Automated Meter Reading Using RF Technology

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Abstract— The paper discusses Automated Meter Reading, a technology used to automate the task of reading consumption records of subscribers. This is one of the immediate issues facing Utilities in Iran and elsewhere. The problem is first defined in terms of Utilities critical infrastructure needs, revenue protection and operational efficiencies. Various drivers as well as impediments within such scopes are then defined. Moreover, different technologies proposed and implemented are discussed. Furthermore, the field trial of one such technology in Orumiyeh, in West Azerbaijan, Iran is outlined. The paper concludes by capturing the conclusions obtained and suggestions for further improvements of such technologies for future applications.

Index Terms— Automated Meter Reading, Advanced Meter Management, Advanced Metering Infrastructure

I. INTRODUCTION

Utility companies across the world are experiencing the need for a major technological evolution in their day-to-day operational systems. A variety of factors are contributing to the drive to overhaul the entire system, tools and processes.

(A). Need to make optimum use of grid infrastructure: Power Generation, Transmission & Distribution is the last remaining mega sector which provides a critical service to customers without having real-time feedback about how its services are utilized at its termination points. In other words, power is generated at the source without any real-time data from where it is used. The utility system has traditionally operated as an open-loop where no real-time data has been captured on instantaneous demand, consumption profiles, system performance, etc.

This means that Power Companies generate power at the top peak of their anticipated demand and blindly push it downstream to termination points. If the generated power is less than the actual demand, then there would be black-outs. And if it is more than the aggregated demand, then the excess power is burnt in dummy loads.

Considering the rising cost of power generation, this approach can no longer be sustained. Utility companies need to have real-time and accurate data about consumption and demand patterns to enable them to optimize power generation at the source.

(B). Need to change pricing model: To achieve balanced loading across the distribution system and reduce peak demand cycles, customers need to be enticed to change their consumption behavior. This can only be done thru multi-tariff pricing of electricity service. Consumption shall thus be charged differently based on the time it has occurred. Consumption during peak hours is penalized by charging a higher tariff, while outside peak hours the tariffs could be considerably less.

In order to implement new pricing models, Utilities need to change the old electromechanical single tariff meters to the new fully digital multi tariff meters. Furthermore, in order to collect data at the consumption point, communicate it back to their
central servers and exert command and control over the entire system, these new meters have to be integrated into an end-to-end data network.

II. PROBLEM DEFINITION:
Traditionally, Utility companies have faced difficulties in embracing Automation in most of their operational environment. While the need for modern Billing and Accounting systems had forced Utilities to modernize their back-office systems, the front-end of the system has seen almost no change in the operational procedures, tools and systems in the past 100 years. In most utilities across the globe, consumption records of customers are still recorded by utility staff using pen and paper (or lately by Hand Held Computers and PDA’s) and inputted off-line into Utility’s backend systems. Accounting and Billing, however, are somewhat exception to the fact as these tasks are to a large extent automated. However, rising cost of energy coupled with the need to have more control over the power distribution grid have convinced Utilities of the inevitability of an end-to-end system overhaul. In other words, Utilities have realized the need to deploy automated meter reading, thru which they could achieve operational efficiencies, improved system management and better revenue protection.

III. AUTOMATED METER READING (AMR)
Consumption records of customers are generally kept in terminal devices inside the premises of customers. These terminals, generally known as meters, are overwhelmingly Electromechanical. By virtue of being electromechanical, such meters present utilities with the following challenges:

(a). Inaccuracy: These meters are extremely inaccurate. Scaling up such inaccuracies across large sectors of the population can result in revenue unpredictability and losses for all parties involved.

(b). Fraud: These meters are prone to tamper and fraud. In many parts of the world, stealing electricity thru tampering with such meters is prevalent.

(c).Rising cost of Data Collection: Depending of where such meters are installed, utilities have to incur manpower and logistical costs associated with physical access to meters to manually record consumption data. Errors in reading and/or recording, intentionally or unintentionally, may mean huge revenue loss to Utilities.

Industry’s response to above challenges is materialized in the form of Electronic Meters capable of remote access and communication. Such meters are simply known as AMR (Automated Meter Reading) meters, which not only measure power consumption accurately and with adequate precision, they are tamper proof and capable of integration in a large scale Integrated Data Network[1].

Being remotely accessible, AMR Meters provide utilities with unimpeded access to consumption data as well as On-demand collection of meters’ data. Moreover, if such meters are equipped with cut-off relays, Utilities can exert full control over the services which they provide for their subscribers. Generally speaking, AMR is viewed as one-way reading technology only [2]. However, if the technology provides for two-way communication between Meters and Utility, enabling exchange of data and commands, the technology is often referred to as Advanced Meter Management (AMM). Given full integration with Utilities back-office tools, providing end-to-end command and control infrastructure, such technologies are referred to as Advanced Metering Infrastructure (AMI)[3].

Having access to instantaneous consumption patterns across geographies will now give Utilities the missing piece of the puzzle to improve Power System Planning and Management. Equipped with Demand Patterns across their distribution network, Utilities can now plan for fair distribution through Demand Control. They could ensure better utilization of existing infrastructure. They could also strive for fair pricing based on usage patterns. But most important of all, armed with such data, Utilities can manage their expensive assets and ensure a better Performance on their costly infrastructure through better system capacity planning across their service areas using Demand Control.

And last but not least, an important byproduct of AMR/AMM/AMI is improved customer services thru internet portals. Such tools provide customers with customizable views, enabling them to gain access to their records, service contracts, detailed usage, applicable rates and historical data. Engaging customers to play their parts as informed consumers goes a long way to enable the public play their fair share of protecting and optimizing the usage of critical national infrastructure.

IV. TECHNOLOGIES USED IN AMR
AMR can be implemented using a variety of technologies. Depending on the scope, available infrastructure and network topologies, many technologies could be employed to realize AMR systems. Generally however, these technologies are divided into three groups:

(a). Legacy Options: These comprises traditionally available technologies used in communication systems today, such as POTS (Plain Old Telephone System), Public Wireless (Paging, GSM, CDMA, GPRS, etc) and Satellite (Low Orbit Communication Satellites)

(b). Broadband Options: Newer technologies used for large bandwidth data communication such as Broadband over Power lines (BPL) and Wireless Broadband (Wi-Fi, WiMax, etc).
Cost-Effective Options: These are the technologies of choice for low bandwidth, cost sensitive applications using Private Wireless (licensed & unlicensed ISM Band) and Narrowband Power Line Communication (PLC) [4].

Legacy technologies are capable of supporting large scale AMM projects and can access geographically dispersed meters via dial-up or dedicated/shared lines. On the flip side, such links are expensive to secure and operate in many locations and countries. While for large industrial customers, or collection of meters, using phone lines to access meter might be justifiable, assigning a single phone line to a residential meter does not make economic sense.

WAEPD has equipped 12 meters installed in remote, difficult to pass mountains with this type of AMR. Most of these meters are inaccessible during 6 months of year due to heavy snow and harsh climate conditions.

Broadband options, on the other hand, provide large communication bandwidth and use commercially available components and Cutting Edge Technologies and Standards. However, such systems prove to be too expensive for AMM applications. They can only be justified if Utilities plan to venture into providing their customers with services other than Power (e.g. Video On Demand, IP Telephony, Video Surveillance, High Speed Internet, etc)[5].

Unlicensed spread spectrum or licensed narrowband technology is proven to be the technology of choice for AMR applications. In this technology, the communication between Meters and Data Collectors are done thru peer to peer radio links, where radio coverage is determined by RF technology and permitted power dissipation.

V. AMR USING RF:

Automated Meter Reading System consists of the following 4 components:

(a). AMR Meters, capable of measuring multitudes of consumption parameters (e.g. active power, reactive power, voltage, current, demand, etc) with acceptable precision and accuracy. Smart Meters should be tamper proof and capable of storing the required data for a number of billing cycles[6].

(b). Short Haul Narrow Band Communication Modem, enabling each meter to communicate with mobile/stationary data collectors (walk-by/drive-by). The communication channel has to be robust, secure & low-cost.

(c). Data Collector Unit (DCU), also known as DAU (Data Aggregator Unit) when the system is equipped with Fixed Wireless System, or HHU (Hand held Unit), when data collection is done through mobile hand held units.

(d). Reading Application Software is tasked with authentication and hand-shake with each meter in the network. It is capable of identifying each meter, querying them, exchanging data and command with them and storing the collected data for scheduled and/or on-demand transfer to Utility Servers.

The architecture of the system is depicted below:

![Figure 1: System Architecture of AMR (Source: BBS)](image)

VI. ORUMIEH’S AMR PILOT PROJECT SPECIFICATIONS, FEATURES AND PARAMETERS

WAEPD serves more than 800000 subscribers in the North Western state of Azerbaijan. Orumiyeh is the center and main city of the state. Orumiyeh includes more than 210000 subscribers. The billing system is based on reading meters every 2 months and sending printed power consumption bills to subscribers by utility staff. According to field studies about 20 percent of meters can't be read because of closed doors and limited hours of reading through daytime.

The process of choosing appropriate technology for the pilot needed careful consideration of operational processes and current practices of the utility. It was necessary to consider relevant facts and issues facing the utility before proposing a solution for the pilot. The possibility of expansion of the pilot into a larger roll out also had to be taken into consideration while selecting the technology.

(A.) Selection Criteria:

The two most important tasks of the selection process were the selection of AMR technology and the selection of metering equipment.

(1). Selection of Technology:

The selected technology had to meet the following requirements:

(a). Easy to integrate and synergize with the current working system of the utility

(b). Able to be deployed quickly

(c). Able to grow from a small number to a large rollout with minimal extra effort

d. No special training should be required for the utility staff. The learning curve for the utility must be steep.
(e) No special resources should be required to supervise and control the pilot
(f) No disruptions and/or undue burdens upon the current practice and processes as a result of the pilot roll out.
(g) Minimal regulatory clearances, if needed

(2) Selection of metering equipment

The following criteria were applied while selecting the appropriate metering device for the pilot
(a) Ability to work in harsh weather conditions
(b) Ability to work in harsh and unpredictable electric conditions
(c) Ability to detect and record specific events
(d) Accuracy of Class of operation to be equal or better than existing
(e) Tamper Resistant
(f) Should be able to provide a wider set of measurements than the existing meters
(g) Soft Connect/Disconnect (Ability to cut off/restore service to customer remotely and without the need to manipulate physical wirings or components

(B). Performance Criteria:
(a) Ability to reduce the number of unread meters in each cycle
(b) Estimate loss of revenue
(c) Provide extensive data for analysis
(d) Estimate time saved in reading each meter
(e) Help utility upgrade the skills of its staff
(f) Able to sufficiently and practically demonstrate the benefits of AMR

(C). Selection of technology and metering instrument:

Keeping the above guidelines in view, it was concluded that the process of collection of data must be as close to present system as possible. It should be possible for any member of the utility staff to install the meters, without applying any complex procedure or using any sophisticated equipment. It was therefore decided to choose Wireless walk-by meter reading system for this pilot. The selection of this method of data collection would function very well in a system where there would be a mixture of manually read meters and remotely read AMR equipped meters.

Regulatory constraints limited the choice of using ISM band RF frequencies. The usage of 2.4 GHz was dropped due to weak penetration of radio signals into concrete walls and shorter "reach" distances as compared to sub-GHZ bands. 433 MHz band was chosen over 868 MHz band due to relatively simple regulatory norms as well as easy availability of components.

In order to make installation and deployment simple, all the constituent components of the system, (metering instrument, and wireless communication system and control mechanism) were packaged in single chassis. This made it easy to install the AMR meter without the need for additional wiring or equipment.

<table>
<thead>
<tr>
<th>Property</th>
<th>Type</th>
<th>Selection criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection Method</td>
<td>Walk-by or Drive-by System</td>
<td>Synergistic approach to existing system and practices. As of now, meter reader visits each point of installation to note a meter read by hand. This process lends itself well to automation with appropriate communication technology.</td>
</tr>
<tr>
<td>Communication Method</td>
<td>RF Wireless</td>
<td>No need for any special wiring, easy to integrate within the metering unit</td>
</tr>
<tr>
<td>Frequency of Operation</td>
<td>433 MHz</td>
<td>License Free, no regulatory permissions needed for operation, longer distance. Relatively simpler regulations, easily available components</td>
</tr>
<tr>
<td>Modulation</td>
<td>FSK</td>
<td>Robust and reliable, easy to penetrate walls</td>
</tr>
<tr>
<td>Distance to read</td>
<td>~50m</td>
<td>Easy to read meters from road side</td>
</tr>
<tr>
<td>Reading Instrument</td>
<td>Pocket PC</td>
<td>Familiar environment and product. Utility already using PDA’s and Hand Held reading Units</td>
</tr>
<tr>
<td>Class of Operation</td>
<td>1</td>
<td>More accurate than existing meters</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>Down to -25 Deg</td>
<td>Meant for extreme conditions</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>Safe from 100V to 350V AC</td>
<td>Withstand harsh conditions</td>
</tr>
<tr>
<td>Tamper Resistant</td>
<td>Reverse Current Removal Terminal Cover</td>
<td>Revenue Protection</td>
</tr>
<tr>
<td>Time of Use information</td>
<td>3 Tariff registers</td>
<td>Analyze consumption during 3 different time zones. This would help utility to plan new peak demand generators</td>
</tr>
<tr>
<td>Monthly consumption history</td>
<td>Up to 12 months for each tariff</td>
<td>Collection of statistical data for customer profiling</td>
</tr>
<tr>
<td>Event Log</td>
<td>Different types</td>
<td>For Audit purposes and as Anti Tamper measure</td>
</tr>
<tr>
<td>Maximum Demand computation with excess demand indicator</td>
<td>Recorded on per billing cycle basis</td>
<td>Analyses peak demand and its time of occurrence. This would help utility to plan new peak demand generators or to change tariff regime Indicates to consumer if he is exceeding allowed limits</td>
</tr>
<tr>
<td>Disconnect Mechanism and Demand Control Function</td>
<td>Allows disconnection in the event of over drawl of energy or by a command from reading instrument</td>
<td>Control Peak Demand and disconnect power supply to non paying consumers</td>
</tr>
<tr>
<td>Single Package</td>
<td>Metering instrument, Communication Module and cut-off mechanism in single chassis</td>
<td>Ease of installation, Little chance or error or failure. Less opportunities to tamper the meters</td>
</tr>
</tbody>
</table>
It was decided not to mix different types of systems in the first stage, and hence the scope of the pilot was limited to single phase installations.

The number of installations was chosen to be 50 so as to be manageable and yet provide a reasonable amount of data for analysis.

The duration of the pilot was set at 3 months with a further extension of 3 months if desired. As can be concluded from the table, the solution provided to the utility was quite unique, specially tailored to their needs.

(D). selecting Location for the pilot project:

The neighborhood of Ostadan in Orumiyeh was chosen for the pilot project. The main criteria for this selection were:

(a). There are different kinds of customers with different patterns of consumption

(b). Indoor and outdoor conditions for installing the meters

(c). Exposing some meters to direct sun arrays, shadows and other different locations to test the effects of environment on radio links and data transmission as well as the meters resistance against harsh climate conditions

(d). Installing some meters in pairs and triples to test the frequency coverage effects

(e). There are BTS stations of communication utility and wireless communicating systems of state departments in the region. This is to test frequency interference

VII. CONCLUSIONS

Regarding low efficiency of traditional meters management, among them: high costs of gathering information, the need to be at the meter's installing location and low accuracy due to the man's role in data aggregation; it would be unavoidable to develop automated meter reading and management as a part of a larger automated network.

The pilot project executed in Orumiyeh was a successful experience of a small scale metering automation. The meters were investigated 4 months. The data was collected and analyzed every 2 weeks. As the new AMR digital meters were installed in series with the conventional electromechanical ones their records were compared. All the 50 installed meters responded to the commands. The least connecting distance was of a meter enclosed in a metal box behind two walls in an indoor situation and the farthest connecting distance belonged to a meter installed outdoor behind a house wall. Time needed to get the last consumption records is 15 seconds which is 1/4 of the time needed to reach inside a house and read the meter. It lasts 40 seconds to download the events data; events data is downloaded for certain meters based on requirement or in special conditions.

Since the majority of electrical meters in Iran are installed indoors, the approach of conventional data aggregation is to enter private zones and read the meters. This approach faces closed doors and includes inconvenience. Applying AMR lessens such problems and improves utility economical performance; moreover it increases subscribers' satisfaction.

Although the mentioned solution is a long step toward metering automation, it suffers from some shortcomings. Still staff should go to the meters locations. The utility can't get real-time data from a central system. Also there is the problem of the HHU charging, memory shortage and time needed to download its data.

All the matters discussed above, pushes mind toward an advanced automated metering infrastructure. However it needs investing an enormous amount of capital, but technology development, lessening prices and appealing benefits of the new age smart grid raises hopes to remove the barriers

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IX. REFERENCES


X. BIOGRAPHIES

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