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Diagnosing Undervoltage in Motor Control Applications

by Erik Barnes, Offer Marketing Manager

Equipment downtime can have a tremendous impact on business and people. Power quality is playing an increasing role in equipment reliability. As energy demands increase and more loads are introduced onto the electrical distribution system, the quality of power supplied to equipment can become strained. Power quality issues can affect equipment operation in various ways—and unfortunately, they can also be difficult to diagnose.

This paper looks at how one power quality issue, undervoltage, can hamper equipment performance (specifically around the motor controller), and methods to resolve this challenge.

Introduction

Power quality issues and equipment downtime can impact a range of areas, including the following:

- safety
- delivery of key services
- production output
- servicing costs
- manufacturer reputation

An increase in energy demands can strain electrical distribution systems, sometimes affecting the quality of the power delivered to equipment and machines. This strain can hamper the ability of the affected equipment and machinery to perform their intended work reliably. For some applications, equipment failure can have serious consequences.

Undervoltage is one common issue resulting from poor power quality. Undervoltage occurs when the measured voltage is more than 15% below the nominal voltage rating of the supply for an extended duration, usually longer than one minute. Often difficult to identify, undervoltage can result in downtime and damage to equipment.

Causes of undervoltage

An increase in energy demands and the evolution of energy systems can create new challenges for an electrical system.

- New equipment or the expansion of existing equipment adds loads to electrical systems.
- New technologies improve the efficiency of electrical equipment, even in remote locations.
- More options exist for powering the equipment with alternative energy sources.

These new and exciting changes can overshadow considerations about the supporting electrical system. Sometimes an assumption exists that the system will always be able to provide consistent and reliable power. When it doesn't, people notice.

Figure 1—Downtime

Undervoltage can have a significant impact on the reliability of equipment and machinery.

Undervoltage can occur in varying degrees, from minor to severe. Its presence can also vary from occasional to ongoing. The strength and occurrence of undervoltage depend on several factors, and the degree of severity of those factors. Situations that can result in an undervoltage condition include the following:

- **Overloading the supply source**—When properly applied, transformers or generators output a specific voltage on the output or secondary side. If the demands of the loads placed on the power supply or generator are beyond what the transformer or generator can support, the current typically increases to above-nominal levels. As a result, the voltage on the output typically decreases.
- **Overloading the control transformer**—Transformers inside the equipment control panel are used to lower the operational voltage in the control circuit. As with larger three-phase transformers, when the control circuit loads overburden a smaller control transformer, undervoltage can result.
- **Excessive impedance**—Systems that have excessive impedance (or resistance) can experience what's known as voltage drop. For example, a voltage drop can occur when long conductor runs power equipment located at a significant distance from the supply. Power is typically dissipated in the form of heat where the impedance occurs.
- **Phase imbalance**—Phase imbalance can occur in the electrical system when loads are imbalanced on the system's three phases: A–B, B–C, A–C. This is more commonly seen where single-phase loads are applied to a three-phase electrical system. A very large single-phase load or multiple single-phase loads not equally distributed among the three phases can result in phase imbalance.
- **Peak demand**—Electrical systems at or near capacity can experience a voltage drop during peak periods of electrical demand. This is also called a brownout.
- **Battery drain**—Voltage supplied from battery systems can drop as the battery becomes depleted.

Symptoms of undervoltage

Undervoltage conditions can manifest in various ways and in some cases can be difficult to detect. The degree of undervoltage plays a significant role in how equipment is affected.

Equipment might not immediately reveal any symptoms of undervoltage. Some installations might operate without any noticeable issues for days, weeks, or even months. While undervoltage can easily be detected using a voltmeter, an undervoltage condition might not be evident during installation. So this test might not be applied until later, after more obvious symptoms appear. As always, consult qualified personnel when diagnosing electrical issues, and follow safe electrical workplace practices as outlined in NFPA 70E and CSA Z462.

To diagnose undervoltage, it's important to understand how devices might respond in an undervoltage condition. In general, systems operating in an undervoltage condition have higher running currents. This increase in current impacts devices and motors in various ways.

Slight decreases in voltage from the nominal rating are somewhat expected in most systems, as all systems likely have some form of impedance. Many electrical components are designed to operate under a reasonable decrease in voltage. For example, contactors are often rated to operate where the coil voltage is as low as 85% of the nominal coil voltage rating. In these cases, an appreciable impact to the performance of the contactor is unlikely—but the operating temperature of the device or system will probably increase.

Overload relay

The motor overload relay is one device in the electrical motor circuit that might provide evidence of an undervoltage condition.

Under normal operating conditions, a motor runs at or below its full-load current (FLC) rating, depending on the type of motor and the amount of work the motor is accomplishing. If the load overburdens the motor, then the running current increases.

The overload relay is designed to protect the motor from an overcurrent condition, which could ultimately result in the motor burning up. When the overload relay senses a sustained current flow above its setting, the overload relay trips. In a typical wiring scheme, the contactor responds to the tripping action by opening the motor circuit. This is the intended operation of the motor control circuit to protect the motor.

In an undervoltage condition, the operating current increases, even if the motor is under acceptable load levels. Depending on the degree of the undervoltage and the load size (the amount of work the motor is accomplishing), the running current can rise to a level sufficient to cause the overload relay to trip. It might be difficult, though, to recognize whether the trip occurs from an undervoltage condition, or from an overburdening of the motor.

Contactor

The contactor itself may also show evidence of an undervoltage condition. Typical contactor designs include a magnetic armature. Under normal operating conditions, when voltage is applied to the contactor coil, the coil generates a magnetic field in the iron core. This magnetic field pulls in the armature and the movable power contacts, closing the circuit to the motor.

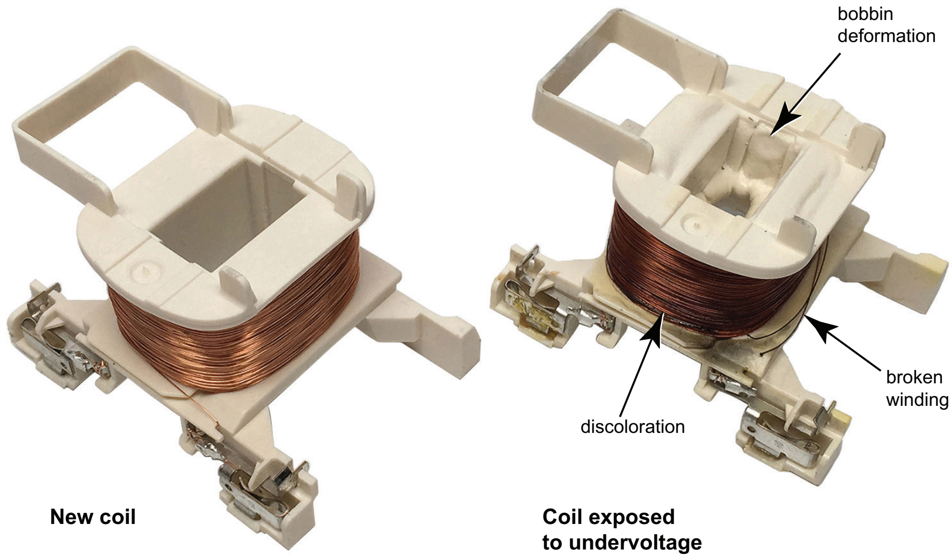
If insufficient voltage is present, the contactor might chatter. This chatter is a hum or vibration caused when the magnetic armature is not able to sufficiently close. If the voltage drops significantly, the contactor might not pull in, or it might drop out after pulling in. Alternatively, the contactor might remain closed even when signaled to open.

This condition can occur when excessive heat from a sustained undervoltage causes the coil bobbin inside to expand, which in turn interferes with the armature and causes the contacts to remain closed even when power is removed from the coil. See Figure 2.

Depending on the application, the inability of the contactor to stop the motor can result in hazards to personnel, as well as damage to equipment and the operating environment.

Figure 2—Heat stress

A contactor coil exposed to undervoltage shows evidence of heat stress.



Undervoltage present over a period of time can affect the contactor in other ways:

- The wire insulation of the contactor coil might break down, such that the contactor does not respond to start commands.
- The contactor housing might show discoloration as a result of the excessive heat generated by the undervoltage.

Circuit protection devices

Undervoltage can also affect circuit protection devices such as circuit breakers or fuses. The increased running current resulting from an undervoltage condition can cause circuit protection devices to open. However, undervoltage conditions might also exist without tripping a circuit breaker or opening a fuse, as a result of a common design application.

Fuses and circuit breakers are typically sized larger than the motor full-load current value to avoid nuisance opening during motor startup. In these cases, the increased current in an undervoltage condition might not rise high enough for the overcurrent protection device to respond.

Control transformer

It can also be difficult to notice an undervoltage condition involving control transformer applications. If undervoltage conditions are present on the primary side of a transformer, then the secondary side will also display a proportional undervoltage. The overcurrent protection on the primary side and the secondary side of the transformer may or may not respond to the increased current in these conditions.

Often on the primary side, the circuit breaker or fuses are sized significantly larger than the operating current of the transformer, to avoid nuisance tripping due to the high transformer inrush. Also the increased current on the secondary side might not rise high enough for the overcurrent protection device to respond—especially in cases where the control transformer is sized with excess capacity for adding control loads in the future.

The undervoltage may increase the transformer operating temperature. In some cases though, the only means of detecting an undervoltage condition in a control circuit may be to measure the control voltage once the transformer is installed in the field.

Summary of symptoms

In summary, undervoltage conditions can be difficult to detect, as the symptoms vary based on numerous factors. Equipment might display multiple issues, depending on the severity of the undervoltage, the size of the load compared to the equipment capacity, and other conditions.

Measuring the voltage might seem an obvious way to detect undervoltage, but often this measurement is not performed until reliability issues occur. Conditions other than undervoltage can show similar symptoms, so careful analysis must be applied when troubleshooting equipment. Always consult qualified personnel when diagnosing electrical equipment.

In general the following symptoms could indicate an undervoltage condition:

- Overload relay tripping when the motor is not overburdened
- Contactors do not pull in on startup
- Contactor chatter during startup or normal operation
- Contactors do not open when signaled
- Contactors dropping out while operating
- Excessive heat inside the control panel
- Discoloration of the contactors
- Nuisance tripping or opening of circuit breakers or fuses

Resolving undervoltage

The solution to an undervoltage condition depends on the cause of the undervoltage and the feasibility of implementing the changes necessary to resolve it.

Some undervoltage conditions are difficult to solve, especially when discovered at the installation site and not in the equipment design phase. Always consult qualified personnel to properly diagnose control issues and devise a resolution.

At the source

Transformer or generator

In cases where a transformer or generator is overburdened, the resolution can be challenging. The following options might improve the condition:

- Replacing the transformer or generator with a properly sized one
- Redistributing some of the downstream loads to other electrical distribution systems
- Installing an uninterruptible power supply dedicated to the equipment

However, these may be difficult or costly to achieve.

Phase Imbalance

If phase imbalance is the contributing factor, redistributing loads to achieve better balance might resolve undervoltage. However, this can be more difficult to accomplish when the system contains one large single-phase load. Applying a buck-boost transformer ahead of affected equipment might also correct undervoltage.

Localized solutions

Some undervoltage conditions cannot be resolved at the source, such as in applications that require long conductor runs to remote systems or to extended equipment in very large facilities. Resolving undervoltage in these cases might require a localized solution.

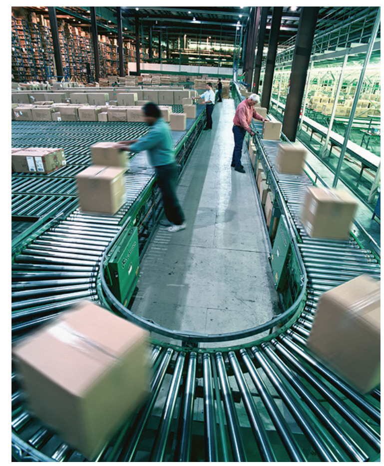


Figure 3—Localized solutions

Some undervoltage condiitons are difficult to resolve at the source, and require localized solutions.

If the control power transformer is undersized, increasing the size might help—but it might not resolve the issue if the undervoltage exists on the primary side. Using a 24 Vdc power supply might also resolve an undervoltage issue, as many newer power supplies have larger input voltage ranges. This solution requires all control components to be converted from a common 120 Vac voltage to 24 Vdc.

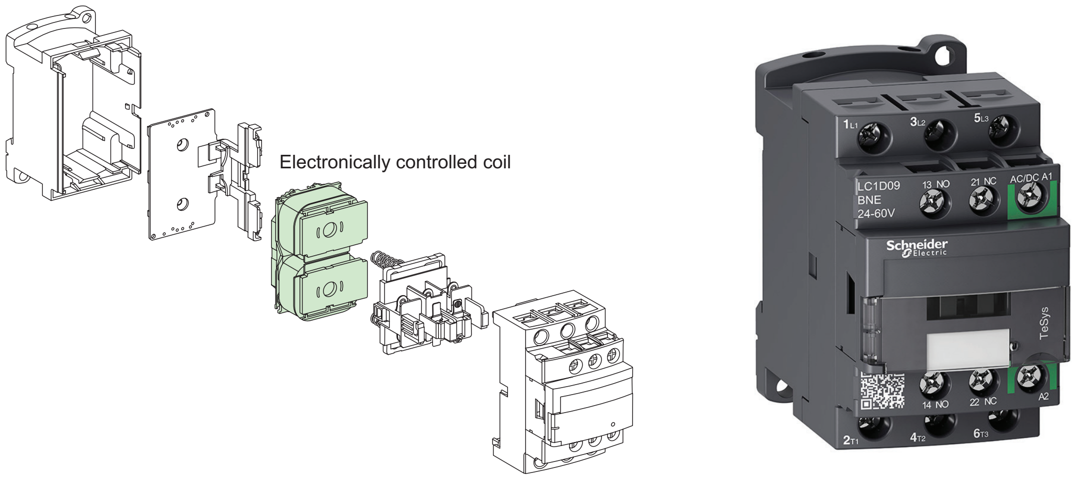
New technology offers another local solution to overcome poor power conditions affecting the motor controller. Circuit board technology integrated into the contactor coil enables a greater tolerance for some power issues such as undervoltage, and offers improved closing and opening performance with lower power consumption.

The TeSys™ D Green contactor by Schneider Electric uses this technology to significantly increase the operating voltage range of the coil (see Figure 4). Popular coil voltage range options include:

- 48–130 Vac/Vdc
- 100–250 Vac/Vdc
- 24–60 Vac/Vdc

Figure 4—Electronically controlled coils

An electronically controlled coil allows the TeSys D Green contactor to increase its voltage range.



This solution allows for a voltage drop of up to 65% from the nominal for 120 or 240 Vac systems without compromising contactor performance. For more information on the TeSys D Green line, contact your local authorized Schneider Electric distributor or sales engineer.

Conclusion

Undervoltage can be difficult to recognize and challenging to resolve. In most applications, the degree of undervoltage is not large enough to create an easily identifiable problem.

Understanding the symptoms is key to diagnosing an undervoltage condition. Undervoltage can become a significant issue when equipment does not perform a critical operation or when downtime results.

Because detection of undervoltage can be challenging, resolutions are often reactive. But in some applications, it is critical to prepare against undervoltage—especially where non-performance can result in significant events such as loss of life, high servicing costs, excessive downtime costs, and loss of reputation. These situations include:

- Equipment used in emergency or life safety applications
- Critical process applications
- Applications where the equipment is difficult to service

Planning, especially in the above applications, can help offset risk associated with undervoltage. Examples of the affected applications include the following:

- Critical use equipment—such as equipment that must be provided with backup generator power according to code—is potentially subject to an increased probability of undervoltage if the generator supply becomes overburdened.
- Machinery and equipment used for remote pumping, irrigation, or agriculture can experience conditions of undervoltage, and can also be difficult to service.
- Single-phase applications have the potential to create an imbalance condition on a three-phase voltage system if not evenly distributed across the three phases. As such, undervoltage can be present for single-phase equipment.

Including solutions that mitigate risks associated with undervoltage is especially prudent in these cases. In these control systems, use of newer technology like TeSys D Green contactors, as well as proper sizing of transformers and conductors, can help the equipment to properly perform its intended function and help minimize the risk of performance issues.

Additional resources

Motor Control Solutions for the North American Market
Data Bulletin 8536DB0901

TeSys D Green Catalog
Catalog LVCATESDELEC-EN

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About the author

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