Industrial Site Power Distribution

An Online Continuing Education Course for Engineers

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1. Introduction

The use of electrical power by industry is a relatively new phenomenon. The first electrical transmission line started operating on June 3, 1889 and transmitted power at 4000 volts of direct current between the generating station at Willamette Falls in Oregon to downtown Portland, Oregon. The electrical energy was used to power 55 arc lamps in downtown Portland, Oregon. The lights would have had to be in series, and if so, each would have about 70 Volts across it. The original generator was a 32.5 Kilowatt generator and was located in Station A. If these numbers are correct, the power use of each light would be about 600 watts. There were originally 4 of these generators and later up to 11 were operating. In 1895 Station B was opened as an Alternating Current generator and is still in operation today at a rated output of 14 Megawatts. As of 2015, that's only 126 years ago. We have come a long way since then. Today the United States uses about 4000 Terawatt Hours ($4 * 10^{15}$ watt hours) of electrical energy every year. To put this into perspective, a 100 Horsepower motor running at full load for one year uses about 700 Megawatt Hours ($7 * 10^{8}$ watt hours) of electrical energy per year. Another way of looking at this is that would be 5.7 million 100 Horsepower motors running full load full time all year long. Clearly, we use a lot of electrical energy in this country, much of it in industrial applications.

Just for reference, Niagara Falls first produced electrical power in 1881 for local industry. Alternating Current generation started on August 26, 1895. By 1896, 75 megawatts of electrical energy were being created and some of that power was being sent to Buffalo, 20 miles away. Because of the increased use of electrical energy and the hazards associated with electrical energy, the National Electrical Code (NEC) came into being and was first published in 1897. The publication was done by the National Fire Protection Association, which publishes the NEC to this day. Presently it is updated every 3 years.

Of the approximately 4000 Terawatt Hours of electrical energy use, about 1500 Terawatt Hours is used for commercial use, 1500 Terawatt Hours for residential use and only 1000 Terawatt Hours is for industrial use. That means that about 25 % of the electrical energy used in the United States is for industrial purposes. That much energy needs to be distributed to the industries using electrical energy, and once distributed to the customers, it needs to be distributed within the individual machines and other devices, including illumination.

2. Single phase Use of Electrical Energy

Many companies have been started in someone's garage, kitchen, or basement. In most such cases, the only electrical power source available was single phase 120/240 Volts AC power. Figure 2.1 shows a schematic of this source.

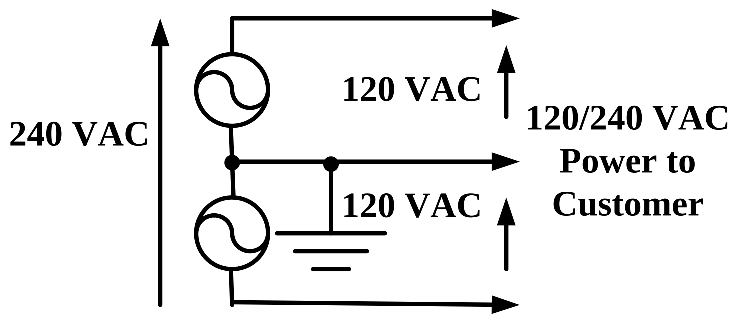

Figure 2.1 Schematic of a Standard 120/240 Volt Single Phase Supply

An example of a one man garage started company is Hewlett Packard, started in 1939 in Palo Alto, California by Bill Hewlett and Dave Packard. The initial investment was $538. Its first successful product was a Model 200A Audio Oscillator. One of their first customers was Walt Disney who purchased 8 of the Model 200A's for use in the making of the movie "Fantasia". Today Hewlett Packard is a world wide company with revenues of $112.3 billion in 2013.

The single phase transformers were usually pad or pole mounted transformers that transformed the higher voltage distribution voltage to the lower 120/240 volts that supplied a residence or neighborhood. The grounding, shown in Figure 2.1, is a very important part of the safe use of electrical energy. Article 250 of the NEC covers grounding. Because of safety considerations proper grounding of power circuits is very important. About 33 of the over 900 pages of the2014 NEC are used to cover grounding requirements. What is shown as a symbol in Figure 2.1 is actually specified in the NEC. Table 250.66 (Grounding Electrode Conductors for Alternating Current Systems) specifies the size of the Grounding Electrode Conductor necessary for the size of the incoming service conductor. For example, Number 2 copper Service Entry Conductor requires a Number 8 copper or Number 6 aluminum ground wire. Article 250.52 specifies that the grounding conductor be connected to earth by means of a ground rod at least 8 feet long and/or metal underground water pipe. Article 250.52 specifies several other allowed Grounding Electrodes. For obvious reasons, underground gas piping systems are not allowed as grounding electrodes. Aluminum is also not allowed. Figure 2.2 shows pictures of typical transformers. The pole mounted transformer is usually used where electric power is transmitted in overhead lines. They can be mounted in ground level enclosures, but this is unusual. The pad mounted transformers are used where underground distribution of electrical power is done. Many newer applications in suburbs use underground distribution for esthetic purposes. Since you can't see underground wires, they are prettier than above ground wires. The Pad Mounted Transformers are required to be locked according to Article 110.31(A)(4). This is to prevent unqualified persons from being injured or killed by the high voltage present in these enclosures.

Figure 2.2 Pictures of Pole Mounted and Pad Mounted Single Phase Transformers

These single phase supplies can supply the power to run small machines, computers, motors, and whatever other equipment is utilized by our garage and backyard entrepreneurs. These entrepreneurs are quite often quite ingenious in their use of this 120/240 Volt AC power. Figure 2.3 is a schematic showing the single phase distribution transformer and also showing the ground connections and primary switch and fuse. The primary switch and fuse is quite often the same device. This is especially true for above ground distribution wires. The National Electric Code is very specific on keeping high voltage connections away from where people can touch them.

Metering for this 120/240 VAC single phase would almost always be on the low voltage or customer side of the distribution transformer. If one side of the distribution transformer is grounded, as is often the case, there is the need for only one fuse. If the incoming distribution voltage is two legs of a high voltage supply, it would be necessary to switch and fuse both lines. For the secondary of the transformer, it is required to always ground the center tap of the transformer. This is not only a requirement in Article 250.24 of the National Electric Code, but is also an important safety consideration.

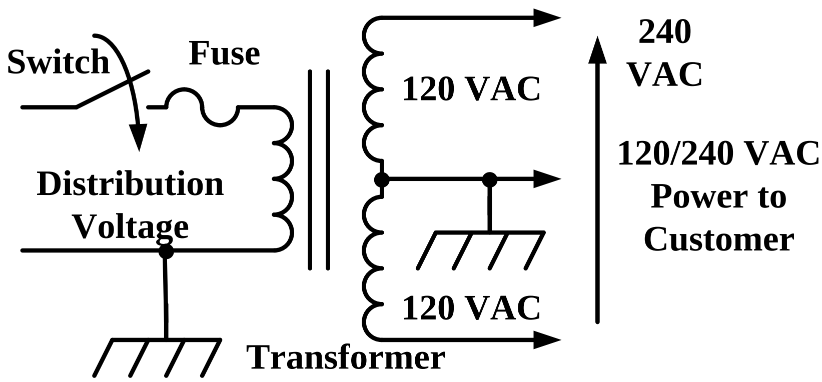

Figure 2.3 Schematic of Single Phase Supply Showing Transformer and Protection

The National Electric Code (NEC) in article 250.119 requires the grounding conductor to be either bare or green or green with one or more yellow stripes. These grounding conductors cannot be used for other purposes such as grounded or ungrounded conductors. As an explanation, a grounding conductor does not normally carry current. The green wire shown in Figure 2.4 is a grounding conductor. Its main function is to protect against electrical shock. It will never carry current except in a case of one of the hot conductors, shown in red and black, shorts out to the metal frame of a piece of equipment. The National Electric Code does not have a requirement for the color coding of the hot wires, but black and red are quite often used by consensus. In case of a hot wire touching a metal frame, the grounding conductor needs to be able to carry enough current to cause the circuit to open, either by tripping a circuit breaker or by blowing a fuse. In any case, a person touching the frame of a piece of equipment will not experience a shock because the grounding conductor is connected to earth ground.

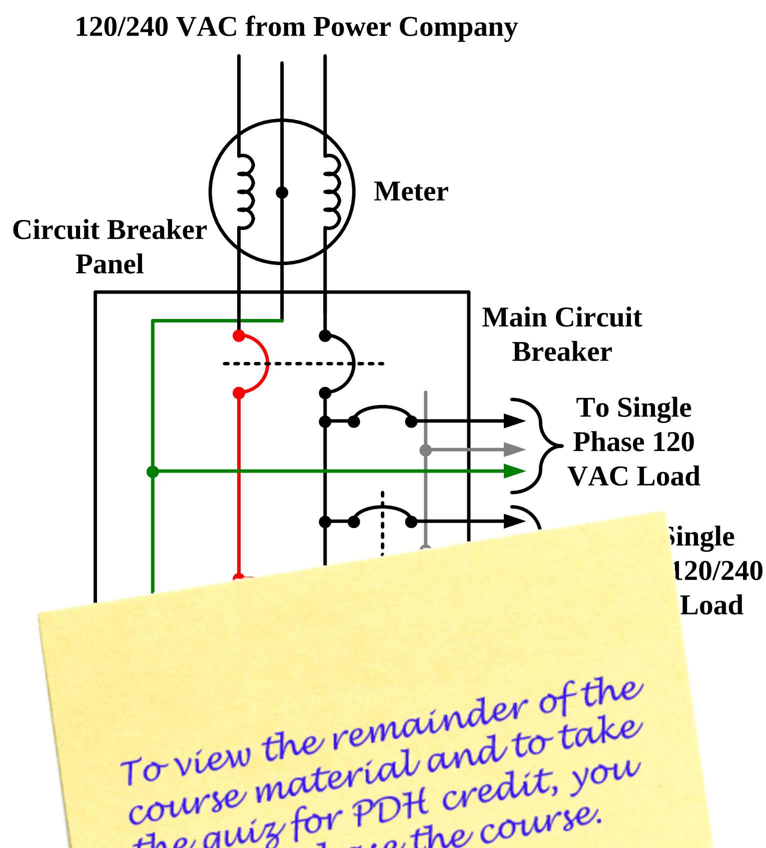

Figure 2.4 Sc... ...aker Panel

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Table 250.122 covers the ... quired for raceways and equipment for circuit ... nd circuit breakers. For example, a 15 Amp cir... 20 Amp circuit requires a Number 12 gro... res a Number 10 grounding conductor. Wh... highly recommended that the NF... nal Electric Code be referred to directly. As ..., but is used by many government and private or... wiring to new and existing structures is being done. Quite often it is necessary to work with local and/or regional authorities when specifying or doing electrical work. The electrical inspector or other Authority Having Jurisdiction (AHJ) can always be counted on to be helpful in areas of confusion or misunderstanding. Quite often it is helpful to have a complete copy of the NEC available to help with any questions that might come up.

The customer is fed the power by means of a fuse or circuit breaker panel. Protection in newer construction is almost always by means of circuit breakers. Figure 2.4 shows a schematic of the meter and circuit breaker panel in a typical installation. Figure 2.5 shows a typical residential single phase 200-amp circuit breaker panel with a main breaker. In this panel, the ground and