Early Underground Residential Distribution (URD) in the Midwest

By

James D. Medek PE, Consultant, ICC Asst. Sec. Publications

1930

URD installations started in the Middle West in the 1930's. The 4kV cable design consisted of a number six solid copper conductor, butyl insulation and six copper concentric strands (tin coated). Field construction practices utilized a sweated copper connector for jointing the conductor, and rubber tape to a prescribed thickness. The concentric strands were joined over the insulated joint. Terminations did not require a stress cone so the construction procedure was to tie off the concentric strands at a prescribed distance from the exposed phase conductor and a turn of tape at the exposed conductor. If necessary a lug was installed on the conductor. One design of cable had a bedding tape under the concentric stranding so it was necessary to tape the bedding tape to keep it from unraveling.

All of these URD cables, and there were not many, were installed by underground personnel. Therefore, many of the construction practices were carried over from the Paper Insulated Lead Covered (PILC) cable used in the city conduit systems.

1940

The 1940's found little to no developments in underground equipment. Mainly because of WWII, and the fact there was minimal residential building in progress. Where residential building did occur it consisted mostly of single homes on existing lots in established neighborhoods. In these locations overhead service was readily available.

1950

The 1950's found many changes in the residential underground areas. First of all the demand for housing exploded as the returning veterans and their families wanted new affordable buildings in rural areas. Instead of building one new house on a lot, contractors started the assembly line principles and started to build many houses at the same time. The contractors or developers purchased large farms, subdivide them into residential lots, and build homes that were sold as fast as they were completed. Another factor, which entered into the underground decision during this period of time, was the change in customer demands. With these new homes the customers no longer wanted to see the poles and wires adjacent their property. Obviously the answer to this public demand was the installation of underground utilities. Both the telephone and electric utilities were confronted with this demand. As we expanded more into the URD business it soon became evident that the telephone and electric company that shared facilities on poles, would also find ways of installing underground plant jointly.

Early in 1951 polyethylene insulation became available and was purchased by utilities. Polyethylene was touted to be the answer of all problems associated with PILC cable systems. It eliminated the problems with moisture entering and damaging the insulation in cable (so we thought at that time) and that, in itself, would make it suitable for direct buried installations in the Midwest since much of the cable was to be installed in wet environment. Polyethylene insulated cable was cheap and it did not need a lead sheath to protect it from moisture!

In addition to the moisture question, it was shown in many testing reports, that polyethylene was a much better insulation than other materials available at that time. Reports were so good we had the impression that it would last forever. However, at the time we gave it a 40-year life as we did other utility products.

The insulation was very inexpensive. So the utilities took the stand that Polyethylene insulation was the only way to go. Accessories were designed to fit the higher voltage and newer insulation thickness. Splices still consisted of soldered sleeves for the copper conductor, penciling, now required at the 12kV voltage level, was done with a knife. Rubber insulating tape was used over the connector and to cover the creepage distance on cable at both cables being joined. It was felt that since the polyethylene insulation was difficult to bond to, the polyethylene was roughened and rubber cement was added before the rubber tape was applied.

The cable design that was first tried for 12kV URD consisted of a stranded copper #4 conductor, over the conductor was a conducting fabric tape as a conductor shield, two layers of 110 mills polyethylene, a conducting fabric tape over the insulation as a insulation shield. The neutral or return conductor consisted of copper concentric strands. Later on in the 50's the design was changed to a solid strand #2 conductor for economic reasons. An aluminum press connector was developed which would accommodate the #4 stranded copper conductor to the #2 solid aluminum. This made it useful when extending lines with the new cable design was connected to the old cables.

Still more changes occurred in the design of the cable: The conductor and insulation shield was now applied by extruding conducting polyethylene compound. This eliminated some of the many problems with the conducting tapes previously used. The original size of the insulation thickness being specified was 220mils. With the excellent record of cables being installed over the past ten years consideration was given to reducing the insulation thickness to 195mills. A considerable amount of thought was given to that change and the result of that study was to reduce the wall thickness to 175mills. Why not, if the insulation is great we might as well make the cable cheaper and go to the smaller thickness. The change in diameter was made based on the existing work practices (taped splices and terminations) being used at that time. It was found out later that it became a problem when pre-molded or pre-formed splices and terminations became the standard.

Operating departments were now having the overhead crews install the URD cable systems. Unfortunately, they were given the work with little or no training resulting in many of the outages that were found in later years.

In the 50's transformers for URD application consisted of overhead designs placed in some form of enclosures. Some of the transformers were coated with various materials to reduce the corrosion we knew would occur. Overhead fuses were used in some of these installations to protect the transformer and sectionalize the circuit. Primary terminations were of the overhead type connected to open spade lugs on these transformers. High profile pad mount transformers replaced the overhead transformers as the demand for URD increased. However, the residential public did not readily accept new transformers. Customers did not like the new transformers because they were very large and in particular excessively tall. Those pad mounted transformers continued to use spade lugs for connections to primary cable in addition to the secondary connections.

1960

It was the development of the Separable connector (elbow), which reduced the height of the transformer and made them more acceptable to the customers. The elbow termination provided another feature, which benefited the utility operations. The completely shielded primary termination allowed work on the secondary connections without de-energizing the primary cable or the need for protective barriers.

Prior to the elbow connector, manufacturers came out with various designs of splicing and termination devices that were preformed to cable dimensions. The goal of manufacturing was to make their devices cover a large range of cable sizes in order to use the same product for different customers. Product designs to cover these ranges of cable diameter included adapters, spring-loaded elastomers, elastomers that were soft enough to cover a range of cables, heat shrinkable, and cold shrinkable products.

Improvements were found in construction skills and tooling. The company became more aware of the necessity in training of URD construction forces. In addition, more and more URD areas were being developed which allowed crews to work on underground installations and not switch between overhead and underground.

Cable manufacturers were developing thermosetting insulation shields for application on primary cables. Construction personnel found these first attempts at thermosetting shields difficult to work since the strip ability of the shield was not consistent. Cables would be reported from the field, which found the insulation shield bonded on one side and loose on another side. Or in some cases it was completely bonded on the insulation. There was no easy way to remove the shield or particles of the shield without using a knife or excessive sanding. As you would expect many early failures occurred as a result of cable splicers' doing the best they could with a poor product.

Corrosion started as the major topic relating to cable problems. We heard companies reporting that corrosion of neutral strands was the cause of cable failures. While our failure examination program found corrosion on cable failures, we did not feel corrosion was the cause but rather the result of the failures in most cases. However, there was concern as to what affect a corroded neutral had on the electrical system. Steps were taken to minimize corrosion.

1970

The 70's found an effort to solve problems, which occurred from the rapid development of URD cable, devices, and installation practices. Manufactures of cable were trying to reduce their cost of producing cable by trying new and improved manufacturing techniques. In addition they were trying new compounds and new suppliers together with the manufacturing equipment, as you will note from the other panelist. In 1971 we started an extensive investigation into the problems with moisture and its effect on URD cable. As testing of URD cables progressed to the point where manufacturers were introducing water to the conductor as well as externally to enhance the growth of failures, we felt it was imperative to reduce the exposure of cable to water. Testing was conducted in which water was put into the strands of an aluminum conductor cable. The result was to produce gas pressure in the cable, which caused the failure of splices and terminations. Results were reported to ICC in 1972, and resulted in the search for cable, which would not allow water to enter and migrate down the conductor. At that time there was only one company capable of producing a cable in which the conductor was filled with a material that would not allow water to enter the cable (blocked or filled strand). By purchasing this design in large quantities we were capable of inducing other manufacturers to develop a similar cable.

In the late 70's an improved EPR (ethylene propylene rubber) insulation became available. This also was utilized in many trial installations with good results. The results of these developments resulted in the approval of both XLPE and EPR insulated cable. While both insulations worked well, each one had its benefits and drawbacks.

1980

The 1980's found improvements in all areas of the residential underground distribution system. Efforts were accelerated in training of URD personnel (those crews that worked in overhead also), tooling, application of existing and new joints and terminations, as well as improving the strip ability of the insulation shield. During this period the purchasing departments established the concept of purchasing cable from one cable company for the length of the purchasing year. This policy again had its benefits and problems. Improvements in joints and terminations continued with the application of hot and cold shrinkable devices, as well as obtaining ranges of sizing for the premolded or premanufactured devices.

1900-2000

From 1900 to today many of the problems remain to be solved in the industry. For some of you in attendance at this session I will mention a few of these areas of concern: Some of the cables purchased are near the range of the diameters specified in AEIC. They are not considered reject however when assembling devices on two different kinds of cable insulation, crews may find them easy or difficult to assemble. Elbows are still difficult to remove and install in some locations. If insufficient or improper grease was applied during installation or when operated after installation, elbows may be difficult to operate causing extended outages. In areas where the frost shifts the transformer foundations, cable may be stretched so tight that it is difficult to install or impossible to install without damaging the elbow or bushing. Conversion of areas from overhead to underground remain a problem depending on the type of service your company provides. Here are a few areas to consider.

- If your company installed the original electrical service in the rear:

1. Can you replace failed or worn facilities in the same place?
2. Is there another direction for supplying service? Front?
3. Will the new location require the customer to move his metering attachments?
4. Who pays for moving customers metering attachments?
5. Is there room for the transformers and switching cabinets?
6. Are the transformers and cables to be installed on customer's property?
7. Does your company have the men and equipment to do the work or is it necessary to hire contractors to do the work?

Abstract:
How did we get to the URD system we have today? By knowing this it may be helpful in planning future additions or making suitable changes in existing systems. Technical journals or papers many times overlook the management decisions, which affected the reasons why certain designs were adopted. This paper will review the development of the Underground Systems as they developed in the Midwest. The advances in underground systems varied in many respects between utilities. Most utilities were

oriented in overhead construction, and did not have a good understanding of how underground systems were to be designed, installed, and maintained. This paper and the subsequent discussion will address these topics, and answer some of the questions engineers ask.