IEA Implementing Agreement on Communications Technologies for Demand Side Management

Evaluation of Communications to meet Customer/Utility Requirements for DSM and Related Functions

FINAL REPORT

Prepared by Operating Agent
Annex II

January 1996

DEMAND-SIDE MANAGEMENT
DSM/IEA
INTERNATIONAL ENERGY AGENCY

IEA DSM ANNEX II

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Report on

SUMMARY

This report is the final report describing progress made within Sub Tasks II/1 and II/2 of IEA, Annex II project "Communications Technologies for Demand Side Management". It covers the collection and processing of data on DSM and related functional needs, together with customer/utility communications technologies to meet the needs within the ten participating countries.

Details are presented of processed data for all countries which identify agreed of customer/utility need for functions and communications at the present time and within the next five years. Consideration is given to communication hierarchies comprising multiple media to utilise the strengths of each in appropriate circumstances. Typical, demonstrated capacities of different media are considered, together with discussion of the way communications systems and media can be structured and used to deal with different functional roll out scenarios.

A methodology is described using a data analysis model, developed to calculate the data exchange requirements between different categories of customers and collections of customers and utilities in order to provide a range of functions. Roll out strategies representing the penetration of collections of functions into market places are simulated and the data exchanges compared with the capacity made available by multiple media communications hierarchies.

General conclusions are drawn which emphasise that no single communication medium is best for all situations and scenarios and that individual evaluations are required.

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References

1 Interim Report on Customer/Utility Functional Needs and Communication Technologies dated January 1995

2 Interim Report on Development and Analysis of Customer/Utility Functional Need and Communication Technology Scenarios dated August 1995

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Evaluation of Communications to meet Customer/Utility Requirements for DSM and Related Functions

1 Introduction

Demand Side Management (DSM) has a central theme of modifying customer end use of electricity (and other utility supplies) to shape demand in a beneficial manner to both customers and utilities. Demand shaping objectives include conservation, peak demand reduction, demand relocation, demand control and load growth.

The results of DSM measures can be an overall reduction of demand throughout energy efficiency programmes, resulting in reduced energy consumption. Such programmes are usually associated with regulatory led objectives to reduce fuel consumption, so reducing environmental pollution, generating capacity requirements and conserving primary fuel.

They can also result in reduction of demand associated with peak generation requirements either through focused energy efficiency programmes or interruption of supply. The aim of such programmes is to avoid investment in additional generation and network assets associated with short term high demand.

Another important aspect of DSM is the reduction of peak generation and network demand through storage options, such as off peak heating. Essentially this strategy is an extension of the peak demand reduction strategy whereby energy sales normally associated with peak demand are relocated to off peak periods.

A further extension of demand relocation and peak demand reduction, in which communication between the supplier and customer allows the supplier (or distributor) to control the customer demand dynamically to optimise generation and network utilisation.

Promotion of electricity consumption can also be a feature of DSM, particularly at periods of low demand, to maximise utilisation of generation and network assets. This strategy has been practised for many years through economy tariffs in the UK.

The application among customers of many of these DSM functions can be greatly improved if increased communication between customers and energy suppliers can be developed at acceptable cost. In order to obtain these acceptable costs at the present time, many different functions have to share communications capacity and infrastructure.

Utilities providing enhanced customer service across a widening range of activities and increasing customer focus of the businesses are features of the directions being taken by utilities in many developed countries. These additional services may include remote metering and end use energy consumption information on an itemised basis, planned and unplanned supply interruption details as well as information on supply quality.

Communication infrastructures are being installed between utilities and distribution substations for network automation purposes to reduce supply restoration times following faults. These communication systems can be shared by customer/utility, DSM traffic to assist cost justifications.

Consequently there is potential for many customer/utility functions, which are not cost effective in their own right, to be integrated together to assist with justification of a communications infrastructure and enable financial benefits to be obtained for customers and utilities.

One of the most difficult problems to resolve in quantifying the communications needs associated with increasing supplier/customer dialogue, is defining what functions are likely to be required by suppliers and customers and which can contribute positively to the economic justification of providing communications links and infrastructure. Answering this question requires consideration of how the relationships between customers and suppliers will change in the future and how much communications infrastructure capacity can be justified at the outset to meet perceived longer term market development. Different communication media and technologies have different strengths and weaknesses in dealing with particular information density requirements. In densely populated areas for example, where the information density to be exchanged between customer and supplier may be relatively large, communication system structures may be appropriate which would not be suitable for more sparsely populated rural areas.

Another critical, but related question is in choosing the communication medium or media with the capacity, reliability, associated costs and technological potential to meet the needs of future data exchange scenarios between suppliers and customers. A generation of customer/supplier information exchange needs will be met using low capacity communication media and presently available technologies. Evolution and migration of customer/utility functions to high speed networks will take place as they become available at a competitive cost in the future.

Different dialogue and functional need scenarios result in different information flow requirements between suppliers and customers and different response times, availabilities and reliabilities. These requirements dictate communication channel capacities, data error rates and securities. Communications media presently being considered for the most critical link in the chain in terms of cost justification, that immediately connected to customers, are low power radio, mains borne LV network signalling and local telephone exchange lines. Broadcast radio is also being used and developed to provide one way communication from suppliers to customers. MV network signalling is also being developed and installed in limited quantities to carry out one way and two way communications on the second level of the communications hierarchy. The increased penetration of cable television and the links this provides to customers, together with the possibilities of satellite communication, mean that they are both potentially viable means for wideband information exchange between customers and suppliers. Many functions requiring customer/utility dialogue can also be carried out using "smart cards" and a reduced communications infrastructure. The "smart card" could be loaded with electricity price information from a local dispenser which could also serve to upload customer consumption patterns and information to the supplier. In this case, the customer acts as the local communication link. However there are significant limitations with these arrangements if dynamic functions such as direct load control are required.

Each communications medium and signalling technology has a channel information capacity, availability, reliability and cost associated with it. Consequently, it is possible to consider future information flow needs, based on different customer and supplier dialogue scenarios and map those needs against the potential for each communication medium to meet them at lowest costs in different geographic environments.

2 Present and Future Customer/Utility Functions and Data Exchanges

In order to quantify the needs for communication and exchange of data between utilities and customers, it is firstly necessary to understand their functional requirements. Information about present and future customer/utility requirements has been collected for all participating countries, by means of questionnaires. Overviews of the information collected and processed were presented in reports, References 1 and 2.

Summary information extracted from the questionnaires shows an overall interest across countries in particular functions and the extent to which they are currently applied (C) or planned for future (F). This is illustrated in Table 1. The table is separated into residential, commercial and industrial customers, so that the impact on the data quantities can be estimated based on the numbers of customers of each type requiring functions in a given area. The table shows that the majority of participating countries are active in load control and tariff switching, as well as in trials of remote metering. It also shows the applications and developments of functions taking place in all customer groups with only marginally more applications in industrial and commercial customer groups than residential groups. This projected expansion of functions to residential customers could mean that a significant increase in the data exchange capacities will be required in future to meet the needs of the relatively large numbers of residential customers.

Countries are at different stages of development in terms of the functions offered to different categories of customers at the present time. However it is possible to draw some overview results from the information and analyses which have been carried out regarding the typical data exchanges required now and in the future between customers and utilities.

The data exchange needs in both directions dictated by the application of these functions are described in Reference 2. Based on this information, total data exchange requirements can be determined for each type of customer equipped with all the functions.

Residential customers with utility communication

Present situation

300 bits per day per customer from utility to customer on the basis of selective broadcast communications. Generally there is no wide scale application of systems which require data flow in the direction from customer to utility.

Future situation - Advanced Narrowband Functions (up to 5 years time scale)

1000 bits per day per customer from utility to customer for selective broadcast and individual customer selective functions. 200 bits per day per customer from customer to utility for individual customer selective functions.

Future situation - Advanced Wideband and Narrowband Functions (10 years time scale)

Wideband Video Channel to customer together with 1000 bits per day from customer.

These channels are likely to be provided by Data Compression and Advanced High Speed Data on PTT (Public Telephone Company) copper pairs, Hybrid Fibre Coax systems or Passive Optical Networks to the kerb or customer.

Commercial Customers with utility communication

Present situation

400 bits per day per customer from utility to customer mainly for selective broadcast functions but some for individual customer selective functions. 20 bits per day per customer from customer to utility for individual customer selective functions.

Future Situation Advanced Narrowband Functions (up to 5 years time scale)

500 bits per day per customer from utility to customer
40,000 bits per day per customer from customer to utility

Future situation Advanced Wideband Functions

Dedicated services using Advanced High Speed data on PTT copper pairs, Hybrid Fibre Coax and Fibre to the customer are now available in some locations where large data flows justify the costs. It may be difficult to justify the costs of adding additional low data need utility functions to these systems for relatively few industrial customers.

Industrial Customers with utility communications

Present situation

400 bits per day per customer from utility to customer for mainly selective broadcast functions but also for individual customer selective functions.

200 bits per day per customer from customer to utility for individual customer selective functions.

Future situation (Advanced Narrowband Functions up to 5 years)
1000 bits per day per customer from utility to customer for mainly selective broadcast functions but also for individual customer selective functions.
40,000 bits per day per customer for individual customer selective functions mainly associated with data collection.

Future situation (Advanced Wideband Functions)
Dedicated services using Advanced High Speed data on PTT copper pairs, Hybrid Fibre Coax and Fibre to the customer are now available in some locations where large data flows justify the costs. It may be difficult to justify the costs of adding additional low data need utility functions to these systems for relatively few industrial customers.

3 Customer/Utility Functions and Communication Strategies

The trend of the anticipated data requirement for the next 5 years for all customer types shows a significant increase in data exchanges, in both directions between customers and utilities. It also shows that the DSM related data exchanges from customer to utility are in order to accommodate the spread of narrow band functions such as time of day metering for commercial and industrial customers. Because these customers are relatively few in number, their contribution to the total data flows for a total population will not be large. Also it is possible to carry out these data exchanges using independent communications media if capacity problems on media shared with residential customers is encountered. This would however increase the data exchange costs due to separate infrastructure being necessary.

It is difficult to visualise what wideband, energy utility functions will be required in the future beyond 5 years either by the utilities themselves or by their customers. It seems likely that wideband services such as Video on Demand and interactive television will be provided by other organisations, maybe owned by energy utilities and the narrowband functions required by the energy utilities superimposed on the wideband channels.

Consequently for the medium term (up to 10 years) there is a requirement to develop cost effective two way communications systems which can handle the projected numbers of customers requiring the data needs as outlined in the previous section. The problem then becomes one of estimating, within given customer populations, the likely numbers of customers of each type who will require the functions identified by the international data (Table 1). A critical issue in estimating the economic viability of any communication medium is the roll out scenario of different functions into the market place. If roll out takes place by setting up communications for groups of customers in an area, then the development of a local communications infrastructure becomes an economic possibility. This could comprise communications hardware located at distribution substations for Distribution Line Communication (DLC) or local radio nodes to accommodate the customer/utility data exchanges. In reality, depending upon the utility structure, it is likely that different market penetration scenarios develop, i.e.

functional requirement needs will grow on both a random way with few concentrations of customers requiring the functions and also in a way which results in high concentrations of customers requiring functions. This could be, for example, blocks of flats or collections of buildings with particular heating or cooling regimes and tariffs/control systems. Consequently it is possible to construct a scenario of communications systems growth which includes two way DLC and cellular radio possibly for the areas of high density of customers requiring functions and telephone or existing infrastructure systems for areas of low density of customers requiring functions. These systems would then be integrated into a common communication hierarchy at the wide area or second level in the communications infrastructure.

The way functions and communications are provided in any situation will also be significantly influenced by the financial drivers which are put in place either through regulation or by competition. Regulations to increase customer services and improve the quality of services are being introduced in many countries. These regulations can influence utilities to offer general increases in functions to all customers and to move towards enhancing customer/utility communications using standardised systems and a national or individual utility basis. In these situations the development of new communications infrastructure becomes more viable because of the likely wide scale usage.

Where competitive forces are used as the main driver for the development of functions and communications into the customer base, it is possible to envisage groups of customers within a utility area being provided with different functions and using different communication media for the data exchanges. Competition between energy suppliers would be on the basis of price and services provided, including added value functions. Consequently the development of new communications infrastructure becomes less certain if competition also takes place in the provision of communication facilities. Many communication service providers could co-exist in a given area and could use combinations of communication media. However the requirements of customers and utilities for DSM related functions and services at an acceptable cost will always be the main driver of market penetration.

4 Penetration of Functions into the Market Place

An example functional roll out scenario for domestic/residential, medium commercial and medium industrial is shown in Table 2. The percentage penetration of functions into the customer base is shown for three steps over time. For simplicity, all functions are shown as being introduced at the start date. The final values of percentage market penetrations of functions are also shown to take place at the same time.

The scenario represents a situation with a predominantly domestic/residential load having a ratio of 60% residential, 32% commercial and 8% industrial. The numbers of customers are 22,000 residential, 88 commercial and 13 industrial.

The functions applied to the customer base are related to load control, remote metering, supply disconnection/reconnection and security alarms. Load control is only applied to the electrically heated residential customer base of 1600 customers in percentage market penetration steps from 10% to 30%. Interruptible tariffs are applied to the medium commercial and industrial customers only. In both cases the market penetrations over time change for 10% at the start to 30% maximum.

Load profiling, which is the remote reading of customer daily load profiles on a sampled basis once per year, is carried out for residential customers only. The market penetration for this function, which is reasonably data intensive, is a maximum of 3% for both small and medium domestic/residential customers.

Non payment disconnection and reconnection is shown as being applied to all customer groups but in different percentages. In reality this function may not be applicable to commercial and industrial customers. The major market penetrations for this function are shown in the residential sector with maximum penetrations of 90%.

The data intensive function of daily load profiling or remote meter reading of hourly or half hourly metered date every day is shown for commercial and industrial customers only. This sort of data collection activity is particularly a feature of competitive energy markets to facilitate trading. However there are also benefits to be obtained in terms of customer load profiles and tariff setting. The market penetrations of these functions are shown to progress from 40% to 100% for commercial and industrial customers.

The scenario of market penetrations of functions represents the sort of situation which could take place in reality in a particular area. Generally however real situations will be more complex with the penetration of some functions increasing and others possibly decreasing. Also the penetration of functions may take place in zones within an area rather than uniformly across an area. These factors influence local data exchange capacity needs on communication channels.

5 The Application of Communications Media to Customer/Utility Functions

As described in the previous chapter the penetration of customer/utility functions into the market place can significantly influence the choice of communications media and infrastructures adopted to exchange the data. In reality different media can be used at different points in the communications hierarchy to obtain benefits in data exchange capacity and function response times. However there are great benefits in standardising customer equipment and communications hardware associated with the different media so as to obtain low costs. This means that standardised interfaces and protocols are desirable between the different communications modems and the main customer processing hardware, irrespective of the communications medium used. The provision of customer hardware containing several modems so that the same hardware can communicate over a choice of media is unlikely to be economically viable. However there may be situations where more than one communications medium between customers and a utility could be attractive, e.g. one medium for one way rapid broadcast functions and another for data collection. A summary diagram of different media is shown in Figure 1.

6 Capacity of Communications Media

The capacity of a communications channel is determined by the available bandwidth and noise level on the medium to achieve a specific error rate performance. International data has been collected and analysed as part of the study and reported in Reference 2. This data quantifies the capacity of different communications media at the present time from the point of view of demonstrated systems rather than theoretical predictions. The quoted capacities therefore tend to be conservative.

The following table summarises the channel capacities which have been used to form the basis of different communications hierarchy structures constructed to exchange customer/utility information. These structures have been assembled to exchange data between utilities and clustered groups as well as sparsely spread customers equipped with functions.

Capacity of Communications Media

Medium	**Typical Capacity**
Radio Channel	1200 bits/sec to 64k bits/sec
Public Switched Telephone Network (PSTN) line	>1200 bits/sec
DLC Low Frequency	20 bits/sec
DLC High Frequency	200 bits/sec
CATV Fibre/Coax	64k bits/sec to 2M bits/sec

Smart Card Systems

Perhaps evaluation of customer/utility communications would not be complete if consideration were not given to the possibilities of using Smart Card Systems to accommodate the data exchanges required for the next ten years. In these systems customers themselves act as the local communications link by manually exchanging data using an intelligent card between customer terminal and local communication terminal. These systems are becoming commercially available and can be used for two way data exchanges. However they have disadvantages in that they cannot be used for functions requiring reasonably rapid response times and they also involve customers in the task of energy management control, meter reading and prepayment. However in restructured energy industries, where customers are offered choices of energy supply, customer involvement in energy purchase may become attractive if sufficient financial incentives can be provided.

7 Communications Hierarchy Structures

The communications hierarchy structures shown in Figures 2 and 3 illustrate mixed media solutions for data exchanges between customers and utilities. Single communications media hierarchy structure are described in Reference 2 with descriptions of the attributes of each medium. These multi media solutions enable each medium to be used in the most appropriate ways to deal with channel capacity requirements and function response times. As already explained, the communications hierarchy solution to be adopted in any situation depends upon the population density of customers requiring functions, the actual functions required, i.e. whether they are broadcast or individual customer selective, the data exchange capacity and the rate of penetration of functions into the market.

In Figure 2, a communication hierarchy is shown using DLC technology to exchange data above the MV/LV substation level. The choice of communication medium in this case is between MV DLC or telephone. The possibility also exists to use telephone/dedicated channel communication directly between customers and utility which would be attractive because of particularly demanding data exchange needs of some customers, e.g. industrial or because of excess data requirements on LV, DLC communication links.

In Figure 3 the communications hierarchy is shown using cellular radio at the customer level with telephone communications for the level above. Telephone communications is also shown directly for exchanging data with selected customers. This could be used where large data exchange needs exist, where radio coverage is difficult or where the radio channel capacity becomes exceeded.

Consideration of using different media at different levels in the communications hierarchy to exchange customer/utility information was outlined in Section 6. Such scenarios could result from different customer types within areas being targeted (such as industrial estates or housing estates/blocks of flats) for equipping with particular functions. It could also be as a result of different energy supply companies or communications providers offering services to groups of customers in a competitive market.

Figure 4 illustrates how a communications hierarchy for such a situation could be constructed. DSM and related services would be provided using the most suitable medium from the points of view of technical capacity and cost.

The communications hierarchy structures can also be used to represent other media such as cable television with the data capacity increased.

Costing the communications hierarchies for particular scenarios of customers and functions can be carried out by determining the numbers of communication nodes and links and allocating costs to each. Transmitter/receiver (Tx/Rx) units, together with signal and data processing capability could be located at these nodes.

8 Availability of Wideband Customer/Utility Communications

The installation of wideband communications channels to customers at the present time is being driven by telephony, Video on Demand, interactive video, home banking and shopping, with great uncertainty as to what technologies are likely to be needed and cost effective for the future. The choice of wideband communications technology depends upon the starting point of the operator with new entrants favouring the fibre/coax or fibre to the kerb (roadside) approaches, as well as wireless local loop. Incumbent telephone operators (PTTs) favouring evolution and development for enhanced data speeds on existing copper local loops, together with the integration of fibre into the local loops. Integration of fibre into the local loops is being carried out also by PTTs, either as fibre to the kerb or passive optical networks to the home. However the most optimistic projections suggest that two way wideband channels will not be connected to the majority of residential customers in under ten years. Even when these communications facilities exist, the costs of using them for relatively slow speed data exchanges may still be significant.

9 Customer/Network Geography

The choice of communications media to meet customer/utility functional need scenario data exchange is based on many factors. Chapter 2 dealt with the actual volumes of data exchanges and channel capacity requirements for communications media. However another important variable in the choice of communication medium is the number of customers requiring functions in a given area and for DLC communications, the numbers of customers connected to different sizes of distribution substations. These factors have been explored in detail using national information collected by participating countries. This has enabled an understanding to be obtained of the areas of coverage of primary (HV/MV) substations and the numbers of customers of different types likely to be supplied by distribution substations in different countries.

This information is important in estimating the numbers of radio cells likely to be required to communicate with a customer population in a defined area based on both area of coverage of individual radio cells and upon the data capacity of each cell. The area of coverage of a radio cell is based on the allocated frequency band and allowable transmitter power and location which can vary for different countries. The area of coverage is also dependent upon signal propagation conditions which generally results in smaller cells in urban environments.

Customer density and the connection of customers to primary and distribution substations are important in estimating the viability of DLC communications structures. Small substations with few connected customers generally result in higher infrastructure costs per customer for high frequency (>2 kHz) DLC systems. This is because signals above this frequency can be significantly attenuated by distribution transformers and require transformer bypass arrangements to be included. However low frequency (<2 kHz) communication systems, where signals pass through transformers, can be used for some low data need functions.

Figure 4 showed how different customer groups and types can exchange data with utilities using a variety of communication media to provide wide area coverage. Where data exchange communication is the responsibility of a single entity, either the utility or designated agent, then generally fewer media would be used. Where however the provision of communications is based on choosing from a variety of service providers, then many different media could be used in different circumstances.

Designing the hardware to be installed at customer premises to be sufficiently flexible so that only minor changes are necessary in order to change communications medium is a challenge for standards forming organisations. Standardisation of customer hardware interfaces will enable different communications media to be used with minor hardware changes and allow installations to be at least partially future proof. Consequently as new communications systems and technologies become available, the replacement of existing infrastructures will be possible while at the same time integrating with existing customer systems.

10 Methodology for evaluating specific situations

A methodology for technically evaluating the suitability of applying particular communications media to customer/utility functional need scenarios in different geographic environments is reported in Reference 2. This methodology attributes data flows to each function applied to customer types and based on whether the functions are broadcast or customer selective. The data flows are aggregated within different communication media hierarchies to determine whether the data capacity constraint of any medium is exceeded. Assuming that no capacity constraints are exceeded at any step in the roll out of functions into the market, up to the maximum defined penetration, the communications hierarchy solution is considered technically viable.

11 Functions, customers and communications analysis methodology

The analysis methodology is based on the use of a software platform called Kappa which has been used to support the detailed calculation algorithms written specifically to carry out the analyses. It is based on an object oriented approach which has several advantages over traditional top down or hierarchical approach to model design strategies. In terms of modelling communications media these advantages include:

- The use of key parameters describing channels and nodes as objects or building blocks to model networks which are well suited to database storage and access.

- Efficient storage and modification of scenarios by archiving and retrieval from databases of those key parameters which, in object oriented design, represent instances of class structures.

- Flexibility to accommodate features being added to a model subsequent to initial design and development. This allows future enhancements in later releases without fundamental redesign or rewriting of code.

Interpretation and General Assumptions of the Model Prototype

Building communications hierarchies within the prototype model is centred on network topologies or layouts based on those used for Distribution Line Carrier communications. Given that this structure is common in all scenarios because it links to the customer base through the electricity supply network, this assumption allows further assumptions to be made which assisted in developing a methodology to assess different communications media linked to a customer base.

Primary assumptions which apply generally to the prototype model are given below:

- All model media infrastructures or networks conform to two levels defined by a distribution network: a Primary substation level; and a Secondary or Distribution substation level.

- Most infrastructure costs and problems of providing communication channels occur at a level adjacent to customers which correlates with the distribution or secondary substation level. By concentrating on distribution and primary substation levels therefore, most potential difficulties in implementing selected media will be highlighted.

- The placement of a communications medium network at the secondary substation level implies that this medium is used to collect or send information from or to the customers.

- Communications networks at a primary substation level represent the ultimate source or destination of data in the model and imply that information aggregated in the lowest level communications media (at the secondary substation level) is re-transmitted to or from the local collection points to a Primary substation collection point.

- One medium which does not conform to the two-layer structure is telephony. Here a local telephone exchange can be located anywhere within a primary substation service area with direct lines to customers without an intermediate node or level.

- Since the topologies of Distribution Line Carrier (DLC) communications structures are of a mesh type with a multi-drop structure, all forms of network can be modelled.

- The overall evaluation model is static so modelling of dynamic situations, such as roll-out strategies, is achieved through storage of static values as data sequences in a spreadsheet package (such as Excel rel. 4) to produce traffic flow graphs against roll-out percentages.

- No spatial geographic information is used in the model. In the modelling of radio cells which is independent of the distribution network structure, averaging of customer type and density across the area is carried out and functions applied to customers on an average basis.

- Data flows at levels above the primary substation are assumed to be within the capacities of communications infrastructures external to the model and are not included in any evaluations.

- Data traffic flows are considered over a daily period.

Permissible Media

The following media can be included in communication evaluations either singly or in combinations :

Distribution Line Carrier

Telephony - PSTN as a data carrier

Radio - broadcast such as Private Mobile Radio
Cellular systems up to 1.5 GHz.

Dedicated cable - Copper, coaxial and optical fibre implementations

Assumptions used in media evaluations

DLC Networks

1. Two level hierarchy at primary and secondary substation level with associated service areas based on area of coverage.

2. Allows build up of customer and function scenarios by allocation of customer types to specific distribution substations which are appropriate for study.

3. In data traffic flow analysis, aggregate of traffic flow totals taken in ascending order up the network hierarchy.

Public Switched Telephone Networks (PSTN)

The following assumptions are considered in data traffic flow analysis of telephony networks :

1. The range in numbers of customers connected to local telephone exchanges is considered similar to that of primary substations.

2. The location of local exchanges is independent of locations of primary substations.

3. The service area of a local exchange may exceed or be less than that of a primary substation service area.

4. All telephony connections consist of one dedicated line per customer; party lines are not included. Their presence would reduce the effective capability of the customer connection to carry the data under high data need conditions.

5. A local telephone exchange can process simultaneously 100 lines only. This has response time implications for implementing broadcast functions to many customers.

6. Call set up and clear down delays in establishing lines from exchange to customer are considered. Other more minor delays are not.

7. When a call is established, all functions attached to a given customer are assumed to be serviced, i.e. the most efficient use is made of any telephone call and line.

Radio Networks

The first step in the evaluation assesses the range of a radio system determined from either user input, default values, or both. A propagation model determines a service area available which is mapped onto the primary substation overall area of coverage. Should this area exceed that of the primary substation area, an option is available to reduce transmitter power and hence radio cell area to produce a match if required.

A second step independent from the range determination calculation performs cell splitting based on the data needs of the customers. This allows an increase in the radio system's data carrying capacity at the local level through using a cellular radio structure and regular reallocation of frequencies.

Step 1 : Calculation of Radio Propagation Areas

1. Size of radio cell determined solely by modelling average radio frequency (RF) propagation in a defined type of area, i.e. urban or rural.

2. Direct or surface waves only are considered in the propagation modelling.

3. Where a single radio cell covers a primary substation area, the location of the radio transmitter base station is assumed to be at the centre of the primary substation service area.

4. Terrain, area type and customer density information for propagation modelling are derived from primary substation attributes input as data.

5. Determination of the numbers of radio transmitters required is carried out solely on the basis of average area of coverage and area to be covered and on data capacity required.

Step 2 : Radio Cell Splitting based on Customer Functional Data Needs

1. Customers are assumed to be uniformly distributed within primary substation service areas by type with an average data requirement for each type.

2. Cellular radio is capable of both specific addressing and broadcast. To distinguish 'broadcast' radio from cellular a single radio cell must cover at least one distribution substation area.

3. The design of radio systems and the specific reuse of frequencies to combat co- and adjacent channel interference are not considered.

4. A regular cell size is assumed, i.e. no anomalous propagation.

5. The communication channel is assumed to be always available for carrying out customer/utility communication functions.

Allocation of functions to the customer base

The following assumptions apply to all considered media :

1. Functions are attached according to customer sub-type.

2. Allocation of the number and type of function is determined by the user at the primary substation service area level. This provides control over the allocation of function by customer sub-type, so as to maintain the defined overall penetration of functions into the market.

3. All functions are quantified in terms of data need as defined in Reference 2.

Classification of Customers

All customers defined in scenarios are classified by a type and further sub-type defined by electricity demand relative to the demand of a of Small Domestic customer sub-type.

Tables presented in Reference 2 describe in more detail the definition and sizes of distribution and primary substations in terms of the numbers of small domestic customers they could typically supply. Customers of particular types, having defined sizes can therefore be allocated to distribution substations so as to remain within the substation capacity. Consequently it is possible to populate distribution substations so as to produce a required mix of residential, commercial and industrial customers at the primary substation level. This process is described in more detail in Reference 2.

Below is a table listing combinations of communications media at both primary and distribution substation levels which can be modelled. Each combination is allocated a reference case number whose interpretation is detailed in the following section.

Secondary Level	Primary Level	Case Number
DLC	DLC	1
Telephony	Telephony	2
Cellular Radio	Cellular Radio	3
DLC	Telephony	4
DLC/Telephony	Telephony	5
DLC/Telephony	DLC	6
Cellular Radio	Telephony	7
DLC/Cellular Radio	Telephony	8
DLC/Cellular Radio	Cellular Radio	9
Cellular Radio	DLC	10
CATV	CATV	11

Interpretations of Each Media Combination by Case Number

Case Number 1
Data travels the low voltage network between customers and local collection points located at secondary substations using DLC data from customers within distribution substation service areas is aggregated and relayed along the medium voltage network using DLC to a collection point located at the primary substation.

Case Number 2
Each customer has a dedicated telephone line available. Data passes along these lines directly to and from a Local Exchange without an intermediate level.

Case Number 3a
For cellular radio systems, each customer within the radio cell boundary exchanges information with a collection point located within the cell at the secondary substation level. Larger radio cells at the primary substation level collect data from the lower levels.

Case Number 3b
For Private Mobile Radio and other non-cellular systems all customers are assumed to be within one single cell located at the primary substation.

Case Number 4
Data is passed along the LV DLC network between customers and local collection points located at the secondary substations. Each secondary substation has a dedicated telephone line to the Local Telephone Exchange assumed to be located at the primary substation level.

Case Number 5
The customers are either served by low voltage DLC or dedicated telephone lines. With DLC the data is passed along the LV network between customers and local collection points located at secondary substations. Each Secondary substation has a telephone line to the Local Exchange at the primary substation level. Where customers are served by telephone lines, then these carry data directly to the same Local Exchange and reduce the data on LV DLC channels.

Case Number 6
The customers are either served by LV DLC or dedicated telephone lines. If they have DLC, then the data is passed along the LV DLC network between customers to local collection points at the secondary substations. This aggregated data is then passed along the MV network to a collection point at the primary substation using MV DLC. The remaining customers served exclusively by telephone lines have their data transmitted directly to the Local Exchange.

Case Number 7
A radio transceiver at each customer's premises exchanges information between the appropriate radio cell transceiver at the distribution substation level. A dedicated telephone line links each distribution substation radio cell transceiver to the Local Exchange at the primary level.

Case Number 8
The customers are served either by LV DLC or by cellular radio cells at the lower level. For DLC, the data travels along the LV DLC network between customers and local collection points at the secondary substations. Customers served by Cellular Radio exchange data with the appropriate data collectors at the secondary substation level. From secondary substations, or from Radio Cell collectors , a telephone line carries the aggregated data to the Local Exchange.

Case Number 9
As for (8), except a transceiver located at each secondary substation and Cellular Radio Cell Collector relays the aggregated data to a collector at the primary substation level Cellular Radio Cell which encompasses them.

Case Number 10

All the customers transmit to, and receive data from, their appropriate Cellular Radio Cells located at secondary substations. The data is aggregated and relayed along one MV DLC to the Primary Substation.

Case Number 11

Cable Television (CATV) at the distribution substation level collects data from and transmits it to customers. Data collection from a shared link in a tree and branch structure can be modelled by aggregation before being sent on along further individual links to the primary substation which acts as a data collector.

12 Methodology for constructing scenarios

Introduction

A methodology has been developed for constructing scenarios following identification and definition of primary and secondary substation capacities by the user. The next step is selection of customer sub-types and their attachment to distribution substations so as to agree with the percentage load mix of each type at the primary substations, as specified by the user. Finally, a manual allocation of functional needs to customer sub-types is carried out to agree with the functional scenario specified by the user. Investigation of communications media to support the resulting data traffic flows is then carried out.

Overview of Steps

A methodology to construct scenarios can be described in the following steps :

1. Identification and definition of primary and secondary substations wiht capacities by the user.

2. Selection of customer sub-types and their attachment to distribution substations.

3. Allocation of functional needs to customer sub-types.

4. Attachment of media to primary substation and distribution substation service areas.

5. Running simulations to determine traffic flows.

6. Further refinement based on results of step 5 to eliminate highlighted traffic bottlenecks and also investigation of various roll-out strategies.

The steps outlined are each described below with references to relevant prototype screens.

Step 1: Building Primary Substation Hierarchies

The model allows the user to select suitable primary substations from a list displayed on a build scenario screen, Figure 5. Following selection of a primary substation, secondary substation types within the capacity of the primary can be selected from a neighbouring list.

There is error checking on the primary substation capacity. Bounds of both primary and secondary substations are available with default values stored in the model.

A more detailed description of the sizes of substations and customers in terms of their capacity and load rating is given in Reference 2.

Step 2: Selection of Customer Sub-types

Customers classified by sub-type are chosen by the user and attached to the distribution substations. See Figure 6.

Step 3: Allocation of Functional Needs

The communications screen enables functional needs to be attached to customers in a global fashion (at primary substation level) or through allocation by percentage of population at distribution substation level or in combination at the user's discretion. See Figures 7 and 8.

Step 4: Attachment of Media to Substation Hierarchies

Media can be attached to the primary and distribution substations and are colour coded in the communications screen, see Figure 9. Mixtures of media at one level are entered via dialogue boxes which allow media attachment to customer types by percentage, Figure 10. Media can be applied throughout distribution substations, or individually at user's discretion.

Step 5: Scenario Runs

Scenarios can then be run which produces an output showing data traffic per day at primary and distribution substations and highlights any substation which would experience congestion, Figure 11.

Step 6: Refinements and Reruns

Refinements though editing of functions or media or any combination thereof can be rerun to determine effective solutions in providing communication media hierarchies which can support defined populations and their functional needs for DSM and related functions.

13 Analysis of Three Scenarios

Urban Scenario Using DLC and Telephony

A scenario describing an urban population (Case A was built with a roll-out of attached DSM functions, see Figure 12 for final percentage values). The data needs were seen to exceed the capacity of the MV network mid-way in the roll-out period and this deficit was filled by a change to a telephony network (PSTN) for the additional data requirements. The data capacity of the LV network with the highest data throughput was never exceeded.

A Modified Urban Scenario with Radio

The population from scenario 1 was retained but a different DSM roll-out for a heavy demand DSM function was used in order to test the capacity of a single radio cell and demonstrate cell splitting based on data needs. The function chosen, Daily Load Profiling, has the highest traffic requirements and was applied to 20% of the population. Given the large number of customers, in particular of a residential type, a high demand was placed on the communications medium resulting in the required cell split as shown in Figure 13. Also included in Figures 12 and 13, under the label of "Minimum channel capacity to meet Function Response Times", is the channel capacity needed to accommodate the function with the largest data exchange rate requirement.

Rural Scenario with DLC

The third scenario shows which DSM functions could be supported by a low capacity network such as a DLC infrastructure from a rural distribution substation. Seven DSM functions listed in Figure 14 form a basic set (Reference 2) and when applied to the population profile shown, can be supported by DLC in a proposed rural environment.

All three scenarios demonstrate different approaches to the testing and analysis of given populations with the Kappa prototype by variation in mixes of media and allocation of DSM functions to customers. The data flows evaluated are compared with specified media capacities. However the data needs specified for implementation of functions do not include the additional data flows associated with communications protocols, system management, addressing and error checking which can add significantly to total channel requirements. Factors to estimate the ratio of data traffic to total traffic, i.e. the overhead needs to be included when evaluating real communications system implementation using proprietary hardware.

14 Conclusions

Evaluations of the suitability of different communication media singly and together for meeting sample customer/utility functional need scenarios have been carried out. These have shown that the methodology developed for carrying out the evaluations using the penetrations of functions into the market place, customer density, distribution network structure and communications channel capacities produce realistic results.

General strengths and weaknesses of each medium, where they can be assessed in isolation from particular scenarios, applications or national regulations have been identified.

There are specific situations, which will be realised in practice, which will particularly favour the selection of any one of the media or mixes of media. If global solutions are required where the same communications technology is used in all circumstances, then the range of circumstances needs to be quantified and the different media options applied and evaluated. In this way the most appropriate standardised technical solution can be identified and costed.

What the studies have shown is that, even for large penetrations into the market place of the majority of functions, the data exchange needs and communication channel capacity needs are modest (<50 bits/sec). Some functions, such as time of use metering, dominate the communications capacity requirements when they are applied to large numbers of customers. Where they are applied only to commercial and industrial customers in areas containing significant numbers of residential customers, then the impact on data channel capacity is small. If they are applied in other than very small quantities to residential customers, then they completely dominate the communications needs and channel capacities in excess of 1000 bits/sec are required to accommodate the data flows.

Investing in the development of communications systems infrastructure for Radio and DLC involves major commitments. Infrastructure costs will also be required in most cases for telephone and CATV systems to enable utility functions to be accommodated. However these costs are likely to be lower than the costs of setting up completely new systems at the customer level. The costing issue becomes one of balancing the combined capital and rental costs of existing infrastructure communication systems against the capital costs and maintenance costs of new infrastructure systems. This assumes that the systems to be compared are all technically viable. Technical issues have been identified in terms of the viability of certain types of media for fulfilling particular functions. These issues relate to a shortage of data capacity in DLC systems if some functions experience wide scale market penetration. They also relate to the ability of telephone based systems to be used for fast response load control to many customers due to high telephone traffic during daytime hours.

The studies have shown that the communication media evaluated can all be used with great effect in terms of data exchange between customers and utilities in appropriate situations. Using the strengths of each medium to implement multi media solutions to get round some of the limitations of each medium separately is very attractive.

The most critical aspect associated with making investment decisions to develop customer/utility communications is to identify as clearly as possible the functions to be included, the market penetrations of those functions and the time scales of those penetrations. In the medium term it is unlikely to be cost effective to install wideband capacity to try to accommodate any functions which may be required. Evolution from narrowband (200-1200 baud) solutions to wideband solutions will take place for the majority of customers over the longer term (≅10 years).

The evaluation methods described in this report have been shown to be effective in quantifying the suitability of any communication medium for meeting functional need scenarios.

15 Recommendations

- That the methodologies developed in this project are used to evaluate the suitability of communication media for meeting the technical requirements of proposed, real situations.
- That methodologies are developed to enable the costs of flexible, multi media communications hierarchies to be evaluated so as to complement the technical evaluations.
- That these methodologies are incorporated in a stand alone software model to enable technical and financial evaluations to be carried out more easily.
- That methodologies are developed to investigate the seemless evolution of narrowband, conventional communications systems to those offering wideband capability.

References

1 Interim Report on Customer/Utility Functional Needs and Communication Technologies dated January 1995

2 Interim Report on Development and Analysis of Customer/Utility Functional Need and Communication Technology Scenarios dated August 1995