Electrical TECHNOLOGY

Electrical Tech Note — 219

Biosystems & Agricultural Engineering Department
Michigan State University

Single-Phase, 120/240 Volt, 3-Wire Electrical System

Electrical power is delivered to customers by means of distribution lines with at least one wire operating at several thousand volts as measured to the earth. The utility installs a transformer near the customer location to convert the high distribution voltage to a level that is safe and convenient for the customer. Typical electrical equipment and appliances sold in the United States operate at 120 volts with larger appliances such as clothes dryers and electric ranges operating at 240 volts. Since equipment and appliances in the home operate at 120 volts or 240 volts, it was necessary for the electrical system to provide both voltages.

Center Tapped Transformers: A transformer is used to convert the high voltage of the distribution line to 240 volts for the typical residential customer. If the secondary winding of the transformer has a wire connected to the center of the winding, the voltage between that winding and either of the other two windings will be 120 volts. This is illustrated in Figure 219.1. Concern over lightning damaging the electrical system and equipment by striking a wire or near a wire lead to the grounding of this 3-wire electrical system to the earth. Electrical codes require the common wire (center wire) to be grounded to the earth. By grounding the common wire, there will be two wires not grounded and they are referred to as the ungrounded wires. The ungrounded wires are frequently called the hot leg A and leg B. In a 3-wire single-phase electrical system such as the one shown in Figure 219.1, the common wire is called the neutral.

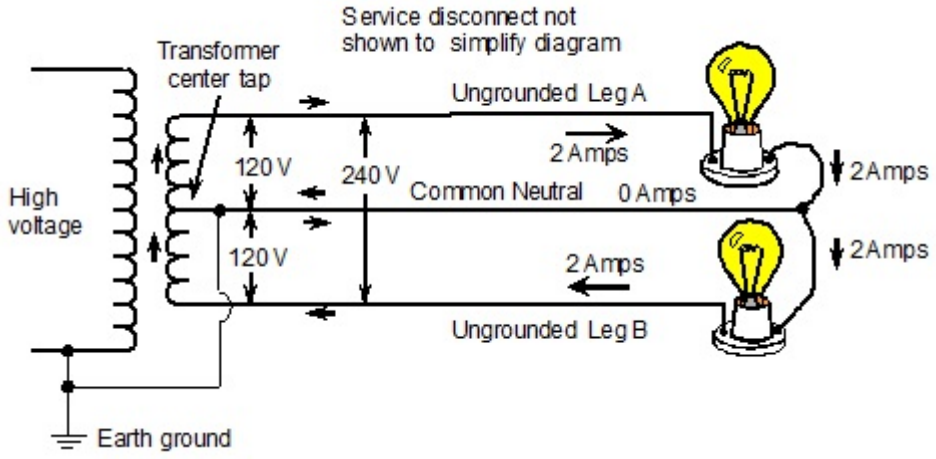

Figure 219.1 *A 3-wire electrical system is created by attaching a center tap wire to the secondary winding of a transformer thus producing 120 and 240 volts.*

Since there is 120 volts from the center tap wire to either of the other wires, the center tap wire was called the common. If two identical 120 volt loads are connected one to each of the ungrounded wires from the transformer, the current flow measured on the common wire is zero. In this condition the 120 volt loads are considered to be balanced. The current flow on the common neutral is the difference between the current flow on the two ungrounded wires.

Copyright 2009/2018, Biosystems & Agricultural Engineering Department, Michigan State University. All rights reserved.©

Single-Phase 3-Wire Electrical Panels: To provide maximum safety, the *National Electrical Code* requires that a means be provided to disconnect power from the two ungrounded conductors as they enter a building. The electrical code calls this the main service disconnect. It is usually the main circuit breaker in the electrical panel of the building. This is illustrated in Figure 219.2 where the three electrical wires from the utility transformer are shown entering the electrical panel. The ungrounded conductors are attached to the main circuit breaker, and the neutral conductor connects to a neutral terminal block in the panel. The utility is required to connect the neutral conductor to a ground rod in the earth at the transformer. The electrician installing the service in a building is required to ground the neutral conductor to the earth at the service of the building. This connection is usually made to a metal water pipe entering the building or to a ground rod driven into the earth to a depth of not less than 8 ft.

Circuit breakers attach to the electrical panel in such a way that they connect to metal conducting bars called bus bars. There are two bus bars in a single-phase electrical panel, one for each of the ungrounded conductors entering the panel. These bus bars are not energized unless the main circuit breaker is turned on. There are two types of circuit breakers that can attach to a single-phase panel. A single-pole circuit breaker attaches to just one of the energized bus bars. A 120 volt circuit originates from a single-pole circuit breaker. It takes two wires to make a single-phase circuit, and the other wire originates at the neutral terminal block. This is also illustrated in Figure 219.2. If a circuit is wired with electrical cable, the black wire attaches to the circuit breaker and the white wire attaches to the neutral terminal in the panel.

A two-pole circuit breaker is used to power a load that requires 240 volts. In this case there generally is no neutral involved. The electric range and electric clothes dryer circuits are exceptions. The circuit breaker attaches in such a way that it makes contact with each of the two ungrounded bus bars. When the circuit breaker is turned on, there will be 240 volts between the two output terminal screws. Safety grounds are required for all circuits in addition to the insulated circuit wires, but they are not shown for the circuits in Figure 219.2.

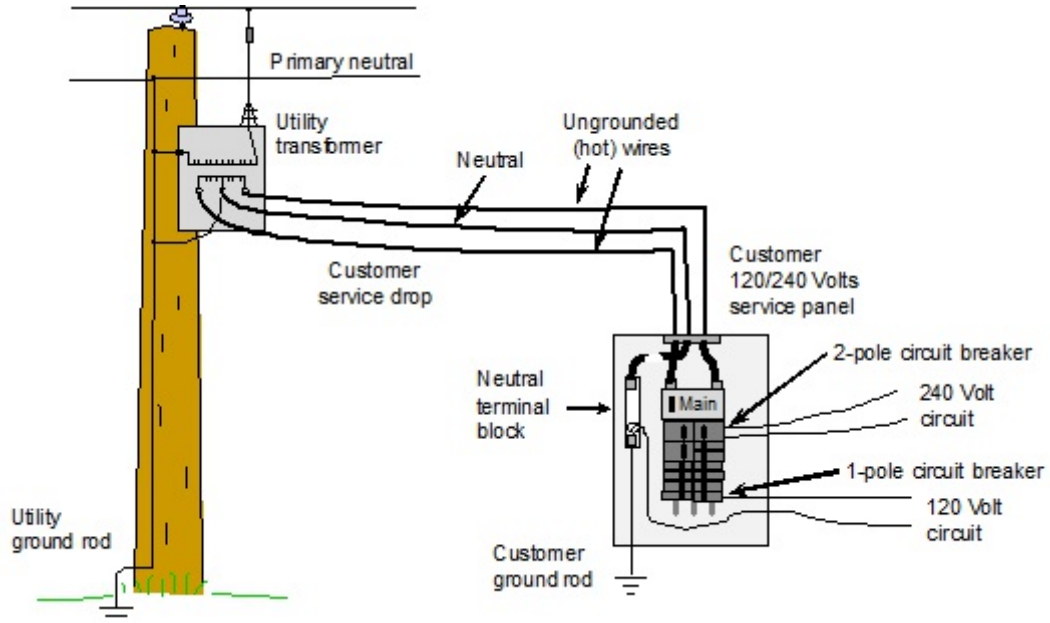

Figure 219.2 *The two ungrounded wires from the utility transformer connect to the main circuit breaker and the neutral conductor connects to the neutral terminal block. A 240 volt circuit originates with a 2-pole circuit breaker, and a 120 volt circuit originates at a 1-pole circuit breaker with the other wire connected to the neutral.*

Copyright 2009/2018, Biosystems & Agricultural Engineering Department, Michigan State University. All rights reserved.©