This is why this LV level is preferable for longer cable lengths.
**SOFT STARTER Application Case**

**Exploration and Extraction/Mine Dewatering**

- **Motor**
  - Motor power: 315 kW
  - Frequency of starting: >1/day

- **Pump**
  - Type of pump: centrifugal
  - Fluid: non-settling slurry

- **Electrical network**
  - Short-circuit power: low

High flow amplitude in dewatering is achieved by parallel pumping at rated speed. Risk of settling material requires progressive starting to avoid water hammer effect. Soft starter also remains a robust solution as it operates only during starting.

**MOTOR MANAGEMENT APPROACH**

**"ANALYZING" STEPS**

- **CUSTOMER NEEDS**
  - Simplicity
  - Frequent starting
  - High starting torque
  - Limited voltage drop
  - Reduced mech. stress
  - Lower heating
  - Harsh environment
  - Variable speed
  - Energy saving
  - Footprint optimization

- **EXPERT SERVICES FOR MOTOR APPLICATIONS**

- **Analyze objectives**
  - DOL
  - RVAT
  - VSD
  - PO
  - Protection
  - Asset management

**"DEFINITION/PROPOSITION" STEPS**

- **ADVANCED MOTOR CONTROL**
  - LV
    - LV Soft starter
  - MV
    - MV Soft starter

- **MOTOR PROTECTION & CONTROL**
  - Circuit Breaker + Relay
  - Contactor + Fuse + Relay

- **POWER QUALITY**
  - Power Factor Correction Bank
  - Individual Power Factor Correction

- **MOTOR ASSET MANAGEMENT**
  - Asset Advisor
  - Asset Advisor

**Cable Length Cost Impact**

- **LV/MV**
  - 315 kW LV/MV cost ratio

**COMMENTS**

The individual motor power to be connected in the system is increased with a soft starter due to the starting current reduction action. In the example, the motor power is compatible with a 690 V installation, but not at all common for 400 V, usually limited at 200 kW.

As in the case of direct on line starting, the decision for LV or MV is mostly dependent on non-economic factors, even for longer cable.
The proposed architectures are very similar as they contain the same elements at the respective voltage levels. The motor protection can also be achieved in a simpler manner through the overcurrent and thermal protections integrated in the motor starter. The selection is dependent on the criticality of the motor and its power.

In MV, the motor protection relay contains a number of protections which are activated according to the project and application requirements.
General Recommendation

This case study analysis is extended in motor power. Context-dependent areas are defined around the LV/MV equivalence limits, based on the same tolerance as before.

The choice of MV or LV is recommended above and below these areas respectively.

Three zones are distinguished in the comparison graphs:

- **“LV”** where LV connection is recommended
- **“MV”** where MV connection is recommended
- **“Context-dependent”** where the connection is subject to the abovementioned cost variation factors

**KEY TAKEAWAYS:**

Compared to the DOL architecture, the use of soft starters slightly increases the applicable cable length for 400 V application. This is mainly due to the MV soft starter cost, which remains high for the motor power range, compared to its LV equivalent.

In the 690 V variant, the soft starter use increases the maximum acceptable motor power compared to the DOL case.

The equilibrium between LV and MV is obtained for longer cables. The MV solution becomes context-dependent from zero cable length between 400 and 630 kW. Compared to the DOL case, the context-dependent zone is larger, leaving room for the non-economic factors in the decision.


Material Handling/Slurry Pipeline

Motor
- Motor power: 400 kW
- Frequency of starting: 2/h

Pump
- Type of pump: positive displacement
- Fluid: slurry

Electrical network
- Short-circuit power: low to high

Dense material, subject to settling, needing higher torque to start. VSD is recommended, as it also minimizes voltage drop in more sensitive process environments.

MOTOR MANAGEMENT APPROACH

"ANALYZING" STEPS

CUSTOMER NEEDS
- Simplicity
- Frequent starting
- High starting torque
- Limited voltage drop
- Reduced mech. stress
- Lower heating
- Harsh environment
- Variable speed
- Energy saving
- Footprint optimization

EXPERT SERVICES FOR MOTOR APPLICATIONS
Analyze objectives
- DOL
- RVAT
- RVSS
- VSD
- PQ
- Protection
- Asset management

"DEFINITION/PROPOSITION" STEPS

ADVANCED MOTOR CONTROL
Control solution
- LV VSD

MOTOR PROTECTION & CONTROL
Protection
- Circuit Breaker + Relay
- AFE VSD option or active harmonic filter

POWER QUALITY
Power quality
- Contactor + Fuse + Relay
- (not necessary)

MOTOR ASSET MANAGEMENT
Asset management
- Asset Advisor

Cable Length Cost Impact

LV/MV

400 kW LV/MV cost ratio

0.4/6.6 kV
0.69/6.6 kV

MV benefit
Equal
LV benefit

0 100 200 300 400 Cable length (m)

COMMENTS
The use of VSD for motor control gives an important advantage to the 690 V solution. The reason is mainly the cost advantage of LV equipment. The 400 V variant also benefits from the VSD LV to MV cost difference and remains within the scope of consideration for cables up to 250 m.
The MV drive multi-level technology makes it naturally a low harmonic drive. In some cases the architecture may contain a grounding switch used for discharging the cables on the motor side.

The proposed LV architecture comprises two feeders, one for the motor and another for the harmonic filter. This solution has been identified as more frequent and suitable for mixed power and multi-motor applications with VSD.

For single motor applications, the VSD should be of low harmonic type, shown as optional on the connected products layer. With a low harmonic VSD the second feeder is eliminated. This is also the solution that will be cost-compared with the MV equivalent.
General Recommendation

This case study analysis is extended in motor power. Context-dependent areas are defined around the LV/MV equivalence limits, based on the same tolerance as before.

The choice of MV or LV is recommended above and below these areas respectively.

Three zones are distinguished in the comparison graphs:

- **"LV"** where LV connection is recommended
- **"MV"** where MV connection is recommended
- **"Context-dependent"** where the connection is subject to the above mentioned cost variation factors

**KEY TAKEAWAYS:**

This variable speed drive LV to MV comparison is one of the most complex.

For both LV voltage levels the context-dependent zones are large and the applications remain interesting in LV even for longer cables. The origin of this extended LV application field is the higher cost of the VSD in MV for the considered power range.
More Information on Motor Management

Discover our high-power Motor Management offer panorama

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