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EE492

# Extra credit Assignment 2

The distribution system is a popular topic in the power system research area. To improve our project for distribution systems to Algona, we do some relative literature review from Google scholar and IEEE XPLORE about distribution system. We search the keywords about distribution system flexible, reliability and cost. Through this literature, we find a lot of useful information that can be used in our demo and final poster.

Underground cable & Overhead line: Though the communication with our sponsor, we understand the final goal of Algona Municipal Utilities is to bury all distribution line. In our design, we still think about using overhead lines because the overhead line and underground cable have their own advantages and disadvantages. Actually, underground cable is the trend for the design of power distribution system. The six states including DC that require the undergrounding cable for the new residential distribution system. We will present different design plans that meet specific requirements with main UG. From the [1], we summaries the main point of OH and UG. The table shows the result

| | **Overhead(OH)** | **Underground(UG)** |
|---|---|---|
| **Weather Situation** | Need to think | Do not need to think |
| **Life Span** | 30-35 years | 60-70 years |
| **69 KV single-circuit/mile[2]** | $285,000 | $1.5 million |
| **Build Cost** | | 4-14 times Higher than OH |
| **Transmission losses** | More than UG | |
| **Maintain Cost** | Higher than UG | |
| **Percentage of Damage** | Higher than UG | |

From the table above, we can find that OH and UG have different advantages and disadvantages. In our design, we will use overhead transmission lines to cross the high-cost area, like road, farmland and so on. That will reduce the influence for the customer and work hours. In the plant area, we choose underground cable to support our customer. The underground cable has a longer lifetime and lower risk in the severe weather. Actually, depends on the weather of Iowa, especially, in the summer, we will use underground transmission lines because of cyclone, tornadoes and heavy lightning. These weather conditions may affect overhead transmission lines that means will increase maintain cost and repair cost.

And for the buried way, we find two different construction types underground in the [2], concentric Neutral Cable Underground lines and Tape-Shielded Cable Underground lines. The construction graph shows like this:

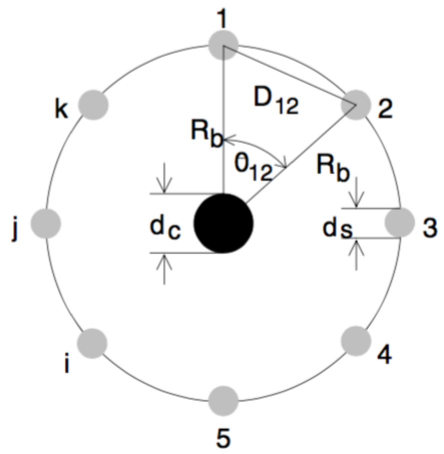


**FIGURE 5.4**
Basic concentric neutral cable.

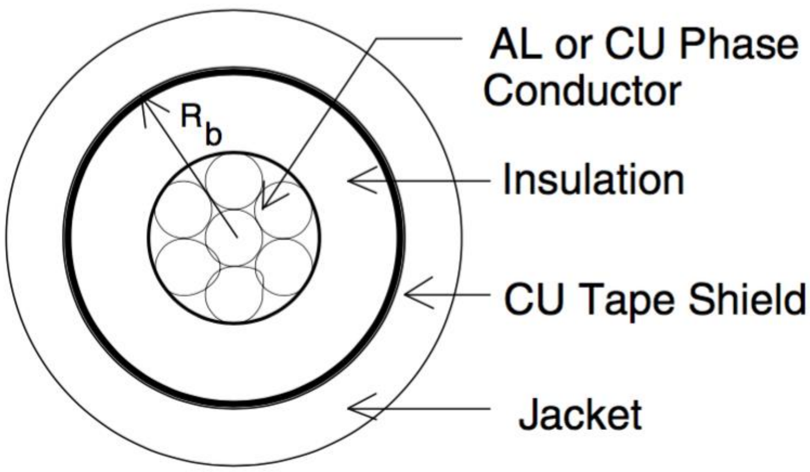


**FIGURE 5.5**
Tape-shielded conductor.

Based on the different construction underground cable, we have two ways to bury the line. The first one is directly buried and another one is in conduit. We prefer to use in conduit because we check the current primary conductor is in conduit in the Algona.

2. Reliability is the most important factor for all utility companies. How to find a way to improve the reliability is challenge for us. Based on the literature review, the traditional reliability measurement includes electrical customers per outage, outage duration and

outage frequency [5]. Reliability indices most commonly used by electric utilities with outage and interruption which both cost utility money.

In general, there are two different choices for power system: Radial System with radial feeders or Loop System with loop feeder. In the [4], the close-loop distribution system already become a trend in the distribution system. The test proves the closed-loop feeder system can increase demands of electric power reliability. Even though the radial feeder system is the simplest and cheap way, we still prefer use closed-loop system in our design. And the [4] presents a novel equivalent model that closed-loop feeder can be equivalent to a radial feeder. That helps to avoid the complex mathematical formulas.

Except the design level method to increase the system reliability, we also find some algorithm methods to help reliability, such as state estimation. State estimation (SE) processes a set of measurement data and estimate the more accurate data that is the basic system security monitoring and control [5]. That means state estimation reduce the errors in the power system. The errors arise from (i) inaccurate transducer calibration, (ii) analog to digital conversion, (iii) noise in communication channels, etc [6]. The imprecise measurements and information from the control center would influence the correct engineering decision about the operations. In our design, we cannot use state estimation because we assume all measurement data are precise from the meter. But we still suggest utilities can use the similar way to decrease the whole system measurement residual and improve the system reliability.

3. The third part is cost. The total cost is a critical point to evaluate our design. To analysis the total cost, there are five elements that we need to think about: investment cost, energy lose cost, interruption and outage cost, fault repair cost and maintain cost. We find the relative function in [7]

Investment Cost:

$$C_{INV}=\Sigma[(C_{eqip}+C_{inst})*N_{eqip}]$$

Where $C_{INV}$ is the investment cost, $C_{eqip}$ is the unit price of equipment, $C_{inst}$ is the installation fee, $N_{eqip}$ is the quantity of equipment.

Energy Lost Cost:

$$P_{tot}=P_L+P_{CONV}$$

Where $P_{tot}$ is the total energy loss; $P_L$ is the energy loss of distribution line;.$P_{conv}$ is the energy loss of DC/AD &AC/DC converters.

Maintains Cost: It includes the power converter or pole transformer inspection cost and line maintenance cost.

Fault Repair Cost:

$$C_{FR}=N_{fault} * L * C_{AFR}$$

where $C_{FR}$ is fault repair cost; $N_{fault}$ is the number of fault per km; L: it the length of distribution line; $C_{AFR}$ is the average repair cost per fault.

Interruption and Outage Cost:

$$C_{POC}=C_{NDE}+C_{ARC}=\sum\{\lambda_{COM}*(a_j+b_j*t_{rep})*P_j*n_j\}+\sum\{\omega_{kfar}*a_{ifar}+\omega_{kdar}*a_{idar})*P_K*n_k\}$$

From above I mentioned, we try to analysis our design with 5 directions. The investment cost (construction cost) should be the most important one in the cost report. And based on the communication with Algona municipal utility. The project will be done with 5 years if the design works. In our cost report, we will use a future 5-year interest to calculate. That will help to evaluate the cost of reality in the future. About the other costs, we need more data, like outage data, equipment reliability, etc. Based on the previous meeting, we maybe cannot get these data because of some limitations.

Reference:


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3. X. Sun *et al.*, "Study of a Novel Equivalent Model and a Long-Feeder Simulator-Based Active Power Filter in a Closed-Loop Distribution Feeder," in *IEEE Transactions on Industrial Electronics*, vol. 63, no. 5, pp. 2702-2712, May 2016.

4. C. N. Lu, J. H. Teng and W. H. E. Liu, "Distribution system state estimation," in *IEEE Transactions on Power Systems*, vol. 10, no. 1, pp. 229-240, Feb 1995.

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7. National Electrical Manufacturers Association, American National Standards Institute, & Edison Electric Institute. (n.d.). *American National Standard for Electric Power Systems and Equipment - Voltage Ratings (60 Hertz).*