Phase-sequence indicator uses few passive components

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In a three-phase ac system, a power source with three wires delivers ac potentials of equal frequency and amplitudes with respect to a zero-potential wire, each shifted in phase by 120° from one wire to the next. Two possibilities exist for establishing a phase sequence. In the first, voltage on the second wire shifts by 120° relative to the first, and, in the second, a −120° shift occurs with respect to the first wire. Phase order determines the direction of rotation of three-phase ac motors and affects other equipment that requires the correct phase sequence: a positive 120° shift. You can use a few low-cost passive components to build a phase-sequence indicator.

Figure 1 shows a conceptual circuit that can detect both phase sequences. For certain component values, the following conditions apply: The voltages across R_1 and C_2 are equal—that is, their magnitudes and phases are the same—only when V_{S2} occurs exactly 120° ahead of V_{S1}, which indicates the correct phase sequence. In this case, the voltage between points A and B is zero. Conversely, the voltages across C_2 and R_3 are equal only when V_{S2} is ahead of V_{S3} by 120°, which corresponds to a reversed sequence.

Referring to the phasor diagram in **Figure 2**, when the voltages across R_1 and C_2 are equal, $V_{C1}=-V_{R2}$, $V_{C1}+V_{R1}=V_{S1}$, and $V_{C2}+V_{R2}=V_{S2}$. The following **equations** satisfy these conditions: $|V_{R1}|=|V_{C2}|=(^1\!/\!_2)|V_{S2}|=(^1\!/\!_2)|V_{S1}|$, and $|V_{C1}|=|V_{R2}|=\cos(30°)|V_{S1}|=\cos(30°)|V_{S2}|$. You calculate the component values by solving the following **equations**: $|X_{C1}|=\tan(60°)\times R_1=\sqrt{3\times R_1}$, and $R_2=\tan(60°)\times|X_{C2}|$, where $X_C=-j[1/(2\pi\times f\times C)]$, and f represents the frequency of the V_S voltages.

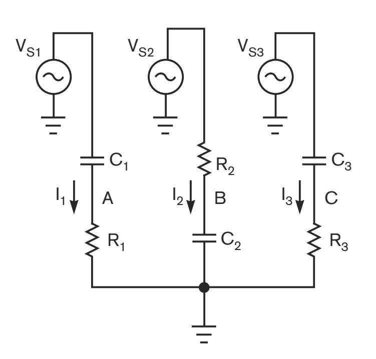

Figure 1 This conceptual circuit can detect both phase sequences.

Also, to ensure detection of a reversed phase sequence, $C_1=C_3$, and $R_1=R_3$; that is, the components in the

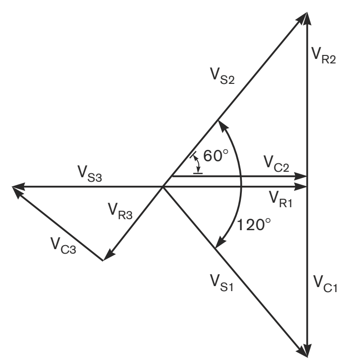

Figure 2 When the voltages across R_1 and C_2 are equal, $V_{C1}=-V_{R2}$, $V_{C1}+V_{R1}=V_{S1}$, and $V_{C2}+V_{R2}=V_{S2}$.

third branch are identical to those in the first branch. The phase-sequence-detection circuit in **Figure 3** eliminates the requirement for an accessible ground wire by adding resistors R_4 and R_5 that connect in parallel with the first and third branches. Eliminating the ground-wire requirement also dictates a ratio between $|X_{C1}+R_1|$ and $|X_{C2}+R_2|$. For no current to flow to ground from Node G, the sum of currents in the branches must equal zero, and, if you disconnect Node G from ground, its potential with respect to ground is also zero.

As long as the proportions of X_{C1} to R_1, X_{C2} to R_2, and X_{C3} to R_3 remain as noted, the balance of voltage drops remains across R_1, C_2, and R_3. Multiplying the impedance of any branch by a constant influences only the magnitude of the currents through the respective branch. The current through any branch presents the same phase angle as the voltage across a resistor in the branch. The phasor diagram in **Figure 4** shows the currents in **Figure 3**. From this diagram, if $|I_2|=\tan(60°)\times|I_1|$, then $I_1+I_2=-2\times I_3$. Thus, I_3 has half the magnitude of and an exactly opposite direction from (I_1+I_2).

A vector diagram of the currents shows that adding two currents, each with magnitudes equal to I_3 and the same phases as V_{S1} and V_{S3}, produces a summed current with the same magnitude and phase as I_3; therefore, the total current at Node G is zero: $I_1+I_2+I_3+I_1'+I_3'=I_1+I_2+2\times I_3=0$. To make the sum of the currents equal zero, $R_4=R_5=|R_1+X_{C1}|=|R_1-j[1/(2\pi\times f\times C_1)]|$. The two LEDs in **Figure 3** indicate correct or reversed-phase sequence. When LED_2 lights and LED_1 remains dark, the voltage between nodes A and B is 0V, which corresponds to a correct phase sequence. A reversed-phase sequence lights LED_1 while LED_2 remains dark. The diodes connected in parallel with the LEDs protect against exceeding the LEDs' reverse-breakdown voltages, and resistors R_6 and R_7 limit forward currents through the LEDs. For greater sensitivity, you can replace the LEDs with high-input-impedance ac-detector circuits.

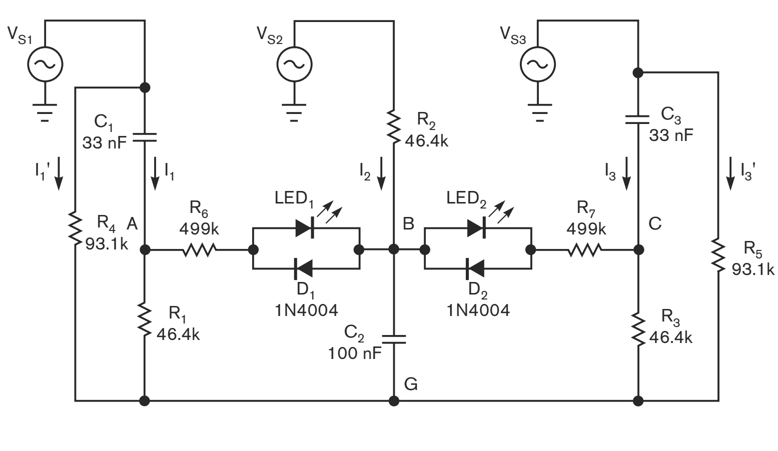

Figure 3 This phase-indicator circuit balances branch voltages and currents and requires no ground reference. These component values are for a 60-Hz line frequency.

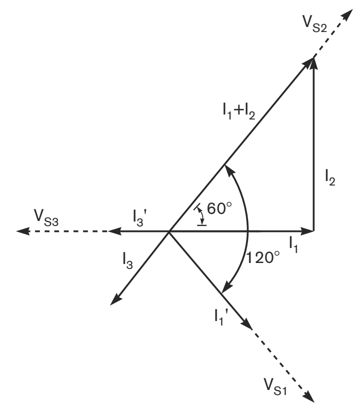

Figure 4 I_3 has half the magnitude and an exactly opposite direction to (I_1+I_2) in Figure 3.

The circuit's final version includes indicators that show whether all three phases carry voltage. In the circuit in **Figure 3**, a phase that carries 0V lights both LEDs. Depending on your application, you can connect voltage-detection circuits comprising LEDs and protection diodes in series with current-limiting resistors between V_{S1}, V_{S2}, and V_{S3} and Node G. You can also use low-wattage neon lamps with appropriate series-current-limiting resistors.

When selecting components, ensure that their values conform to the following proportions. For an arbitrarily chosen value for C_1, $R_1=R_2=R_3=1/(2\pi\times f\times C_1\times\tan(60°))$, $C_1=C_3$, $C_2=3C_1$, and $R_4=R_5=2\times R_1$. When you select a value for C_1, the currents through the detection circuitry should be significantly lower than the currents through the branches, which excludes arbitrarily low values for C_1. EDN