# Cost Benefits Resulting From Use of Integrated Communication for Distribution Automation

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**DA/DSM Asia**
27-29 September, 1995
Singapore International
Convention and Exhibition Centre

MOTOROLA

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## ABSTRACT

Distribution Automation **(DA)** systems are increasingly being introduced by electric utilities to improve system efficiency, ensure a reliable supply of electric power and reduce maintenance and operating costs. Utilities naturally want to keep customers satisfied by providing good service at minimal billing while showing a reasonable profit for their shareholders.

Utilities in most countries operate as sole suppliers of electric energy to their regions, but the recent deregulation trend is changing this status. In order to prepare themselves for the competitive market they are exploring the introduction of DA. While proceeding in this direction, utility managers raise three basic questions: How quickly can DA be integrated into their operation, at what cost and which is the best vendor?

Two-way communication allows utilizing the same infrastructure (radio channels) for several functions. In addition to DA it can also serve as the medium for Demand Side Management **(DSM)** and as a data highway for Automated Meter Reading **(AMR).**

Integrated voice and data communication enables the utility to provide better service to more customers. It helps prevent and shorten the duration of power outages and losses resulting from non-optimal power factors. These benefits and cost saving factors immediately affect the utility's financial viability. A detailed evaluation, performed by an expert, should explore the actual cost figures and benefits which obviously are specific to each utility.

This paper describes the main considerations and cost benefits resulting from the integration of *advanced integrated communications* for monitoring and control of DA, DSM and AMR systems.

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## 1. INTRODUCTION

Modern electronic and communications systems provide a base for improved management and performance of Distribution Automation **(DA)** networks. Unfortunately, many utilities tend to view both Supervisory Control and Data Acquisition **(SCADA)** and DA systems only as remote control and status indication tools. DA systems do more than that. They play an important role by providing the means for more sophisticated monitoring and display for the Medium Voltage **(MV)** distribution grid, and enabling precise and quick fault location and system restoration.

Remote Terminal Units (**RTUs**) integrated with data communications for controlling MV switchgears, provide smarter response to changes in the power network. This results in greater utilization of available resources and more efficient operation of the system, since fewer margins need to be reserved for unexpected events, such as an unforeseen rise in demand or a sudden power outage .

Electric utilities evaluating their future investment in DA, often ask some basic questions:

1. What *key goals* are to be achieved?
2. Which *application programs* are needed to fulfill these goals?
3. How much will the *system cost*?
4. Will the operation be *too complex* to handle?
5. What are the *various alternative solutions*?
6. What *added value* will the system provide?
7. How is the *return on the investment* calculated?
8. What type *of communication method* serves the DA and DSM functions best?
9. What *other functions* might the utility need in the future?

After talking to several potential vendors and analyzing their answers to these questions, the utility will find that the common quantifiable cost benefits related to DA are**:**

- Reduced operating costs
- Reduced operating losses due to:
    1. Faster detection of power outages
    2. Fewer and shorter power outages
    3. Faster power restoration to majority of customers
- Lower expenditure for routine maintenance
- Deferred capital expenditure for expansion of generating capacity and transmission lines
- Lower energy losses due to more optimal use of the power network.
- Improved real time power factor control
- Prevention of damage to equipment and lines

The actual figures can be calculated by experts, after they review the utility's operating environment and its future goals. Due to a lack of actual data, this paper is neither aimed at providing formulas, specific recommendations and estimated figures, nor giving detailed calculations on savings. However, in order to realize all the advantages provided by an advanced communications based DA system, the following non-quantifiable cost issues must also be considered:

- How will the system lead to more *optimized energy consumption*?
- How will it integrate with *existing installations*?
- Will it improve *manpower utilization* and *customer satisfaction*?
- Does such a modern system enhance the *safety of field personnel*?
- Can the system be managed by the *current employees*?, or
- Will it require *hiring new operators* who are more skilled?
- Are there any *fringe benefits* resulting from implementation of such a system?

Table 1 shows the growth in investments of electric utilities in the various segments of their electric network. As reported by Newton Evans Co. (Elliot City, MD, USA), most of the investments are now directed to Distribution Automation. This includes switchgear automation, capacitor bank control, transformer monitoring, communications and computer hardware and software.

| **Year** **$ Mill.** | **EMS & SCADA** | **Substation Automation** | **Plant Control Systems** | **Distribution Automation** | **Worldwide Total** |
|---|---|---|---|---|---|
| **1993** | 475 | 185 | 360 | 1500 | 2520 |
| **1994** | 497 | 216 | 391 | 1840 | 2944 |
| **1995** | 528 | 257 | 424 | 2175 | 3384 |
| **1996** | 548 | 313 | 450 | 2550 | 3861 |
| **Total for 1994** | 17 % | 7% | 13% | 63% | 100% |
| **Average annual growth** | 5% | 23% | 8% | 23% | 18% |

*Source*: Newton Evans Co. Publication 12/94

Table 1. Market information on SCADA and DA Investments

## 2. COMMUNICATIONS MEDIA

Electric utilities often use several types of communication media for different functions. This is certainly understandable, since diverse operations such as, voice communication for mobiles, computerized dissemination of work orders, monitoring of fixed installed equipment, etc., require a suitable medium. Telephone lines may be the best choice for many applications, but data communication to inaccessible remote sites is best served by radio. For example, control of an MV distribution grid requires radio, since no other communications infrastructure is available at these locations. Various types of radio infrastructures (VHF/UHF, conventional and trunked radio, etc.) are widely used by electric utilities for transmitting status, alarms and control commands between the control center and the RTUs. The following is a short review of commonly used communications media for DA.

### 2.1 Power Line Carrier

Power line carrier communication **(PLCC)** was quite popular in the past, mainly for signaling. Throughout the years, utility engineers learned that this medium does not offer a reliable solution for DA, although the implementation of smart protocols and advanced electronics resulted in some improvements. Communication with remote sites cannot be maintained while a disturbance, such as damaged poles or broken power lines, is in progress in the electric distribution network. Therefore, PLCC effectiveness for DA is limited.

### 2.2 Dedicated Wirelines

Many SCADA systems employ wireline links (private networks) to communicate between the SCADA Master Control Center **(MCC)** and substation RTUs. The commonly used wireline and telephone networks allow very reliable point-to-point or point-to-multi-point (multi-drop) communication.

The main advantage of wireline is its capability to provide high data rates. In rare cases, dedicated lines may have some advantages for “hard to reach locations” such as underground installations and heavily populated areas.

Wirelines are impractical for controlling overhead MV grids (pole mounted switches) due to lack of connectivity in remote areas. Installation of private lines on electric poles is expensive, and in addition, lines run the risk of vandalism. Public networks are dependent on third party providers and are subject to service charges.

### 2.3 Conventional Radio Systems

Dedicated conventional radio systems, based on licensed channels, are very suitable for DA. If the system is properly designed, these channels are available when needed. However, many countries suffer from a shortage of available frequencies in the VHF/UHF bands, forcing utilities to use the same frequencies for both voice and data communication.

Integration of voice and data communication often requires additional investment in infrastructure (repeaters). To assure reliable operation of the system, these RTUs must use radio-type protocols suitable for SCADA. It is important to note that using line protocols over radio, results in unreliable communications and poor utilization of air time. This in turn, limits the number of RTUs/pole mounted switches that can be controlled.

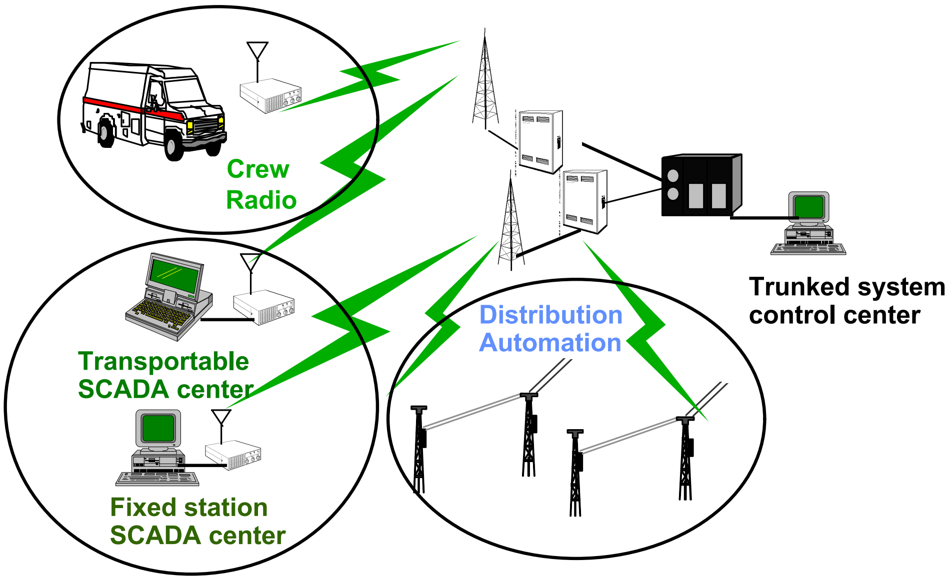


Figure 1. Integrated Communication for voice and data

## 2.4 Trunked Radio Systems

The concept of radio trunking is similar to that of long distance telephone systems. Trunking allows many groups of subscribers to share a common “bank” of resources (channels, or frequencies) instead of a group of subscribers sharing the same (single) frequency. Similarly to telephone networks, in trunking systems the same infrastructure (radio repeaters, base stations, antennas, etc.) is utilized for more than one function, and its overall cost is shared among several user groups. [1,3]

Statistically, the probability that at least one of the trunked frequencies in the “bank” will be free, is much higher than in a conventional radio system (See Figure 1). Using a trunked radio system has definite advantages, since DA systems typically transmit very short and infrequent messages. Trunked systems use licensed channels. In most countries, these are available in the VHF, UHF and 800 MHz bands.

Trunked radio channels can be assigned with a pre-defined priority schedule. If required, the system can also feature a “data near trunking” concept. Here, the voice communication radios use the “bank” channels, while at the same time, data users (RTUs) are provided with dedicated channels which are immediately available when needed.

Providing connectivity for SCADA data terminals over trunked systems is very worthwhile. For example, Jeff Moore, Control System Maintenance Specialist for Savannah Electric and Power Company (USA), commented on combining distribution automation with a Motorola trunked network: “MOSCAD allowed us to increase the capacity of our system tremendously and to take advantage of our existing trunked infrastructure.” [1]

## 2.5 Multiple Address Systems

To meet the growing needs of electric utilities for remote control of SCADA elements, via radio, the FCC (USA) assigned several channels in the 900 MHz band for Multiple Address System **(MAS)** communication. MAS provide half or full duplex connection between the serial ports (RS-232) of the data terminal and the control center.

MAS have both some advantages and disadvantages. The main advantage of this concept lies in its dedication to data, and that it provides a service similar to that of a wireline. The disadvantage is, that for MAS channels, all communication related functions (i.e. networking, error handling, communication retries, etc.) must be handled by the protocol of the RTU. In addition, the cost of the dedicated data infrastructure and installation must be considered.

## 2.6 Spread Spectrum

Spread Spectrum communication was originally introduced for use over non-licensed frequencies and for low RF power. The assigned frequencies for this medium (by the FCC in the USA) is 902 to 928 MHz and in the 2.4 GHz band.

Due to overutilization of these unlicensed frequencies by mass consumer applications (phones, intercom, remote control, etc.), their reliability for commercial and industrial use is questionable. In addition, the FCC has recently reallocated part of this band for Automatic Vehicle Location **(AVL)** and other applications. Another disadvantage is that because of low RF power, a large number of repeater installations is required in order to transfer data over a wide area.

As a result of these limitations, Spread Spectrum technology is now popular mainly for short range communications. SCADA system integrators are looking for very high reliability, and tend to shy away from this concept. They prefer using the more reliable licensed frequency channels, rather than using this band.

## 2.7 Fiber Optics Communication

Fiber optics communications is a most suitable medium for substation monitoring and control, because of its high data transfer rate and immunity to electrical noise. However, dedicated infrastructure for controlling overhead DA equipment might not be suitable, due to potential vandalism and exposure to the environment and other hazards. For example a falling tree might damage both the electrical wires and the fiber optic cables. Field repair of the fiber optic link is complicated and expensive.

Some utilities became aware of their need to establish a high-speed, quality backbone, and they are installing fiber links along their high voltage **(HV)** transmission grid. The cost of installation is high and it may take some time before utilities will start using fiber optic links installed along the MV distribution grid.

## 2.8 Comparison of communication media

Table 2, below, shows a summary of the main communication features and performance ratings for each of the communication media, discussed above.

| | Comm. Data Rate | Bit Error Rate | Suitability for DA | Infrastructure Cost | Channel Access | Cost of Usage |
|---|---|---|---|---|---|---|
| **Power Line Carrier** | Low | Very high | Very Poor | Medium | Slow | Very Low |
| **Dedicated Wirelines** | High | Low | Poor | High | Very Fast | High |
| **Conventional radio** | Medium | Medium | Good | Low | Fast | Low |
| **Trunked radio** | Low | Medium | Very Good | Very Low | Fast | Very Low |
| **MAS radio** | High | Medium | Very Good | Low | Very Fast | Low |
| **Spread Spectrum** | Medium | High | Good | Medium | Very Slow | Low |
| **Fiber Optics Link** | Very high | Very Low | Poor | Very High | Very Fast | Very High |

Table 2. Relative rating of communication media for DA

## 2.9 Importance of SCADA protocols

Most protocols used today for SCADA, implement only three layers: Physical, Link, and Application. This leaves out the most important function of data communication, the *Networking* feature (i.e. routing the message to the desired destination). The routing feature, built into the protocol makes it suitable for Wide Area Networks **(WANs)**.

Use of an OSI/ISO type seven layer protocol is important in order to enable seamless routing of messages in the network *efficiently, easily and cost-effectively*. Networking services can be provided (via several media) by integrating the communications modem for radio, lines, fiber, etc. One example is the MOSCAD RTU. It uses the Motorola Data Link Communications **(MDLC)** protocol, which is optimized for SCADA and "multimedia" communication.

SCADA communication protocols must support multitasking environments, and allow handling of parallel communication tasks. Layered protocols allow for future migration and system improvements without *losing the investment* spent on existing hardware. Improvements such as secure communications, time tagging support, synchronization, etc., are implemented within the proper protocol layers. These upgrades, therefore, do not affect the application.

# 3. INTEGRATED COMMUNICATIONS

This presentation suggests using radio for DA. The fact is, that there is always a need for more channels, for additional voice users, for more frequent monitoring of additional remote sites and for many other applications. However, in many countries radio communication users suffer from a severe shortage of available channels (frequencies).

To cope with this scarcity, it is important to select the communication medium best suited to the specific need. This obviously requires special knowledge in designing communication systems. If such communications expertise is not available within the electric utility, use of an experienced communications consultant is strongly recommended.

## 3.1 Communication Tasks

Utilities may often decide to combine the operation of several functions (mobile data, monitoring of the distribution grid, etc.) over the same radio channel. See Figure 2.

To build the most optimal network, utilities may decide to integrate a combined system using lines, radio, fiber, etc.

- Backbone for long distance - wide area communications
- Wide area and local area network
- "Last mile" communications - low cost data terminal

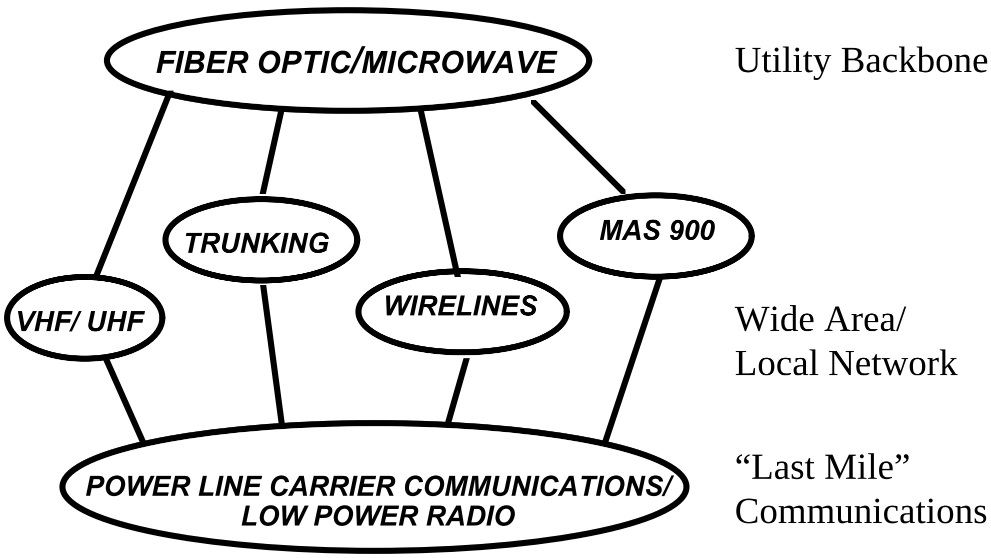


Figure 2. Use of Communications media for DA

In order to determine which operations/functions may be combined, the following considerations must be checked separately for each function:

- What is the expected time frame during the day when the communication is needed?
- For what periods of time are the channels utilized (e.g. within a period of 10 min.)?
- What is the maximum time delay allowed to obtain a channel?
- What communication alternatives are available for each function?
- How many frequency channels are available for the integrated system?
- What is the expected increase in channel utilization (over the next 5-10 years)?
- Which new/other functions and applications are foreseen?
- Does the utility have plans for network expansion by adding new media?
- Is any type of shared network available for use by the utility?

### 3.2 Control of the Distribution Grid

Automation of overhead MV networks (6.6-36 kV) is now becoming very popular. In many countries, the highest growth in investments is going towards DA (See Table 1). Many of these systems require the use of radio to control equipment (switchgears) that are installed in areas where wirelines and fiber links are unavailable or not viable.

For example, Northern States Power (USA) realized substantial savings in their Grand Forks, North Dakota operation. “Originally, we were looking at a $2 million substation capacity upgrade project. By implementing the Motorola MOSCAD distribution automation system, we were able to defer the project. And the Motorola system will pay for itself within two years”, commented Dick Wolfe, the utility’s senior division engineer. [7]

RTUs used for DA, mostly communicate using short messages. As a result, the communication response is not a function of the data rate, but depends mainly on the protocol, channel noise, channel access mechanism and data network structure.

Although fast response (update on the operator’s screen) is always desirable, it is important to remember that performing functions, such as isolating a damaged portion of the grid and restoring the power, can be done even after a delay of several seconds or even minutes. Using radio for these applications is therefore acceptable. Radio allows reliable access to remote locations (switches) and for performing grid reconfiguration. This in itself provides many financial and operational benefits.

Among the most popular DA functions are:

- *Motorized breakers.* Actuating pole and/or pad mounted switch controllers (SF-6 and air brake type) for Fault Isolation and System Restoration **(FISR)**, as well as for shifting the actual load between the substations (load balancing).
- *Key parameter measurements.:* Measuring Voltages, Currents, Active and Reactive Power, power consumption and related calculations performed at certain strategic points, Total Harmonic Distortion **(THD**), etc.
- *Monitoring of large HV-MV substations*: This function is very important for load balancing. Large substation typically use a combination of wirelines and fiber optics. Smaller and less complex substations can, on the other hand, use radio.
- *Capacitor bank control.* Real-time correction of the power factor **(cos $\phi$)** uses remotely controlled field installed capacitor banks and radio operated RTUs. These RTUs also monitor the power quality (wave distortions, level fluctuations, etc.) and report on any irregular condition.
- *Line voltage measurement*. Measurements performed at the MV voltage level (6.6-36kV) in the customer neighborhoods provide major benefits since it helps ensure a more stable supply of electricity and more efficient operation of customer equipment.
- *Transformer Station Monitoring.* Involves real time monitoring of **MV/LV** regional transformers. The RTUs installed next to these transformers, report on loading conditions and on key parameters such as oil pressure and temperature.

## 3.3 Demand Side Management Communications

While DA has already been adopted by many utilities, the new thrust is for Demand Side Management **(DSM)** applications. Like DA functions, DSM is also driven by the interest of electric utilities to improve service and reduce operating costs. Both are heavily based on two-way communications**.** Providing communication for monitoring and control at the consumer sites, produces great benefits both to the utility and its customers.

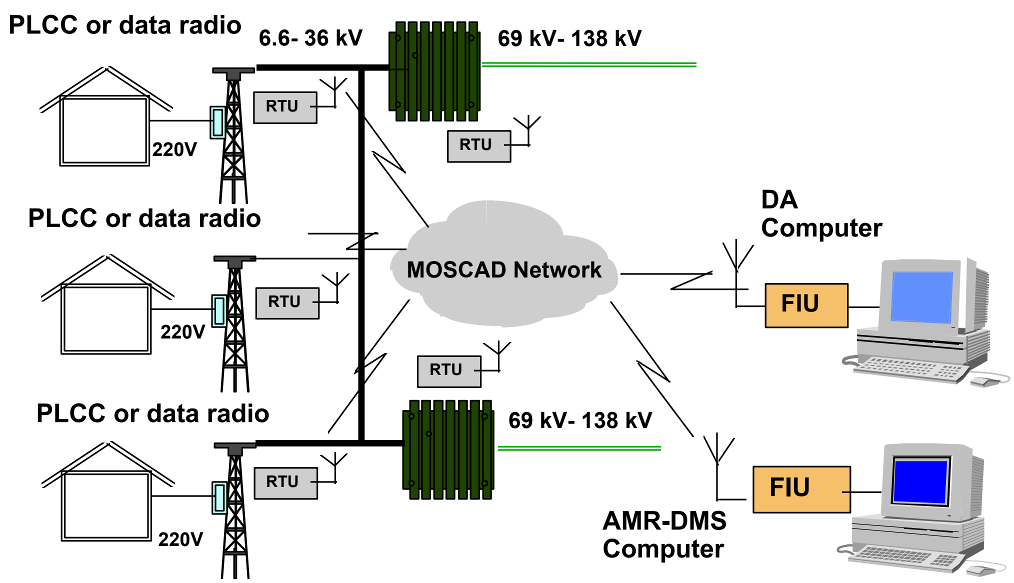


Figure 3: Integrated Communication for DA/DSM/AMR

A number of DSM applications have some commonality with DA and may share the same infrastructure. Others are based on an already installed infrastructure used for Automated Meter Reading **(AMR)**. Figure 3 provides an illustration of a combined system which integrates both DA, DSM and AMR functions.

The following are typical DSM and AMR applications.

- *Load management on the consumer side*. Communications to customer premises allow the utility to control user appliances according to a known time schedule. This prevents transformer overloading and avoids possible power outages.
- *Dynamically adjusted customer tariffs.* Flexible Time of Use **(TOU)** tariffs are set according to a known time schedule and according to the anticipated loading. TOU is used to encourage customers to shift operating non-critical appliances from peak to off-peak hours.

- *Remote meter reading*. Communications allow the utility to read customer meters via a dedicated AMR network, rather than using field personnel entering customer premises. This is a “mistake-free” operation , and it results in fewer complaint calls to the utility.
- *Remote consumer disconnect and reconnect*. This operation, done via the AMR network, contributes to lower utility operating costs. Faster execution of disconnect work orders prevents losses and faster execution of reconnect work orders increases revenues.
- *Fraud Detection.* Detection of fraud is an important enhancement feature of those AMR systems which are based on two-way communications. Utilities worldwide have reported significant loss of revenue due to unpaid bills and due to intentional tampering of meters. These tampers can be detected by diagnosis done via the AMR network.

## 3.4 Investment Considerations

The decision to enhance the system with more advanced communications, isn't always a pure issue of economics. Rather it is driven by the desire to modernize operations, improve service, and more efficiently maintain and operate the power distribution network. This can't be done without *modern integrated communications* serving management, crew, operators, and of course, the customer.

The Return On Investment **(ROI)** and the cost-benefit ratio are important tools. These can be determined by analyzing the real costs involved in owning and operating the utility’s communications infrastructure. The cost of such a system is composed of the following:

- *Annual depreciation.* Relates to the capital cost of the equipment, which needs to be purchased to operate the systems . The calculation is based on the expected lifetime of the system and the equipment, for example 10 or 15 years.
- *Capital cost*. The calculation is based on the interest rate on the capital, initially invested in the communication infrastructure, equipment and on future expansion.
- *Operating costs*. Covers all ongoing expenses for dedicated manpower, operator training, travel, maintenance costs, etc. which can be attributed to the system. It also includes communication charges, licensing for radio channels, software updates, etc.
- *Computer Hardware:* Comprises the Master Control Center **(MCC),** power supplies, backup batteries, Local Area Network **(LAN),** Gateway and other data network equipment for SCADA. Frequent releases of software updates, which often require more powerful machines makes the hardware selection a critical decision.
- *Computer Software* . Utilities can decide to use PC/DOS, PC/UNIX, PC/Windows/NT, or DEC/ Open VMS based application packages. The selection depends on the desired features, physical length and complexity of the MV grid and the number of controlled points.

- *GIS or AM/FM.* The more advanced software packages integrate Geographical Information Systems **(GIS)** which provide maps displayed on the same screen as the MV grid schematic. In some literature this feature is called Automatic Mapping/Facility Management **(AM/FM).**
- *Field Equipment.* Radio equipment for data, (provided "built-in" with some RTUs), includes the antenna and power supply with backup battery. During a power outage, the RTU communicates with the MCC and reports on the events associated with the power failure.
- *Consulting versus In-house Engineering.* Designing a customized DA/DSM system with many features requires a great deal of technical expertise. If such expertise is not available in-house, use of an external consultant is recommended.
- *System installation and commissioning*. A professional communications survey of the geographical area is as important as any other step in engineering a DA system. This work can be done by an expert in both *radio communications and SCADA systems*.
- *System and field equipment maintenance*. Includes the costs for all repairs (labor and material) and preventive maintenance. The overall figure can be broken down into the specific areas of the DA system (e.g. equipment, RTUs, communications computers, etc.)

## 4. FINANCIAL EVALUATION OF BENEFITS

How can a utility evaluate the operating benefits resulting from using integrated communication network serving both DA, DSM and AMR? This can be easily performed by using in-house databases and criteria that are readily available to the utility.

Utilities are often the sole suppliers of electric energy to a specific region or even to the entire country. Their operating expenditures and consumer charging policy are regulated by government authorities. Thus utilities must monitor their performance, constantly strive to improve their grade of services and avoid increase of tariffs. Lets see what added values an integrated system may provide:

### 4.1 Operating Benefits

Implementation of advanced communications for DA and DSM means fewer and shorter power outages and as a result, increased revenues for the utility. Supply of reliable service encourages more users to prefer electric power over other alternative sources of energy.

- *Fewer customer complaints.* Faster field service response to customers who experience power outages, results in fewer customer complaints. This means reduced labor costs for service and dispatch personnel who handle such calls.

- *Optimized control.* DA and DSM systems require *more* frequent and automatic collection of data from strategic remote strategic points. As a result, energy consumption (peak/off-peak demand) can be better balanced and the number and duration of power outages can be reduced. Prolonged overloading of the electric network and damage to the power network components (transformers, cables, fuses, etc.) are avoided.
- *Reliable supply of power*: Recurrent outages are costly to customers because they are unable to plan and conduct their business activities, and can not rely on a reliable supply of power. DA systems assist the operator to better utilize the resources and help him make more intelligent and faster decisions when sufficient electric capacity is lacking.
- *Early warning feature.* Early warning of impending problems can prevent damage. For example, upon receiving an early warning signal in the control center, of an overloaded transformer, some sections of the grid can be redirected (via radio communications) to another transformer substation. This will reduce the load on the overloaded transformer.

## 4.2 Communication Benefits

Communication network evaluation is as important as evaluation of the distribution grid operation. It may contribute a great deal to the successful and cost-effective implementation of the DA system. Alternatively, any improperly designed system might cause unnecessary complexity due to handling large amounts of useless data.

- *Up-to-date information.* Status indication and measured parameters at the sites are communicated to the control center for processing by spreadsheet or similar programs. Thanks to radio communication, the operator's Man Machine Interface **(MMI )** screen displays more meaningful and real-time data, which enhances its value to the operator.
- *Power quality monitoring.* Modern technology and communications allow detection of power quality problems by means of RTUs. For example, high level harmonics (caused by unusual loading) might cause transformer burnout, faulty operation of equipment and operating losses to the utilities and customers.
- *Reduced number of operators:* Integrated communication enables more optimal control with fewer operators. However, these people must be better trained and highly motivated, because more data, which flows from more remote sites to the control center, is to be handled.
- *Communications backup for wirelines and fiber links.* This is a fringe benefit of the existing radio infrastructure serving as a communication highway for DA and other applications. Once the RTUs and radio are there, the rest is a matter of investment in RTU programs.

## 5. SUMMARY

It is easy to monitor and evaluate the quantifiable benefits of using advanced DA systems and integrated communications. In most cases, these are expressed in economic terms and the attitude of employees and customers. However, as explained in this paper, use of modern radio based data communication contributes many additional benefits, that should be taken into consideration as much as the utility's balance sheet. Some of these benefits are: faster response, a more reliable database, more satisfied operators, improved service, and customer satisfaction..

Jeff Olson, Engineering technician at the Pierce-Pepin Cooperative utility in the USA summarized: "By automating our distribution network, we can provide better service to our customers through more efficient line crew dispatch. The integration of advanced radio communications with electric DA systems more than justifies the investment".[5]

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