

Application Note

Operating Principles of Basler ES-47 Phase Sequence Relay

The ES-47 is a simple, yet advanced microprocessor-based phase sequence relay that can be used on A-B-C (L1-L2-L3) or A-C-B (L1-L3-L2) systems. This application note explains the types of relay-to-system connections and describes ES-47 operating principles.

The ES-47 can be connected directly to systems up to 480 V or connected through a set of voltage transformers (VTs) to systems with higher voltages. To ensure correct operation of the ES-47, it is imperative that the relay be properly connected to the system. There are two basic configurations for connecting the ES-47 to accommodate a system with A-B-C (L1-L2-L3) or A-C-B (L1-L3-L2) phase rotation. A brief review of phase sequence will help you select the correct connection type. It is important to remember that phase sequence is defined with a set of phasors rotating in a counterclockwise direction. Figures 1 and 2 illustrate this principle by showing the phasors in the correct order for both configurations. Note the difference of L2 and L3 between

Figure 1 (L1-L2-L3 rotation) and Figure 2 (L1-L3-L2 rotation).



ES-47 Phase Sequence Relay

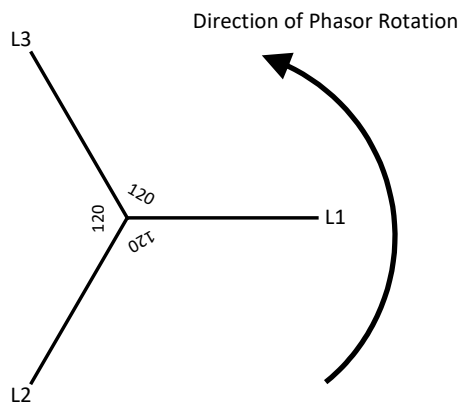


Figure 1 - Phasor Illustration, A-B-C (L1-L2-L3) Phase Rotation

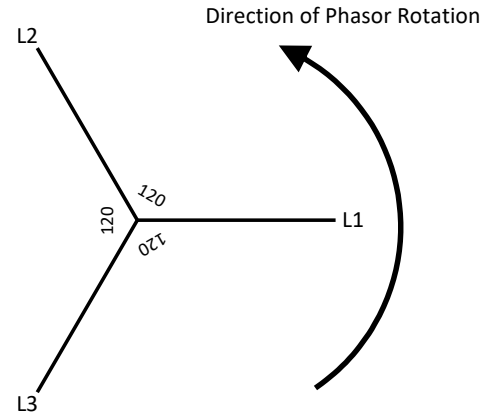


Figure 2 - Phasor Illustration, A-C-B (L1-L3-L2) Phase Rotation

ES-47 connections are shown in Figures 3 and 4. Figure 3 illustrates the connections for A-B-C (L1-L2-L3) phase rotation and Figure 4 illustrates the connections for A-C-B (L1-L3-L2) phase rotation. In the case of A-C-B (L1-L3-L2) connections, the relay's "123" LED lights when the sequence calculations determine that the phase sequence is correct. It does not indicate that the phase rotation is A-B-C (L1-L2-L3). For this reason, the physical connections to L2 and L3 are swapped as shown in Figure 4.

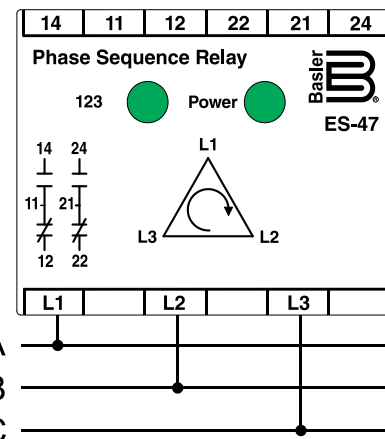


Figure 3 - ES-47 Connections for A-B-C (L1-L2-L3) Phase Rotation

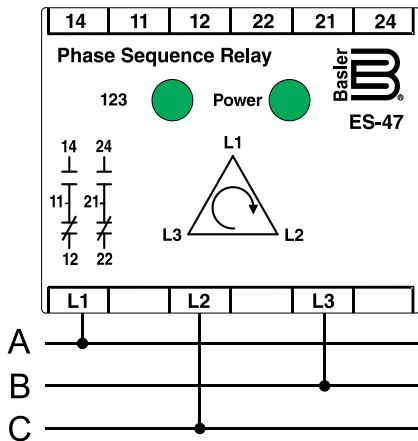


Figure 4 - ES-47 Connections for A-C-B (L1-L3-L2) Phase Rotation

The ES-47 relay operates on the principle of positive-sequence and negative-sequence components. Once the ES-47 is connected to a system and powered appropriately, the three-phase fundamental frequency is extracted and the positive-sequence and negative-sequence components are computed. Then, the quantity of positive-sequence voltage is compared to the quantity of negative-sequence voltage. If the positive-sequence voltage is greater than the negative-sequence voltage and the ratio of positive-sequence voltage to the relay nominal voltage is 75% or greater, the relay will indicate that the phase sequence is correct by lighting the “123” LED and energizing the contact outputs. These calculations provide three key features:

- Ensure proper phase sequence
- Prevent the ES-47 from operating on harmonics quantities
- Enable detection of a loss of phase or undervoltage condition

When properly connected to a balanced three-phase system, the positive-sequence voltage will be equal to the line-to-line voltage at the device terminals. If the relay is connected improperly, the negative-sequence voltage will be equal to the line-to-line voltage. If properly connected when an unbalance occurs, the negative-sequence voltage will increase and the positive-sequence voltage will decrease proportionally to the amount of unbalance.

NOTE

The following example uses sequence component calculations. A full review of sequence components is beyond the scope of this application note. For more information about the derivation of sequence components, see <https://www.basler.com/ResourceDownload.aspx?id=162>. Additionally, a spreadsheet available at <https://www.basler.com/ResourceDownload.aspx?id=113> can be used to assist with sequence component calculations.

For example, consider that an ES-47 with 120 V nominal sensing is connected to a system as shown in Figure 1. This application incorporates fuses and the system is configured as shown in Figure 3 with a system voltage of 120 V line-to-line. If the A (L1) fuse opens, the line-to-line voltages will be A-B = 69.28 V, B-C = 120 V, and C-A = 69.28 V. The positive-sequence voltage will be 69.28 V and the negative-sequence voltage will be -34.64 V. In this case the positive-sequence voltage is greater than the negative-sequence voltage but the relay is secured from operating because a loss of phase or undervoltage condition is realized. The ratio of positive-sequence voltage to the relay nominal voltage is 57.7%, which is less than the 75% threshold. Using this same example configuration, the relay would not operate until the positive-sequence voltage was equal to or greater than 90 V, which would satisfy the 75% threshold. For example, if the system voltages were A-B = 98 V, B-C = 120 V, and C-A = 98 V, the positive-sequence voltage would be 90.71 V which, compared to the nominal voltage of 120 V, is 75.5%.