White Paper

Basic Control of Automatic Transfer Switches

ASCO®

Introduction

An automatic transfer switch (ATS) consists of two primary components, an electrically operated double-throw switch and a controller. Key controller functions include voltage monitoring, control signaling, timing delays, and switch mechanism operation. This paper describes how controllers monitor voltage, frequency, and phase angle differences between Normal and Emergency power sources, and explains how timing delays are applied to ensure the availability of reliable power. While this document specifically describes three-phase systems, many of the principles apply to single-phase systems as well.

Controller Operation

In evaluating whether to transfer loads, modern ATS controllers measure characteristics of incoming power such as voltage, frequency, and phase angle. In the broadest terms, the controller compares the resulting values against user–defined ranges to evaluate the acceptability of a source. If one or more of the values is out-of-range, then the power source is considered unacceptable. Based upon the condition of the sources, the controller may then initiate a series of actions to switch the load.

Power Source Characteristics

Modern ATS controllers typically monitor the same set of parameters between the Normal and Emergency sources. However, it is important to understand each parameter in the context of the source to which it is being transferred. The following sections describe common monitoring functions in the context of each source.

Normal Source Sensing

Most often, the Normal source is an electric utility company whose power is transmitted many miles to the point of use. The ATS controller continuously monitors each line-to-line voltage of the Normal source. If a deviation such as an under-voltage is detected, the controller initiates a sequence to transfer the load to an Emergency power source, most often an engine-generator.

In modern controllers, both the frequency and voltage of incoming utility power are monitored, including line-to-line voltage in both split-phase and 3-phase systems. On 3-phase systems, all three line-to-line voltages should be monitored to provide full protection.

In addition to protecting against total loss of Normal power, voltage monitoring protects loads from damage caused by the loss of power on a single phase, also known as “single phasing”, and by periods of undervoltage or “brownouts”. ATS controllers typically offer adjustable settings for dropout and pickup voltages because the tolerance for low voltage differs among various types of load. The settings can also be adjusted to compensate for the unique characteristics of the power supplied by a specific local utility company.

The dropout voltage is one criterion for initiating transfer of the load to the Emergency source. When the voltage dips below this level, the ATS controller will detect that the power source is unacceptable, and then initiate a sequence of events to transfer the load to the Emergency source. The pickup voltage is one criterion for identifying when a power source is acceptable, and is a prerequisite for re-transferring the load back to the Normal source. Typical settings for most types of loads might be 85% of nominal voltage for dropout and 90% for pickup.

For illustration purposes, the Normal source in Figure 1 will be considered unacceptable only after the voltage decreases below 75% percent of its nominal value. The same source will be considered acceptable only after its voltage increases above 90% of the nominal value. The region where voltage rises from the dropout value to the pickup value represents hysteresis, and is sometimes referred to as “deadband”. The purpose for inserting an interval of hysteresis is to ensure that voltage has become both acceptable and stable to avoid repeated cycling between acceptable and unacceptable states.

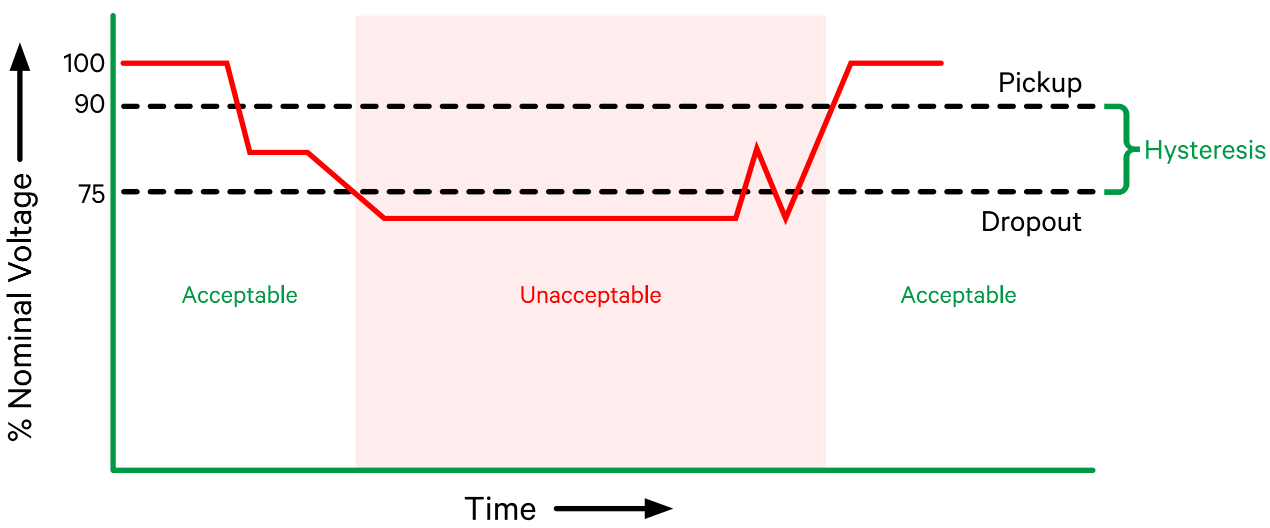

Figure 1: Pickup voltages are typically set higher than dropout voltages to avoid unnecessary cycling of the transfer switch. Voltage is only one parameter considered to assess source acceptability.

ATS controllers also monitor frequency on each phase of the Normal and Emergency power sources. Because frequency is typically well-regulated by utility companies, unacceptable frequency variations on utility power are uncommon. However, facilities at remote locations, such as an offshore oil rig, may use internal combustion engines as the prime movers for both the Normal and Emergency sources, increasing the potential for frequency aberrations on either source. Frequency monitoring of the Normal source becomes especially important in such applications.

Emergency Source Sensing

To ensure that it will reliably carry a load, the voltage of the Emergency source must be monitored prior to transferring load from the Normal source. Thereafter, the voltage should be monitored continuously to ensure that the Emergency source is still capable of carrying the transferred load.

When compared to utility power, frequency variations are more common on Emergency sources, where the capacity of the prime mover is closely matched to the total load of the system. Because engine-generators are susceptible to frequency changes due to momentary changes in load and overloading, the frequency of the Emergency source must be monitored to assure acceptability. Voltage and frequency must be within acceptable ranges for successful transfer or retransfer to occur.

Load Characteristics

In order to optimize dropout and pickup voltage settings, the types of loads must be considered. Several types of loads are best served by dropout and pickup values that are relatively close. For instance, electronic equipment can be sensitive to decreases in voltage. In applications such as health care, data processing, and telecommunications, voltage drops can cause malfunctions in equipment serving critical operations or life-safety systems. A smaller difference between dropout and pickup voltages may be necessary for these types of loads.

Three-Phase Voltage Sensing

When monitoring voltage on 3-phase systems, it is important to consider which phases will be measured. In critical applications, it is necessary to be able to detect a voltage loss on even a single phase. For motor loads, a voltage loss on one phase can cause motor damage or failure. Consequently, voltage should be monitored on each of the three phases shown in Figure 2 below. In cost-sensitive applications, single-phase voltage measurement can provide an acceptable level of monitoring after fully evaluating risks to equipment from undetected singe-phase conditions.

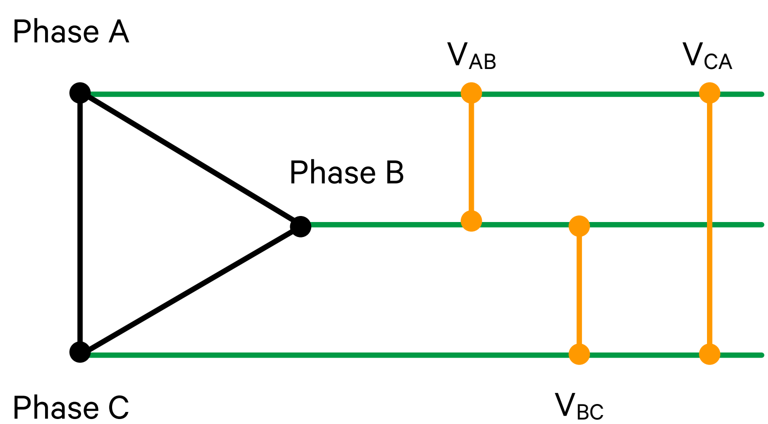

Figure 2: For most 3-phase applications, line-to-line voltages are monitored between every phase.

In-Phase Monitoring

In addition to sensing voltage, there is sometimes a need to monitor the changing phase angle relationship between the Normal and Emergency sources. Doing so will help avoid creating damaging transients when transferring loads between unsynchronized sources of power. One example is in-phase transfer of motor loads.

Automatic transfer switches operate rapidly. Depending on their design and rating, ATSs typically require only a few cycles to transfer a load. For this reason, out-of-phase transfer between two sources will cause a rotor to attempt to instantly move to a new position to match the phase angle of the new power source. The resulting force could stress and damage the rotor, its shaft, or other motor components. The amount of transient current drawn during this event might trip an overcurrent protective device or damage the load equipment.

When switching from a failed Normal source to an engine-generator, it is usually unnecessary to monitor phase angle of the Normal and Emergency sources. When the Normal supply is lost, there usually is a delay of several seconds before the engine-generator develops adequate speed and voltage. During this period, a small motor's residual voltage will decay to near zero. However, when testing transfer switches, loads are often transferred from one live source to another. In this case, it is important to ensure that transfer to the alternate source occurs only when phase angle differences are within an acceptable range. Alternatively, a delayed-transition ATS may be used to introduce a sufficient disconnect time between both sources that will allow for residual voltages to decay.

In-phase monitoring is required for closed-transition transfer of loads, such as digital equipment that cannot tolerate power interruption. A closed-transition transfer momentarily parallels both power sources, avoiding power loss when transferring loads between two live sources. To ensure a safe closed-transition transfer, alternate prerequisites must be met, including tighter tolerances for phase angle, voltage, and frequency differences between the two sources. These are necessary to avoid creating electrical transients while the sources are paralleled.

Timing Delays

In order to prevent unnecessary cycling, an ATS controller typically incorporates timing delays to fully assess power source stability. Controllers also use delays to filter momentary outages or transients that could mask the true suitability of the source. When electrical systems contain multiple transfer switches, ATS controllers may use staggered delays for step-wise loading or unloading of power to or from a source as follows.

Upon detecting a potentially abnormal condition, an ATS controller would continue to monitor the Normal power source for a period of time to verify whether the abnormality is sustained. The controller would consider the Normal power source as unacceptable only if the anomaly remained following the delay. Thereafter, the controller would start the engine-generator for the Emergency source, then delay load transfer to allow that source to stabilize. The controller would then transfer its load to the Emergency source according to its user-configured delay. When the utility source returns to Normal, the controller would apply another user–configured delay, perhaps 10 minutes, to ensure that the utility source is stable. In systems with multiple ATSs, the controllers may retransfer their loads to the Normal source in a step-wise fashion according to their respective re-transfer timing delays. Following re-transfer, a delay may be applied to run the engine for a specified cooling period prior to shut down.

Typical Transfer Sequence

Load Connected to Normal Source

1. **Monitor acceptability of Normal source**
2. **If Normal fails, invoke Engine Start Delay**
3. **Start engine**
4. **Monitor acceptability of Emergency source**
5. **Invoke Transfer-to-Emergency Delay**
6. **Transfer to Emergency if source remains acceptable**

Load Connected to Emergency Source

7. **Monitor acceptability of Normal source**
8. **When Normal source returns, invoke**
9. **Re-Transfer Delay**
10. **Re-Transfer to Normal if source remains acceptable**

Load is Reconnected to Normal Power

11. **Invoke Engine Cooling Delay**
12. **Stop Engine**

The scenario above shows how controllers may apply delays to power system functions at the most elementary level. In practice, additional types of control delays may be applied according to the nature of the application, requirements of users, and the proprietary schemes of specific power equipment manufacturers. Controllers are typically configured to seek the Normal source, but can be configured to seek the Emergency Source.

Summary

ATS controllers measure parameters such as voltage, frequency, and phase angle to assess the acceptability of both the Normal and Emergency power sources. On the Normal source, voltage monitoring protects equipment from under voltages that could fail to carry the load, or could damage load equipment. By setting appropriate drop-out and pickup voltages, users can help ensure that criteria for source acceptability will adequately accommodate the types of loads served by the backup power system as well as the unique characteristics of their local utility.

For Emergency sources, frequency and phase monitoring gain increased importance because these parameters are likely to vary over a wider range. By using various types of delays, controllers can verify whether abnormal conditions actually warrant a transfer of load to avoid unnecessary cycling between acceptable and unacceptable states.

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