Electric Power Distribution Model

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Abstract:

This paper describes a student project that focused on understanding the distribution system of a local Rural Electric Cooperative Company (RECC). The project's intention was to familiarize undergraduate students with the organizational form of the local electric power companies, and their electric distribution systems. We will briefly explain the history and organizational structure of a local nonprofit Rural Electric Cooperative Company (RECC). We will explore the concept of a consumer owned, consumer controlled, and nonprofit RECC. We will explain the organizational form of an Inter-County RECC. We will also consider loan financing and operational expenses of these types of utility companies. How does deregulation of electric utilities affect the Rural Electric Cooperative Company (RECC)? A better understanding of a RECC should help us to forecast their future in a time of Electric Utility deregulation.

Students used electric simulation software to build a model of the electric utility transmission system displayed in figure 1. The model shows a common method of generating electricity via a Steam Turbine Electric Station, and a Hydroelectric Station. The transforming of nominal alternating voltages from the stations to high voltage for transmissions will be simulated. Different step down configurations such as the Wye connected and Open Delta connected transformers, and the system configuration shown, is a typical layout for one of the local electric cooperative utility companies. After a plant visit and discussion with company officials, students built the model and explored transformer configurations. Six sub circuits simulate substations where AC voltage is stepped up, or down. The first sub circuit in the simulation represents three individual generators generating 3-phase, 34KV, 60 HZ electric power. The second sub circuit is a Wye-Wye connected transformer that produces 345KV AC voltage for long distance transmissions in remote areas. The third sub- circuit is a Wye-Open Delta transformer configuration to step down the transmission voltage to 115KV in the vicinities close to the city. The fourth sub circuit shows reduction of 115 KV to 11.5 KV for local distribution in the city. The fifth sub circuit displays a typically Pad-mounted transformer that provides a usable nominal voltage of 3-phase, 460 volts for light industrial and manufacturing plants. The sixth sub circuit shows a typical single-phase step down transformer that provides common residential single-phase, 120/208 voltage. This voltage is connected to a circuit simulating a Three-Way / Four-Way switch, providing connection to a 120V light bulb.

Introduction:

In order to become familiar with a generating system, students toured the E.W. Brown plant in Burgin, KY. They spoke with the head electrician in charge of the plant. They also visited the metering division of Kentucky Utilities, in Danville, KY. In addition, they visited the Inter-County Rural Electric Cooperative Corporation (RECC) in Danville, KY, where they learned about the history of rural electrification. Once students completed their research on the facilities, they used several available text books [1, 2, 3] to review their understanding of the operation of electric generators, power transmission lines, and transformers. Finally, they used simulation software [4] to build and simulate the power distribution layout displayed in Figure 1.

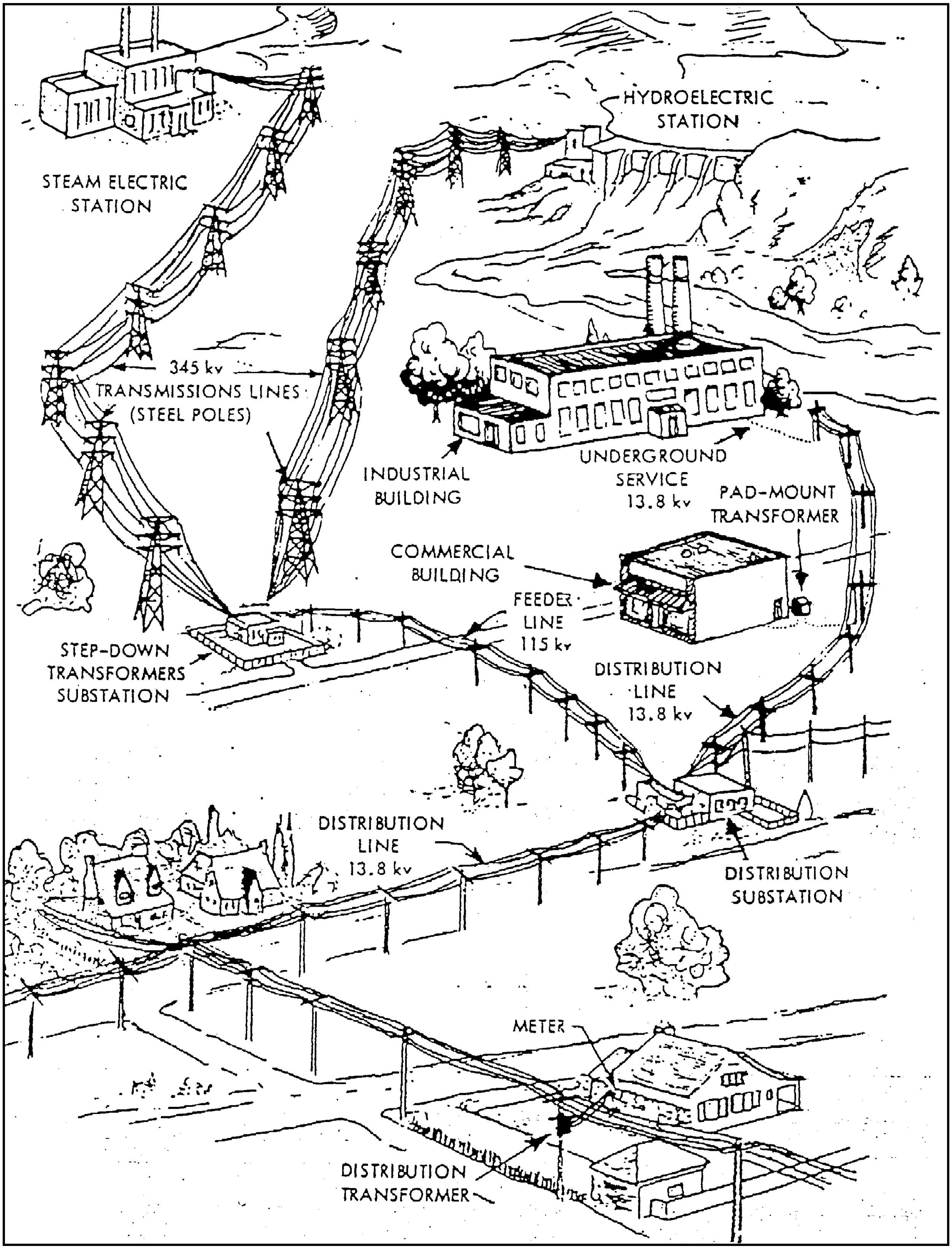

Figure 1 Transmission of Electrical Power from the Generating Station to the Consumer.

Brief Historical Facts:

It has been possible since 1915 to provide electricity to farms as far as 100 miles from generating plants. Only 10% however, were receiving electricity in 1935. As citizens of the United States we consider our nation to be the world leader in most areas of technology. In 1935 the United States was by no means the leading nation in rural electrification. Smaller nations of the world were significantly ahead of the United States in this field. Where as we had 10% rural electrification, Sweden had 65%; Denmark 85%; Japan 90%; France 98%; and the Netherlands 100%. With these imminent facts, it was long overdue that rural America be electrified.

Citizens in rural America were concerned about the lack of electrification. These citizens were seeking electric service in hopes of receiving the many benefits such service would provide. This seemed only fair, considering the many years city dwellers had enjoyed the ease and rewards of electric service. To help rural people in the implication of electric service, the Rural Electrification Administration (R.E.A.) was formed by an executive Order of the president of the United States, Franklin D. Roosevelt, on May 11, 1935. Currently, R.E.A. is referred to as Rural Utilities Service (R.U.S.).

The purpose of this agency was to make long term, low interest rate loans, to the existing utility companies. The utility company was to then construct electric lines in these rural areas. Even though these loans were available through R.E.A., these requests fell on deaf ears and service was not forth coming.

Local People Serve Themselves:

In the United States of America, the country of free enterprise there are four basic structures of business. They are, Individual Ownerships; Partnerships; For-Profit Corporations; and Non-Profit Cooperative Organizations. Since no one else in the nineteen-thirties (1930's) was willing to serve the sparsely populated rural areas, the people organized their own businesses and served their own needs. After becoming legal entities, with the help of borrowed monies from the Rural Electrification Administration (R.E.A.), the cooperative constructed lines in rural areas.

On June 14, 1937, a small group of people from Boyle, Garrrad, and Marion Counties met in the Farm Bureau Office in Danville, Kentucky and officially organized the Inter-County Rural Electric Cooperative Corporation (R.E.C.C.). The local rural electric cooperative borrowed money with low interest rates from the Rural Electrification Administration (R.E.A.) to begin construction of electric lines. The first lines in the Inter-County RECC's service area were energized from the Perryville Substation on June 10, 1938. The Garrad Substation was energized on August 24, 1938, and the Marrion County Substation was energized in September of 1938.

People in adjoining counties contacted the Inter-County RECC in an effort to obtain electric power in their areas. As a result, the Inter-County RECC now serves twelve (12) counties. It serves six (6) major counties and serves a small number of members in six (6) other counties. As of the end of December, 1996, the Inter-County RECC served 19,689 consumers on 3,025 miles of line. Table 1 lists the number of consumers served in each county.

A cooperative enterprise is one which belongs to the people whom it serves. The control rests with the members, and any economic gain is distributed to the members in proportion to the use they make of its services. It must be understood that a cooperative is organized to provide services, not necessarily for the purpose of a large cash return to members. In addition, the cooperative is not organized to compete with the local For-Profit Electric Companies.

County	Number of Consumers	County	Number of Consumers	County	Number of Consumers
Boyle	2,791	Lincoln	5,634	Nelson	320
Casey	1,584	Madison	53	Rockcastle	28
Garrad	3,370	Marrion	3,882	Taylor	60
Larue	127	Mercer	1,638	Washington	202

Table 1. Counties and Number of Consumers in the Inter-County RECC.

A review of the past history of the RECC's members indicate that they doubled their electric power consumption every seven to nine years. In recent years, the growth rate has slowed down due to conservation methods and consumers using more efficient equipment. Increased consumption is due primarily to the addition of new consumers and the fact that existing consumers are placing more electric devices on the system.

The System Circuitry Layout:

Figure 2 displays a computer model of the distribution layout displayed in figure 1. Students used the Electronic Workbench 5.1 for Windows 95 software to simulate the distribution model [4].

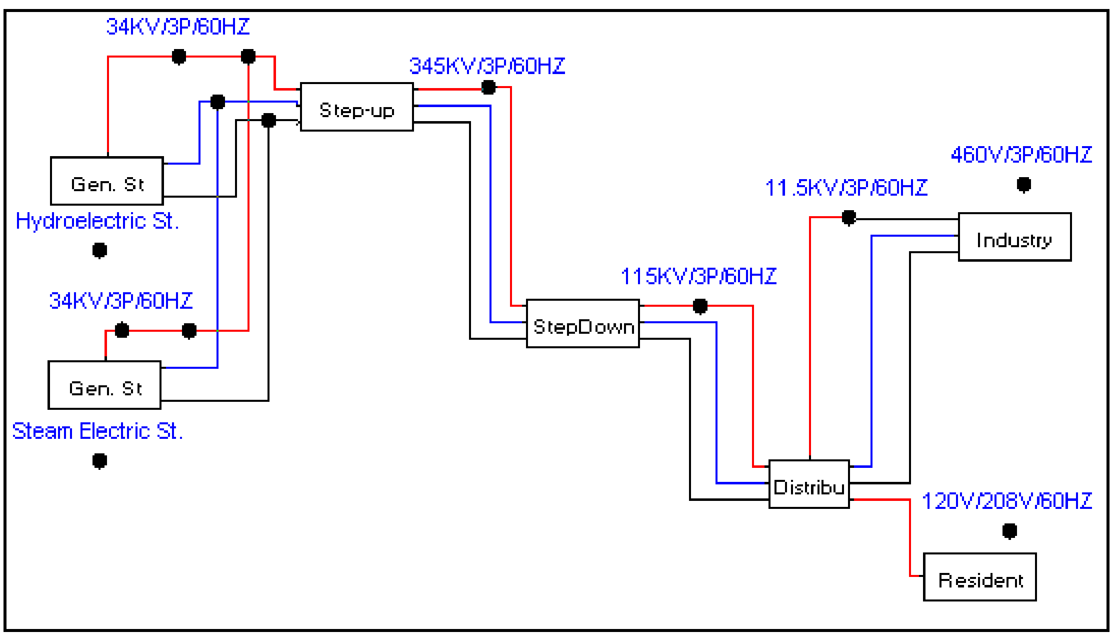

Figure2. Simulation Circuit for the Main Distribution Layout.

The model consists of two generating stations; a Steam Turbine Electric Station, and a Hydroelectric Station. Figure 3 displays a computer model of a Three-Phase, 34KV, 60 HZ generating station. The power lines from these stations are connected together in the first substation. The substation includes Three-Phase step-up transformers to change the voltage to a higher voltage value of 345KV.

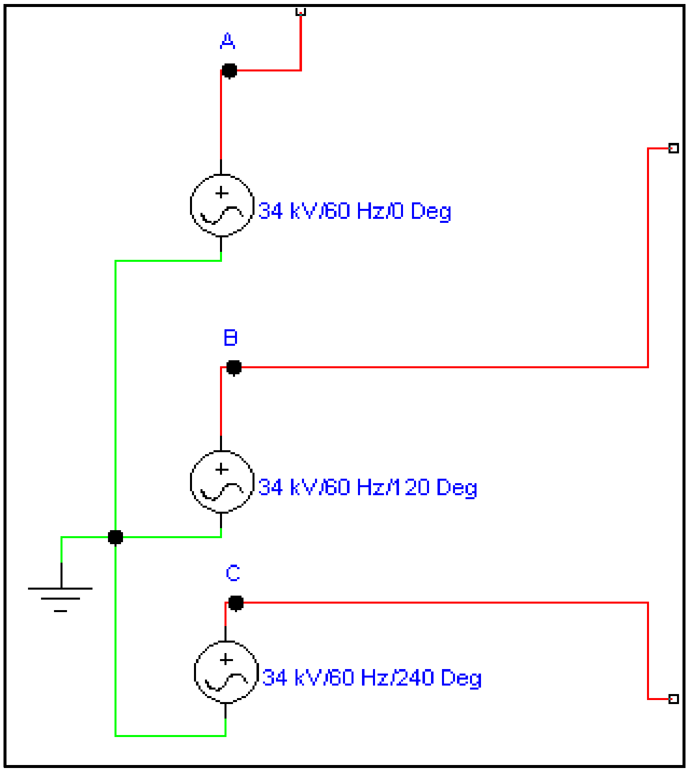

Figure 3. Wye Connected, Generator Model.

Figure 4 displays a computer model of three transformers connected in a Wye-to-Wye, step-up configuration. The three-phase transformer displayed in figure 4 is a "1-to-10", step-up transformer. The high voltage transmission lines will deliver electric power to the second substation. Resistive losses are reduced due to the high voltage setting of the electric utility. High voltage transmission lines are typically located in sparsely populated Wilderness areas of the country. These Aluminum power lines are not insulated. They are placed on very large, approximately one hundred feet tall metal poles. Guy Wires sometimes support these metal poles. Figure 1 displays these poles.

Figure 5 displays the computer model of a Three-Phase, Wye-Delta connected, Step-down transformer housed in the second substation. The three-phase transformer displayed in figure 5 is a "3-to-1", step down transformer. Typically, the voltage is stepped down to 115 KV. The lower "high voltage" power lines are used to carry electricity to the vicinity of towns, and cities. These Aluminum power lines are also not insulated. They are placed on wooden, or smaller metal poles. The 115 KV electric power is delivered to the Distribution Substation. The Distribution Substations are located outside towns, and cities.

The Distribution Substations house three phase transformers that will step down the voltage to a voltage level between 14.4 KV and 11.5 KV. Power lines placed on wooden poles carry electric power to towns and cities, and then to consumer sites. Figure 6 displays the computer model of a three-phase, Delta-Wye connected distribution transformer. The three-phase transformer displayed in Figure 6 is a "10-to-1" step-down transformer. This transformer will step down the voltage level to 11.5 KV. Insulated Copper or Aluminum power lines carry these voltage levels in towns and cities. Figure 1 displays the 115 KV, and 13.8 KV power lines and their associated poles.

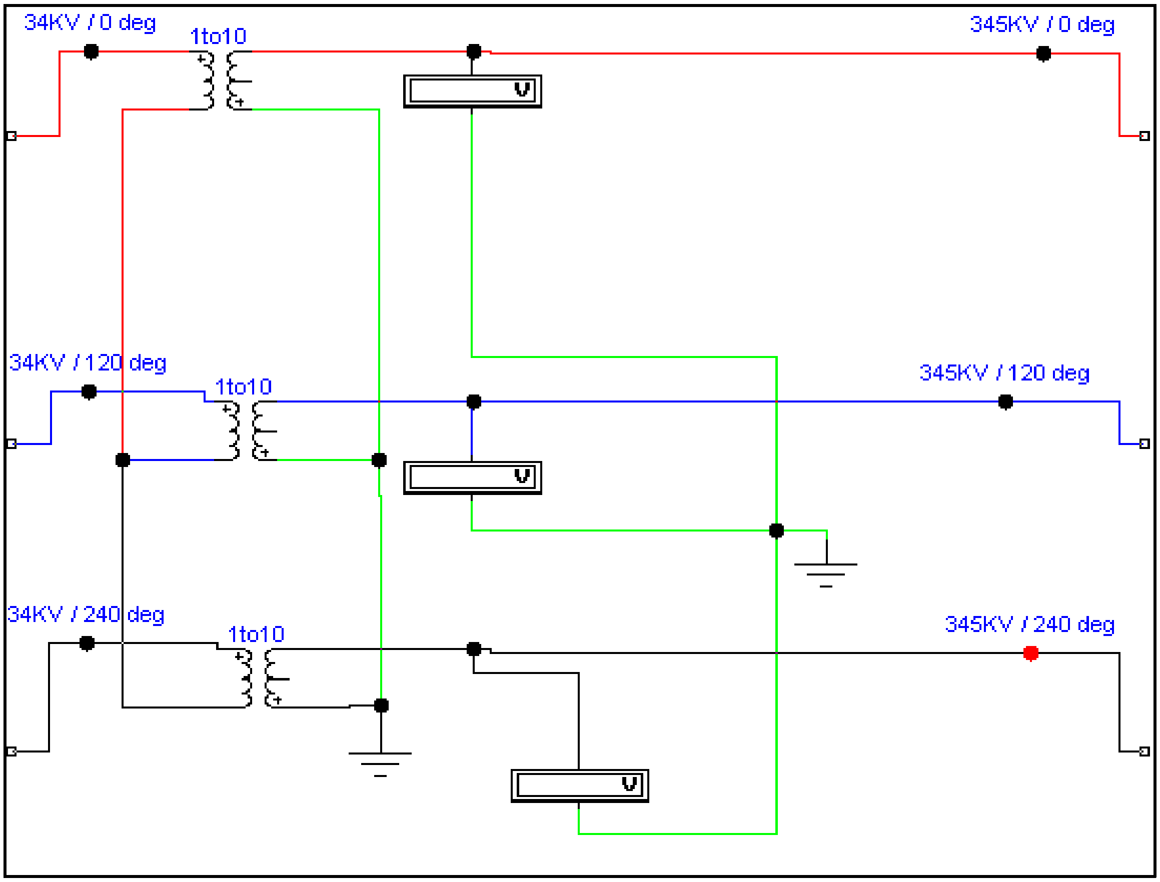

Figure 4 Three-Phase, Wye-to-Wye Connected, Step-Up Transformer Model.

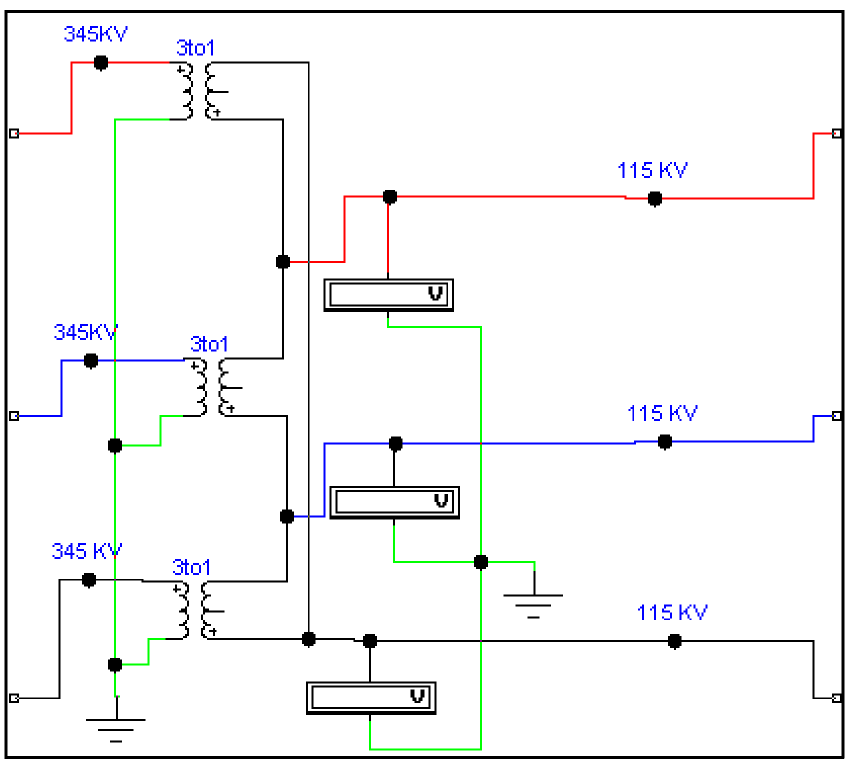

Figure 5 Three-Phase, Wye-to-Delta, Step down Transformer.

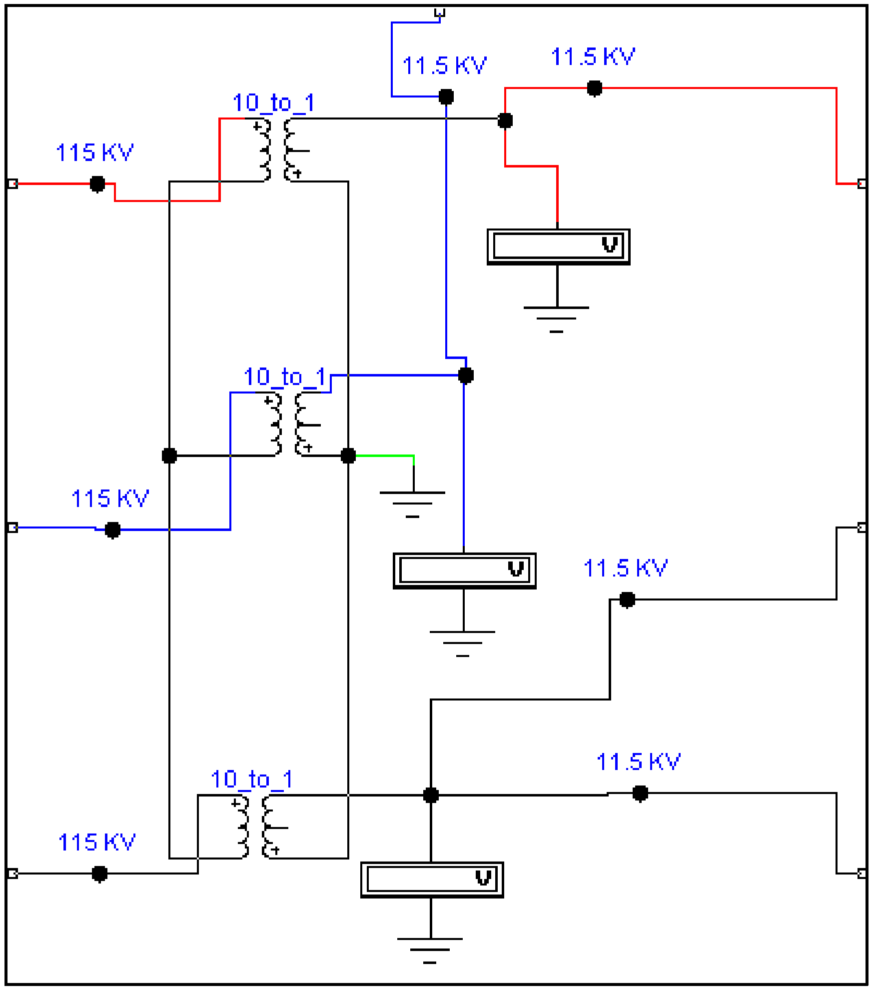

Figure 6 Three-Phase, Delta-to-Wye, Distribution Transformer.

Pad-mounted, Three phase transformers are used to supply 460V, 3-Phase, 60HZ electric power to manufacturing and industrial plants. Figure 7 displays the computer model of a “25-to-1", Wye-Delta connected, three-phase, step-down transformer. Underground cables deliver electricity to a main utility room inside the plant, where the cable is connected to a main circuit breaker.

Pole-mounted single phase transformers are used to provide single phase 208V / 120V electric power to the residential homes. Figure 8 displays computer model of a pole-mounted, “50-to-1", step down transformer. Typically, the overhead lines are connected to a 100 Ampere or 200 Ampere main circuit breaker located in the basement, or garage.

The 208 voltage electricity is used by the Heating / Ventilation /Air-Conditioning (HVAC), Electric Range, and Washing / Dryer machines. While the 120 voltage electricity is used for lighting and receptacles. Figure 9 displays a computer simulation of Three-Way and Four-Way switches connected to the lights in the corridors and halls.

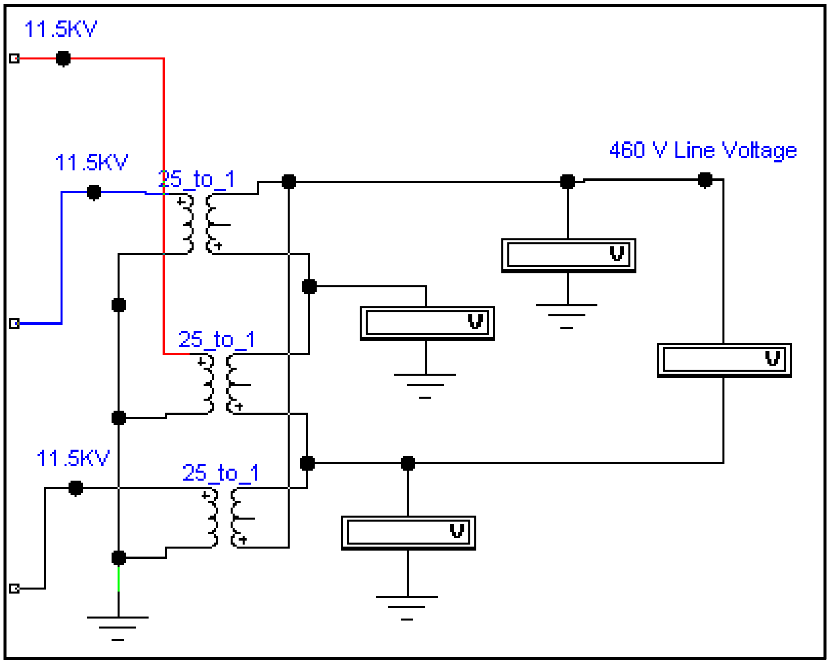

Figure 7 Three-Phase, 460 Volt Pad-mounted Transformer.

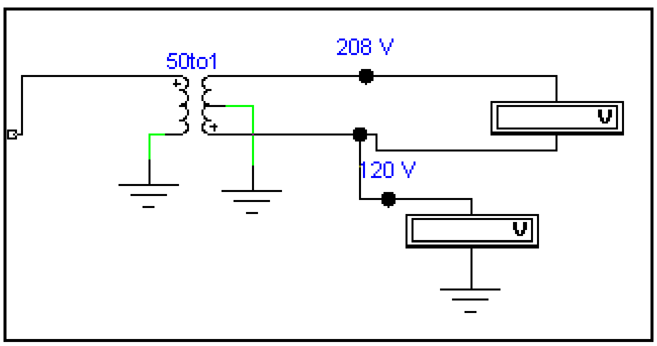

Figure 8 Pole- Mounted Residential Transformer.

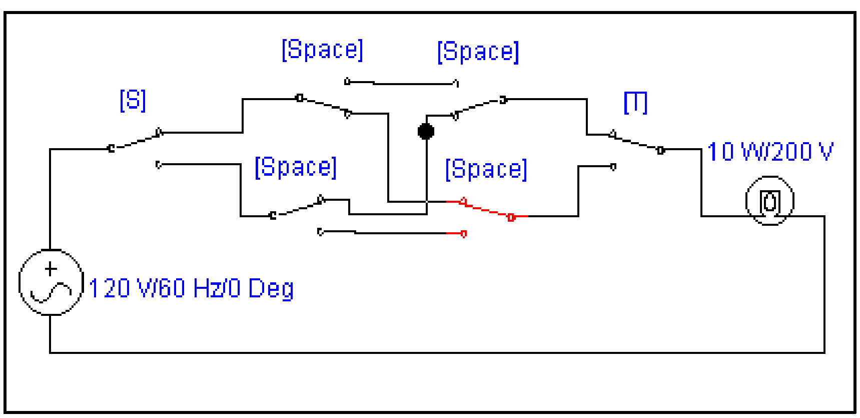

Figure 9 Three-Way and Four-Way Light Switches.

Conclusion:

This paper described a project that was intended to familiarize students with one of the electric utility company organizational forms that provide electricity for the sparsely populated counties in the United States. The project also was instrumental in students having a dialogue with local electric utility companies' technicians and managers. The simulation part of the project encouraged students to study and explore different transformer configurations, and the reasons for stepping up or stepping down voltage levels. Students also studied and became familiar with different types of transmission lines, their current ratings, and various methods of mounting them on utility poles.

References:

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4. Electronics Workbench, Interactive Image Technologies LTD., 111 Peter Street, #801, Toronto, Ontario, Canada M5V 2H1.

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