INNOVATIVE SOLUTIONS FOR DISTRIBUTION AUTOMATION AND AUTOMATIC METER READING

R. Cettou **S. Mattatia**

Services Industriels de Genève, CH1211 Genève 2 (Switzerland)
Tel : +41 22 420 7822
E-mail : raymond.cettou@sig-ge.ch

P. H. Dondi **J. Favre**

ABB Power Automation Ltd. CH5300 Turgi (Switzerland)
Tel : +41 56 299 3716 – Fax : +41 56 299 4062
E-mail : peter.dondi@chpau.mail.abb.com

Summary *The paper describes the automation scheme presently being implemented to support SIG in providing service excellence to its customer base. A description of the innovative distribution line carrier technology, which provides the communication for the automation of this high density, highly meshed cable network is provided. The engineering of the pilot scheme, which has been in operational tests between Sept. and Dec. 1998, is used to indicate how the distribution automation process can be handled.*

1. INTRODUCTION

Many changes are taking place in the utility industry. As a result, the operation, maintenance and customer service organisations, within the utilities are requiring more and accurate information of the state of the network down to the household. Furthermore, the need to balance security with supply quality, and optimal network operation, implies more active intervention in the network, and innovative control strategies. In particular, to provide cost effective technologies to support these requirements means bundling functionality to obtain optimal usage of automation infrastructure [1].

Within the canton of Geneva, the distribution of electricity, gas, water and district heating is the responsibility of the

the general pressures on such a company to provide high quality of supply in an urban environment, the company is fully aware of its position in focussing on the high level of demands placed upon it by its international clientele. In a sense, it can be said that the company has needed to be very customer oriented even prior to the introduction of deregulation, simply because international institutions will move their offices to more competitive environments if the quality of the infrastructure is not to their expectations. As the introduction of the deregulated energy market approaches, the company is moving to understand better the needs of its clients, and to provide products and services in line with their requirements.

To support a competitive position in the future energy markets, a thorough evaluation of the customer requirements, interrupt and service situation and possible improvement areas has been made. Based on this, an innovative move into network and energy metering automation has been undertaken.

In the following section, an overview of the customer base, the network, and the improvement scheme is discussed. The latter to provide automatic switching, improved remote control, better monitoring of secondary substations and remote meter reading to enhance the customer services improvement areas discussed.

Section 3 describes the technology used to implement such a scheme on a network consisting mainly of cables. The scheme uses medium voltage distribution line carrier (DLC) communications. The system is based on newly developed general-purpose modems with programmable digital signal processors (DSP) and powerful micro-controllers for application and protocol handling. Within the designated CENELEC frequency range, a gross data transfer rate of 36kbps is achieved, permitting fast transmission of control-commands, alarms and measurements, and allowing capacity for meter values. Coupling to the power line is an important DLC factor to which much attention has been paid, and coupling methods include a newly patented inductive coupler. Intelligent node controllers (INC) provide processing functions for local communications handling and process control, in particular, combining the remote control of switches and meter reading.

Section 4 gives a brief description of the implementation of the pilot project and the results attained. Particular attention is paid to the implementation of a general-purpose communication server to integrate with the utility information system. Finally, the conclusion summarises the results and presents an outlook for the roll out.

2. SIG – SERVING A MAJOR CITY

2.1 Characteristics of the customer base

The company is an independent multi-utility supplying electricity, water, gas and district heating to the city of Geneva and the surroundings. The approximately 400,000 inhabitants together with numerous industrial and commercial customers have a total consumption of electricity of the order of 2500 GWh (1998) with a very small growth rate (less than 1% over the past few years), (A review of the supply structure can be found in [2]). The peak load reaches 450 MW and the mean load is seasonally quite stable. The load demand is met by around 30% own production (3 hydro power plants), whilst the bulk is covered by supply contracts with other companies.

The city's major role as a centre for international companies and organisations is renown, and reflects in the structure of the customer base. Of the energy sold:

- 48% serves banks and financial companies, UN and international organisations, trading corporations, telecom companies.
- Another 15% serves the industrial sector which in the Geneva area consists largely of the refined chemical industry and small/medium sized high tech companies.
- The household sector represents 35 % of the total consumption.

The needs to be fulfilled, to support the activities of this customer base, have been paramount in the continuous effort to maintain and to develop high quality of supply.

In supporting this customer base, the commercial strategy is now fully aligned with the coming liberalisation of the Swiss energy market. The regulations governing the liberalisation foresee a separation of users, basically into two categories:

- Major electricity consumers who may participate in the energy market and may negotiate contracts for supply.
- Consumers who continue to be supplied by the local utility, which is under obligation to deliver the energy as needed.

For the former category, the major customers, the choice of individual contracts has already been introduced, replacing the standard tariff structure, which has been typical for the "public service" regime.

2.2 Characteristics of the network

The distribution network covers the whole district of Geneva (241 km2). It is connected to the European 380/220 kV grid by means of two main stations 220/130 kV. It comprises nine primary 130/18 kV substations and more than 1500 secondary substations.

The network consists of approximately 95% underground cables. The MV network has a strongly meshed structure but is operated in a radial configuration from the primary substations where the breakers are remote controlled and where the MV feeders are equipped with over current protection relays. The MV network is grounded with the Petersen coil technique, allowing uninterrupted supply in the case of a single-phase fault to earth.

The secondary substations are located in roadside cabins, underground street sites, accessible via manholes, and more and more in building basements. The MV and LV switches are presently manually operated, no automatic reclosers are installed in the network (due to the cabled structure of the network) but feeders are equipped with current fault indicators.

Service crews working on the network communicate with the control centre over the utility private mobile radio (PMR) system. A single frequency is available to the utility for this purpose.

An existing ripple control load management system is installed with 30,000 receivers.

2.3 Evaluation of the advantages of Automation

To ensure an optimal infrastructure for Geneva, its inhabitants and the companies situated in the area, a policy of continuous improvement in supply quality has always been followed. This has included reducing the dependence on overhead lines, reinforcing the primary equipment in particular areas, and searching for automation methods to reduce customer interrupts.

In 1997 the mean duration of interrupts had been reduced to 72min with 85 % of the customers without any interrupts and 12 % of the customers with 1 or 2 interrupts.

Further reduction in customer interrupt time, basically implies:

- reduction of the time to locate the fault and also the number of undesired reclosing,
- faster intervention in the network, which is a major problem due to traffic congestion in the city.

These considerations have led the company to undertake the introduction of fault indicators and remote control of a subset (10 %) of the secondary substations with the following expectations:

- The introduction of fault indicators will provide a global reduction of around 25% of the interrupt time for a fault at the MV level, and also 1 to 2 less reclosing trials (maximum 3 to 4 in city and 6 to 7 in rural areas),
- The remote control of less than 200 judiciously chosen secondary substations will allow the reduction of 30-50% of the interrupt time with half of the customers being reconnected in less than 15 minutes.

In estimating the return on investment in automation of secondary substations with DLC, the reduction in the non-delivered energy (NDE) (MWh) and the interrupted power IP (MW) were considered. The cost attributed to NDE and IP represent the actual difficulties caused to the customers by a supply interrupt, and thus the price that the utility is ready to pay in order to achieve its policy of quality.

Finally, with the approaching market liberalisation, the possibility to automate meter reading, particularly for larger consumers is expected to provide an optimal way to tailor customer contracts with their energy and power requirements.

3. THE AUTOMATION SCHEME

3.1 General overview

The analysis made led to the conclusion that the implementation of an automation scheme would positively enhance the service to their customers. The requirements placed on the technology are as follows:

- Flexible and cost-effective. The implementation of an automation scheme must lead to an increase in productivity,
- Easy to implement and expand. As with may distribution automation schemes, the implementation is not in a "green-field" site, but must be possible to carry out in a staged roll-out, typically following the motorization of the manual switches,
- Support fault finding and remote switching, independent of switching equipment,
- Support meter reading – independent of meter supplier,
- Allow independent testing and integration into present and future utility IT systems.

As is clear from section 2.3 above, not all substations are to be remotely controlled, and the metering involves both MV and LV metering. The meters may or may not be at the site of remote controlled switches.

DLC was chosen based on a comparison with other solutions like dedicated or direct dial telephone links, CATV or radio for supporting DA. The fact that metering and network automation can be combined brings an added advantage for those substations where DLC is installed.

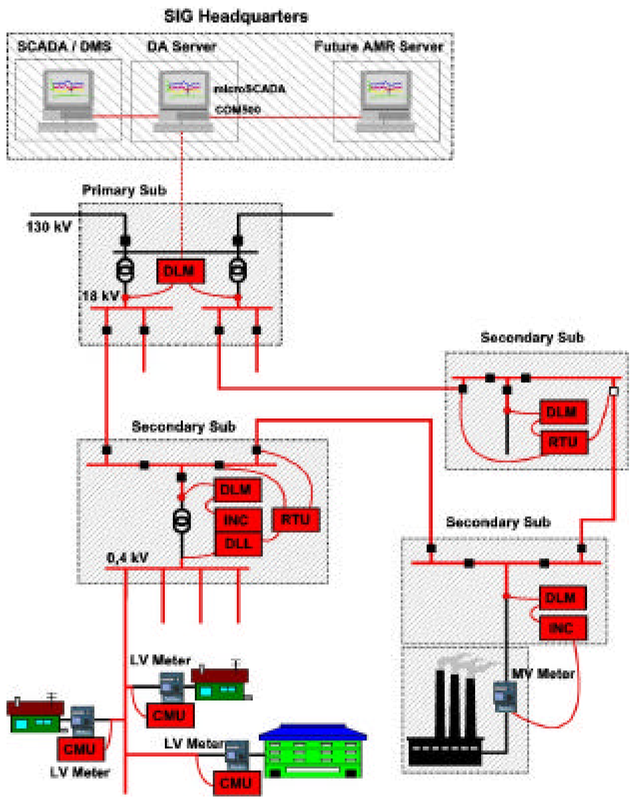

Figure 1 The general automation scheme indicating the communication channels over the power lines from the 130/18kV substation down to individual LV meters. The up link to the DA Server is the fibre optic WAN. The DLM modems handle the communication on the MV network, the DLL on the LV network. INC processors are implemented according to the required functionality.

3.2 Automation Concept

The concept, provided by ABB to satisfy the automation requirements, consists of 3 major components (Figure 1). These include the latest developments in Distribution technologies:

- Modern DLC communications system
- Intelligent node controllers
- Distribution Automation (DA) server

Together with modern, standard RTUs and Alpha meters.

3.2.1 The DLC communication system

There are a number of communication technologies that can be applied in power distribution systems. One of the most cost-effective solutions in urban areas, where most substations are either under ground or in building basements, is distribution line carrier equipment. The communication technology provided for the automation is based on the latest DLC modems. In order to obtain the best characteristics, and the optimum in cost effectiveness, the DLC system involves a MV and a separate LV part which are able to be implemented individually, and are connected by intelligent node controllers. Because of the conditions on the MV networks, large distances, changing network configuration and various interference characteristics, special attention has been paid to this communication system [3,4,5]. The modem is in-fact an advanced intelligent communication module based on a DSP and microcontroller. The communications uses the frequency band designated by CENELEC for power line carriers at this voltage level. To support the communications over MV lines with high noise and routing changes with switching, the modem supports both adaptive algorithm techniques and adaptive path adjustment. Furthermore, the modem has the full capabilities to operate as a repeater. The gross data rate achieved is 36kbit/s, which allows for excellent data rates even with the high overheads for error correction built into the algorithms.

Coupling to the power line is an important DLC factor to which much attention has been paid. Advances in both capacitor and inductive coupling allow the best advantages to be taken of the network infrastructure. In the SIG network, the newly developed inductive coupling methods involve injecting the signals into the cable sheath. One of the major advantages for the utility where inductive couplers are feasible is that the coupler can be mounted non-intrusively, i.e.

without having to switch off the line. It should be noted that capacitor coupling is to be used where a sheath is not available. However, communication in mixed cable and overhead line systems using inductive and capacitor coupling has been successfully tested, and allows the advantages of inductive couplers to be fully taken into account.

The DLC at the low-voltage level completes the communication link to the LV metering sites and provides two-way communication for meter reading, and can further support load management, and other services.

3.2.2 Intelligent node controllers

As is generally known, transformer stations act as a barrier for communication at all but the lowest frequencies in the CENELEC band. Thus, when using the whole range to obtain the availability and speed desired for modern automation requirements, the MV/LV transformer stations act as a junction between the up-link and down-link communication channels. At these points, it is often convenient, not only to make the interface for communications, but also to provide a range of possible applications.

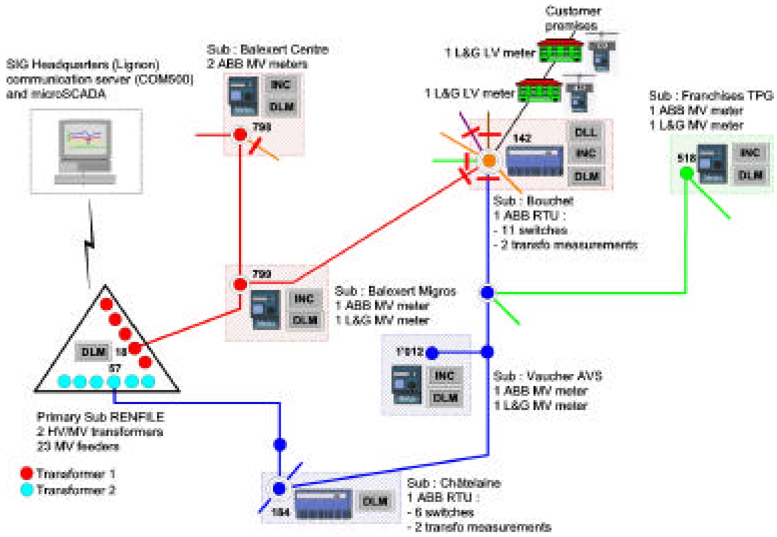

Figure 2 The two pilot feeders with open loop operation. The diagram indicates the communication loop with the meters and RTU placement. The INC is used in various configurations including both LV metering and MV metering. The DA Server is presently situated in the utility headquarters, connected to the primary substation via the optical fibre WAN.

Intelligent node controllers (INC) provide for these capabilities. These are based on a flexible hardware platform, with real-time operating system and Object-oriented design, and can be programmed to handle communication protocols, meter data, load management functionality and process control. They can be set up to perform router, repeater, data packaging, compression, error processing, protocol conversion and gateway functions for the communications system. For DSM schemes the INC maintains load management schedules. In large systems with many thousands of LV meters to be read, the INC polls the meters and concentrates the data for transmission across the various levels of the communication system to the utility control centre. In the substations they support automation, analyse faults, carry out calculations and independently support the lower level controllers. By segmenting the distribution system into sub-networks, each with its own intelligent node controller, many more meters and remote stations can be independently and reliably supervised and controlled. The very general modular structure allows interfacing between a variety of up- and down-link communications, of which MV and LV Distribution line carriers are used in this system.

3.2.3 DA server

The DA server is a flexible communications server, which can be easily extended with a man-machine interface (MMI) and basic SCADA functionality. It thus provides a complete SCADA system for the implemented automation scheme, which can run autonomously, or act simply as a communications server for a large distribution management system DMS/SCADA or automatic meter reading AMR system. The DA Server is a PC based communications front end (COM500), and is easily extended to a complete microSCADA as required.

The DA server, apart from being configurable with its own SCADA functionality can be implemented as a master/slave unit with a variety of telecontrol protocols (RP570, TG800, Simatic and IEC60870-5-101). It can however, also support data exchange via Elcom and TASE.2 (IEC60870-6), which provides Centre-Centre type data exchange rather than telecontrol data organisation.

4. PROJECT ORGANISATION

Early in 1998, SIG decided to implement a scheme to support the concept for automation and set up the appropriate project organisation with ABB.

Based on the requirements, the scheme to be delivered included both, network automation and automatic meter reading for customers with MV and LV connections.

The scope of supply thus included:

- An RTU for each of the major secondary substations indicated in the planning analysis as those to be automated on this feeder,
- Metering INC units for substations with MV meters,
- INC unit for handling LV meters,
- Alpha meters to expand the meter park at various installations,
- Consumer Management Units (CMU) to interface to installed LV meters,

- A microSCADA to provide supervision and control of the scheme,
- MV distribution line carrier communications consisting of:
    - DLM modems
    - Inductive couplers
    - Network management applications
- LV distribution line carrier communications consisting of:
    - DLL modems, integrated in the CMU for the customer sites , and in the INC units at the relevant transformer station.

The scheme is fully implemented for test and operation using the microSCADA configured and engineered as a stand-alone SCADA system. Thus, the data engineering and MMI has been provided on this system although, in the long term, it is foreseen that the DA server functionality is limited to its communication server function (COM500). The data will then be transferred to the utility central systems (see Section 4.4).

The project was divided into 3 steps:

- Communication test
- Configuration of SCADA, RTU, INC and meters in-house and function test
- Installation and operational tests.

4.1 Communication Analysis and Test

The basis for this part of the project was to obtain an overview of the cable network structure, and demonstrate the feasibility of implementing the whole scheme with inductive couplers. The communication analysis requires an overview of the network structure, distances to be covered, operational characteristics, and cable/line types. Based on SIG's network knowledge (and independent of the actual scheme to be implemented), a test cable was decided upon which is notorious for high noise and interference levels. It is to be noted that the cable chosen for this test was made up of several segments, and that the segments varied both in type (lead, PVC and EPR), and age (dating back on some segments to 1932). The test scheme required mounting two inductive couplers and modems with one end acting as a signal injection point and the other as the receiver. This is typical of the type of configuration used for tests and demonstrations. The tests [6] could be carried out successfully in a single day, including mounting of the inductive couplers. Since the coupler technology is non-intrusive, the mounting operation could be planned and carried out without organising a network reconfiguration, and thus was considered a major plus point in the test scheme. Using semi-automated, PC based analysis tools [7], not only was enough data taken to demonstrate on-line a very good signal to noise ratio, but also, a complete picture of the characteristics of the cable, and the types of noise and interference could be obtained. This type of data has been used to build up a significant library of scenarios based on real test situations, and has provided a very good simulation tool for checking and comparing communication algorithms in house.

4.2 In-house Configuration

Based on the requirements of the automation scheme (Figure 2) the various components were brought together and configured in house at the supplier's site. At this stage, the configuration was set up to test the basic functionality of the various units in an integrated environment. The basic system was set up in the test field, including the SCADA, RTUs configured as required, meters (both ABB Alpha meters and L&G meters), the relevant INC, and the communications systems. Of course, in the test field, the communications modems were linked together with no attempt being made to include live MV cables!

This in-house test configuration was then verified in the standard way according to the set of project verification procedures. This type of configuration for a single feeder is small and includes rather little functionality in comparison to major SCADA/EMS/DMS systems. Never the less, the completion of in-house tests forms the basis for ensuring

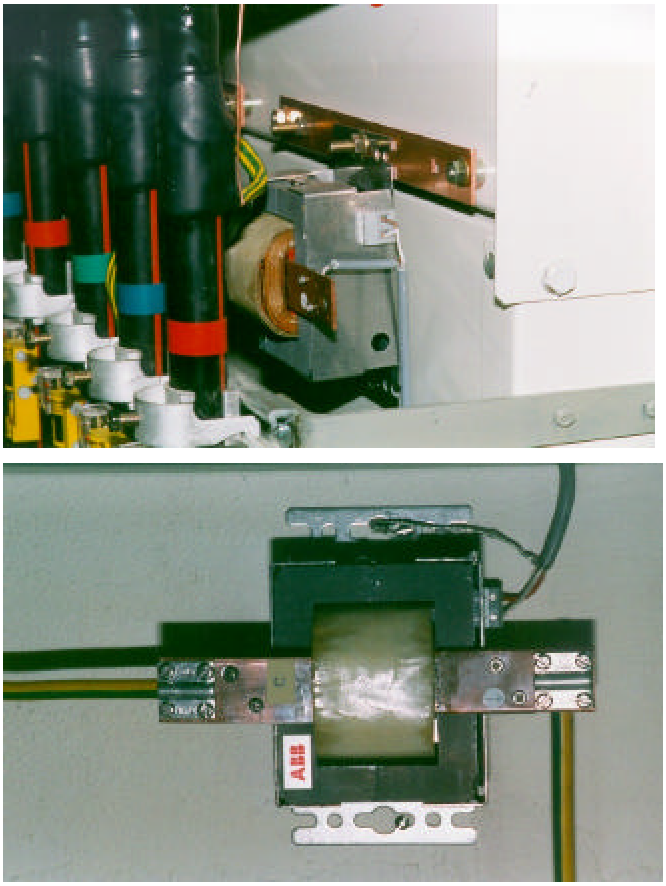

Figure 3 Two views of inductive couplers as mounted by the utility engineers

that the system fulfils the complete set of requirements, prior to on-site commissioning.

4.3 On-site Commissioning, Operational Testing

Prior to the on site activities, the commissioning plans were set up. For this particular pilot, the mounting of the couplers was carried out by the utility (Figure 3) based simply on the experience gained in mounting the equipment in the original test phase. The communication network was then commissioned on 2 feeders supplying 6 secondary substations (Figure 2). The modems were connected, and the PC based Network Management tool used to initialise the addressing configuration from the master modem in the main sub-station. At this stage, it was also confirmed that only one of the modems operated in repeater mode. A check on the communication, over a period of 24 hrs, showed that the signal quality was very good and that the communications was robust.

The control centre (DA Server), together with the RTUs and INCs were then ready to be commissioned. This includes DLC network parameter configuration such as time-outs and delay times, and then a complete test of the database for the RTUs and meters. Lastly, the connection to the LV meters via the INC, which handles the meters by polling and relaying the data back to the control centre could be tested.

The system was then tested against the verification procedures, and then left under the control of the utility project team for long-term tests and monitoring. Finally, in December ’98, after successfully completing 3 months trial operation, the system was deemed ready for transfer to the operations department.

4.4 Integration in utility information system

As the automation of the network and meter park progresses, a large amount of new data will be brought into the utility headquarters, and new control strategies will be supported. The present SCADA/EMS system in operation to control the primary substations will be integrated in March 1999 with a new SCADA/DMS System for the operation of the whole MV network with enhanced DMS functions including fault location and network restoration. Moreover by mid-1999, an AMR server will be integrated into the utility distribution management system for a first step of automating 250 major customers with contracts (both DLC and telephone dial up will be used). When the commissioning of this part of the utility information system is completed, the DA Server will deliver data to this system and to the meter management system so that all data being retrieved through the new distribution communication network is available throughout the utility. It is foreseen to connect the DA Server to this system via ICCP/TASE.2.

5. CONCLUSION

In order to improve both the operation of the network, reducing interrupts, and obtain better insight of its customer base, SIG has embarked upon a program of distribution network automation. To implement such a scheme in the urban environment of the city and canton of Geneva, a modern distribution line carrier technology has been tried and tested with successful results. The pilot scheme including the communications system from ABB, together with a DA communications server and the appropriate RTUs and meters has been fully configured and put into operation. The open communications architecture has also allowed for the integration of previously mounted meters, and is ready to be extended from the supplied DA server control centre to complete integration into the utility headquarters information system environment.

6. REFERENCES

[1] Dondi P., Singh N., ‘Impacts of communication technologies in integrated systems’. Proceedings of the EPSOM 98 Conference (Zurich), 1998.

[2] Bissat O., Genier M. :’Retour d’expérience de l’étranger: alimentation de Genève’,REE No. 1,January 1999, ISBN1265-6534..

[3] Ostertag, M., Imboden, C.: 'A High Data Rate Powerline Communication System for Combined DA/DSM', Proceedings 1998 International Symposium on Power-Line Communications and its Applications, March 24-26, 1998, Soka University, Tokyo, Japan, pp. 141 - 152, ISBN 90-74249-18-3.

[4] Ostertag, M., Imboden, C.: 'High Data Rate, Medium Voltage Powerline Communications for Hybrid DA/DSM', accepted for 1999 IEEE/PES T&D Conference, New Orleans, April 11 - 17, 1999.

[5] Ramseier, S., Arzberger, M., Hauser, A.: 'MV and LV Powerline Communications: New Proposed IEC Standards', accepted for 1999 IEEE/PES T&D Conference, New Orleans, April 11 - 17, 1999.

[6] Ramseier, S., Sabbattini, B., Imboden, C.: 'A Novel Method for Measuring the Characteristics of the Powerline Channel for High Speed Communications', Proceedings 1998 International Symposium on Power-Line Communications and its Applications, March 24-26, 1998, Soka University, Tokyo, Japan, ISBN 90-74249-18-3.

[7] Sabbattini, B., Ramseier, S.: 'The Virtual Power Line for Virtual Field Tests', Proceedings 1998 NI Week, August 1998, Austin, USA, National Instruments Compact Disk 350371B-00.