COMMUNICATIONS ARCHITECTURE IN MODERN DISTRIBUTION SYSTEMS

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Abstract: Distribution Automation has become a rapidly growing segment in today’s electric utility industry. Deregulatory and competitive pressures have forced many utilities to consider value-added services to compete. Power quality and reliability of supply concerns have resulted in increased monitoring and control of the power system. Thus, Distribution Automation has become the primary way to accomplish value-added services and stay competitive in today’s power industry. Decentralized Intelligence schemes provide an improvement in reliability. The industry standard performance indices prove the reliability advantages of the decentralized automation scheme.

CONCLUSION

While Distribution Automation costs continue to decrease, the complexity increases. For example, many of the advanced protocols such as DNP3, IEC 870-5, and UCA2.0 while being more flexible and allowing greater communications control, also have more communications overhead. They require more bandwidth and greater speed than the previous ‘legacy’ protocols due to their complexity. This complexity can be overlooked, but should be evaluated when choosing communications protocols. Many devices are available that offer the same protocol, and it is a misconception that all devices employing the same protocol must work together. Devices offering a lack of configurability may have difficulties working with devices offering more configurability. It is recommended that an in-house or consulting integrator be employed to handle incompatibilities.

As communications systems continue to evolve, centralized intelligence schemes may reach the fault isolating speeds of decentralized systems. However, centralized intelligence schemes still require the central location to maintain control of the system. A malfunction at this location can cause system failure perhaps affecting reliability. Although redundancy can increase reliability of centralized systems, the ideal solution will include the best of both systems.

Many communication architectures exist for power systems today. Decentralized Intelligence schemes represent a desirable answer for protection, reliability, and control of today’s power systems. Utilities that evaluate performance indices can see marked improvements of reliability with the application of decentralized intelligence. In today’s competitive power industry, utilities that embrace this idea today will continue to thrive in the future.
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COMMUNICATIONS CONSIDERATIONS

Due to technological advancements, costs associated with automation have substantially decreased; however, complications associated with automation equipment have increased. Microprocessor and mobile communication cost decreases have made Distribution Automation (or DA) schemes much more accessible and affordable to the industry, and a variety of DA equipment and architecture are available making implementation confusing and cumbersome. Common practices and concerns that utilities should consider when implementing DA systems include the following:

1. Communications Architecture
2. Evaluating Communications Architecture using Performance Indices
3. Communications Equipment to Accomplish Communication Architecture

Communications and Power Systems Architecture

Centralized vs. Decentralized. Two primary types of Distribution Automation architecture include Centralized and Decentralized Intelligence schemes. Centralized intelligence schemes require a communication system that links all controlled IED’s (or Intelligent Electronic Device) to a centralized location. Protection and reconfiguration intelligence would reside at this central location. The communication system is of paramount importance in a centralized intelligence scheme and protection usually relies on its secure operation. Decentralized intelligence schemes use local intelligence for protection and reconfiguration. Central intelligence schemes could be used to supplement local intelligence for purposes of restoration and data analysis. However, a decentralized intelligence scheme does not require a communication system. Decentralized intelligence schemes provide the following advantages to protection and control schemes:

1. Not communication dependent; however, a centralized communication scheme can assist with data analysis. Communication system speed is not a paramount concern.
2. Coordination of protective devices is more complicated; however, increased sensitivity of the protection scheme is possible.
3. Autoreclosers used for fault interruption on the power system expose only affected areas to momentary outages. By further sectionalizing the distribution feeder this inherently improves reliability indices.
4. Increased safety for line personnel and equipment with fault interrupting equipment on the distribution feeder.
5. Speed in isolating faults can be improved with distributed intelligence.

Centralized intelligence schemes most often employ circuit breakers at the substation and remotely operated switches along the distribution feeder. Alternatively, a decentralized intelligence scheme employs autoreclosers along the distribution feeder. In this case, the autorecloser (or IED) is part of decentralized intelligence, as it has the ability to act autonomously. The centralized intelligence scheme is called upon to operate for system faults during adverse conditions which can also affect the communication system on which it relies. The result can be problematic or result in slower system response. (1)

With the use of centralized protection schemes, depending on sensitivity, momentary outages can result along an entire distribution feeder until a central control center can analyze and respond to the outage cause. Alternatively, the largest contributing factors for using decentralized intelligence schemes, employing autoreclosers, is continuity of supply and reliability. Autoreclosers can provide improved reliability and fault isolation for transient as well as permanent faults, reducing process time by moving the processing closer to the actual device. Many power system studies have shown that 75% of electrical faults are transient in nature. By employing autoreclosers along the feeder length, outages are isolated to the affected areas of the grid eliminating many momentary outages due to system reconfiguration. (2)
High technology manufacturing and/or health care facilities may not allow momentary outages for any time period. Furthermore, these facilities may require compensation for consequential damages in the result of momentary outages. More than 20% of utilities today track momentary outages, and that number is rapidly growing. (1)

Evaluating Communications Architecture Using Performance Indices

In today’s operating climate, more and more utilities are using reliability analysis to evaluate their system performance. These performance indices not only allow evaluation of the system, but also allow comparison of other feeders or even other utilities. Reliability analysis has become a way to describe the performance of a distribution system, and is affected by the type of equipment that is utilized. Remotely operated switches or autoreclosers are considered alternatives on many distribution feeders for Distribution Automation. Performance indices will quantify the difference in reliability performance between these two options.

Many utilities have experienced deteriorating service reliability when converting to higher voltages for load growth or line extension. Possible solutions include adding autoreclosing and voltage regulation along the length of the feeder. This equipment is readily available and widely used to extend feeder lengths without the construction of new substations. Most importantly, feeder extension has been the most cost-effective way to serve new loads and allow for load growth. The addition of autonomous sectionalizing points improves reliability on existing feeders. As long as protection coordination is maintained, autoreclosers are an obvious choice.

Commonly, distribution feeders use a substation circuit breaker and centrally automated load interrupting switches to sectionalize the feeder. This centralized scheme makes it necessary to ‘blink’ the entire feeder for temporary as well as momentary faults. A critical load near the substation may not or can not allow momentary interruptions due to manufacturing or other reasons. An autorecloser can add support for a critical load, by exposing the load to less of the potential feeder problems.

A proven way to improve feeder dynamics is to allow each section of the feeder to operate independently of the entire feeder. This allows automatic sectionalizing without relying on a single communications link or a single substation breaker of which could exhibit a problem that would render the feeder protection ineffective.

A decentralized intelligence scheme or one employing fault interrupting devices along a feeder will show an increase in reliability. The next example looks at MAIFI_E, or the Momentary Average Interruption Event Frequency Index:

\[
\text{MAIFI}_E = \frac{\text{Total Number of customer momentary interrupting events}}{\text{Total number of customers served}}
\]

A MAIFI_E analysis will prove the advantages of autoreclosers on a distribution feeder. By increasing the amount of fault interrupting devices (in this case autoreclosers) on a feeder you increase the sectionalizing points on the feeder, and also decrease the momentary outages on the rest of the feeder. A decentralized intelligence scheme as it relates to the application of autoreclosers is a proven technique for increasing service reliability. (3)

**MAIFI_E** Here is an example applying the industry performance index MAIFI_E, assuming an average outage duration of 30 seconds. The reader should recall that MAIFI_E looks at an auto-restoration sequence as one incident. (3)

**Figure 1. Distribution Feeder with Switch and Recloser**

With a sectionalizer or switch at A:

\[
\text{MAIFI}_E = \frac{1000+1000}{1000} = 2.00
\]

With an autorecloser applied at A:

\[
\text{MAIFI}_E = \frac{1000+500}{1000} = 1.50
\]

**TABLE 1 - Distribution Feeder MAIFI_E Analysis**

<table>
<thead>
<tr>
<th>Momentary Fault</th>
<th>Switch Application</th>
<th>Recloser Application</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>1000</td>
<td>1000</td>
<td>30 sec</td>
</tr>
<tr>
<td>F2</td>
<td>1000</td>
<td>500</td>
<td>30 sec</td>
</tr>
</tbody>
</table>

In this application, the addition of a recloser offers a direct reduction in MAIFI_E of 25%. In today’s climate, with electric consumers demanding more reliability for sensitive electronics, the costs associated with momentary outages should not be ignored. A recent study, conducted in the US, of 198 large industrial and commercial customers quantified the costs of a momentary outage. The survey included detailed descriptions of interrupting costs such as lost production, damage, and restart costs. It concluded, for a momentary outage of one to two seconds, during a summer afternoon in clear weather, The average total cost incurred per customer was over $11,000USD. This study did not quantify the utilities lost revenues. While oversimplified,
this example seeks to show the advantages of distributed intelligence by applying autoreclosers along the distribution feeder. Additionally, this example shows an increase in fault isolation speed which has become a paramount concern of utilities under regulatory pressures. (1)

Many new regulations and standards exist that evaluate the performance or reliability of supply. Sustained and momentary outages have become less and less acceptable by today’s power consumers. Many countries have instituted regulations which include penalties on electric suppliers for interruption of supply and poor power quality. In response to this climate a distribution feeder employing autoreclosers in a decentralized intelligence scheme represent a better approach to feeder sectionalizing and reconfiguration than the classic distribution automation switch.

Zones of Protection. Autoreclosers also increase the sensitivity of the system and allow quick response to faults at the ends of feeder lengths. Many substation protection schemes cannot be set reliably to provide reach for protection to the ends of all taps. An autorecloser can provide an additional zone of protection to a distribution feeder. Figure 2 shows the effective ‘zone of protection’:

Reach = Maximum available fault current at feeder end
Minimum pickup of protective device

Reach illustrates the fault levels covered by a particular protective device and can help place autoreclosers, but it also provides an accurate picture of feeder sensitivity.

Communications Equipment to Accomplish Communication Architecture

Planning. Many options and devices exist today to automate and communicate with remote IED’s. It can be a daunting task to evaluate all possible options for a Distribution Automation system. To simply this process, it is best to start with an automation plan. The DA plan should include the following:

1. What information is needed from each device? It is helpful to separate what is "need-to-know" from what is "nice-to-know" information. Often this can be the biggest obstacle. When in doubt limit the information, as it is good communication practice to design a quiet system. The most critical time for communications is during a system disturbance, and having less traffic and more bandwidth on the communications channels at this time will allow quicker response to system anomalies.

2. What communication protocol will be used to relay the needed information? Many communication protocols can exist in one system, but the type and quantity of information required should help to define the protocol needed for each device.

3. What communication medium will be chosen? Most common choices include low-power digital radio, telephone, and fiber optics. Although the costs associated with each vary widely, the decision of medium is often decided by existing infrastructure.

4. What kinds of automation and control are required for each device?

5. What response time is required for information transfer and automation/restoration? This may define many of the other questions.

Proper planning at this stage will help select the correct communications equipment for the application.
Many communications options exist for distribution automation systems. Modems provide the intelligence needed for speed of service, increased reliability, and safety. This decentralized or distributed intelligence option will provide a good solution for DA.

Reclosers. Early limitations of autoreclosers, such as non-directionality, and limited protection functions have been surpassed by microprocessor-based multi-function relays that allow autoreclosers very sophisticated functionality. Directional Protection, Negative Sequence Protection, Oscillography, Symmetrical Components and Energy Metering are among a few of the more advanced features in modern autoreclosers. There are few applications that cannot employ autoreclosers, and modern recloser functionality has decreased that possibility even further.

Modems. Modems can also be a low-cost alternative for communications, and can be used over the PSTN (Public Switched Telephone Network), Leased lines, or cellular systems. As with radio communications, speed is of primary importance because the modem is usually the slowest link in the communication chain. Low power is needed to allow full operation of all communication with only battery back-up support in the recloser control. A fiber optic or RS-232 interface is needed to handle the communications output of the IED. Radios are extremely successful as a low-cost communications medium because of their availability and ease of use. Radio Frequency availability and bandwidth needs to be considered before radios are chosen for this purpose.

Radios. Radios are available in many forms including microwave, unlicensed spread spectrum, licensed, and trunked radios. High speed, low power, data radios are preferred for most line applications. Speed is important, as the radio is typically the slowest link in the communication chain. Low power is needed to allow full operation of all communication over the recloser control. A fiber optic or RS-232 interface is needed to handle the communications output of the IED. Radios are extremely successful as a low-cost communications medium because of their availability and ease of use. Radio Frequency availability and bandwidth needs to be considered before radios are chosen for this purpose.

Protocols. Protocol decisions are an important consideration in distribution automation systems, as they define the method and the capability of communication between devices. There are many different types of communication protocols available and often a combination of protocols is the best answer for a system. Protocols such as Modbus and ASCII have very simple structures and were designed as simple substation protocols with control and monitoring features. DNP3, IEC870-5, and UCA2.0 have more complex structures and were designed for control, monitoring, and file transfer capabilities. While the advanced protocols are desirable for obtaining things such as oscillographic or event history records, they also have increased overhead requiring more bandwidth, faster speeds, and more preparation to use. These types of protocols may not be necessary depending on the type of monitoring and control desired. It is important to evaluate how the protocol will be used in order to determine the best protocol for the communications system.

CONCLUSION

While Distribution Automation costs continue to decrease, the complexity increases. For example many of the advanced protocols such as DNP3, IEC 870-5, and UCA2.0 while being more flexible and allowing greater communications control, also have more communications overhead. They require more bandwidth and greater speed than the previous ‘legacy’ protocols due to their complexity. This complexity can be overlooked, but should be evaluated when choosing communications protocols. Many devices are available that offer the same protocol, and it is a misconception that all devices employing the same protocol must work together. Devices offering a lack of configurability may have difficulties working with devices offering more configurability. It is recommended that an in-house or consulting integrator be employed to handle incompatibilities.

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Many communication architectures exist for power systems today. Decentralized Intelligence schemes represent a desirable answer for protection, reliability, and control of today’s power systems. Utilities that evaluate performance indices can see marked improvements of reliability with the application of decentralized intelligence, as evidenced in Figure 1. In today’s competitive power industry, utilities that embrace this idea today will continue to thrive in the future.
REFERENCES


