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**OPERATING DISPERSED
GENERATION WITH ICT
(Information & Communication
Technology)**

**Working Group
C6.03**

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OPERATING DISPERSED GENERATION WITH ICT (Information & Communication Technology)

Working Group C6.03

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Abbreviation

BTB: Back To Back
CGS: Co-Generation System
CHP: Cogeneration of Heat and Power
CT: Current Transformer
DC: Direct Current
DG: Dispersed Generator
GSM: Global System for Mobile Communications
ICT: Information & Communication Technology
LDC: Line Drop Compensator
PLC: Power Line Carrier
PV: Photovoltaic
PT: Potential Devices
RCT: Residual Current Transformer
RES: Renewable Energy Source
SCADA: Supervisory Control And Data Acquisition
SVR: Step Voltage Regulator

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1. Introduction

Dispersed Generation (DG) is now being promoted worldwide as a means of reducing energy costs and environmental burdens by limiting the emissions of greenhouse gases or reducing transmission and distribution loss. DG is expected to play an important role in power generation in emergencies and as a source of compensative energy in peak times. One of the demerits of DG, however, is the small scale and unstableness in energy generation. Because of this, support from the network is indispensable for maintaining stable frequency and voltage nearby the sites of generation and for the variable loads. Therefore the total number of grid-interconnection of DG, especially for non-dispatched DG, cannot be excessive. With excessive grid-interconnection, the stability, reliability, and power quality of a system will be influenced. No user would ever wish for this consequence or the associated deterioration in the value of electricity as a common asset. For these reasons, we would like to develop measures to maintain the grid-interconnection for DG at the optimal level in order to ensure the soundness of the distribution system.

WGC6.03 has studied technologies for putting DG to use as an efficient method for power supply and for preventing losses of system stability, reliability, and power quality using Information & Communication Technology (ICT). ICT will make it possible to efficiently use the existing distribution network and reinforce tolerance to future problems by providing capabilities for the monitoring, the control of network equipment, the control of DG, and the provision better customer services. These ICT functions will be deployed for the operation of networks in coordination with a number of connected DG.

This report presents the results of surveys we have conducted on ICT use in the member countries of CIGRE SCC6 and WGC6.03.

2. Definition of the term

2.1 Distribution System

First of all, we worked to clearly define the "Distribution System", where DG is to be interconnected. Then we made a survey through questionnaires about the following topics to identify the view of individual member countries because it was expected to vary in different countries.

- (1) Definition of the term "distribution system" (the difference between a distribution system and a transmission system)

(2) Composition of distribution system

- The distribution voltages
- Usual transformer capacity
- The number of circuits of distribution line from a transformer
- A length of distribution line

The following is the results of this investigation.

(1) Definition of the term "Distribution System"

Table 2.1.1. Definition of the term "Distribution System"

Country	Definition
Australia	A network which is not a transmission network (operating at nominal voltages of 220 kV and above plus)
Canada	Network operating at nominal voltages of 1000V – 25kV
Finland	Voltage level below 40 kV, typically radially operated network
Germany	Locally restricted task to distribute electric power on lower voltage levels
Italy	Networks supplying MV and LV customers
Japan	A system that supplies electric power to medium and small-sized customers.

(2) Composition of distribution system

Table 2.1.2. Composition of distribution system

Country	Canada	Finland	Germany
the distribution voltages	HV	33kV-500kV	(45kV), 110kV
	MV	4.2kV-25kV	10kV, 20kV
	LV	120V-600V	400V
the typical type of distribution line	urban area	overhead and underground	mainly underground
	rural area	mainly overhead	overhead and underground
usual transformer capacity	urban area	3-150MVA(HV/MV)	800kVA(MV/LV)
	rural area	3-28MVA	100kVA
The number of circuits of distribution line from a transformer	urban area	1-40cct	8cct
	rural area	1-8cct	3cct
a length of distribution line	urban area	5-15km(MV)	0.01-0.5km(LV)
	rural area	10-80km(MV)	0.05-1km(LV)

Country	Italy	Japan	Switzerland	
the distribution voltages	HV	132kV-500kV	33kV-500kV	45kV, 110kV
	MV	6.6kV-33kV	4.2kV-25kV	10kV, 20kV
	LV	240V/415V	100V 100/200V 200V 230/400V	400V
the typical type of distribution line	urban area	mainly overhead	overhead and underground	mainly underground
	rural area	overhead and underground	mainly overhead	mainly underground
usual transformer capacity	urban area	250kVA(MV/LV)	10-30MVA(HV/MV)	630-1500kVA
	rural area	100kVA(MV/LV)	10-20MVA(HV/MV)	100-630kVA
The number of circuits of distribution line from a transformer	urban area	4, 8cct	4-8cct	20-100cct
	rural area	4cct	3-7cct	5-20cct
a length of distribution line	urban area	5-10km	0.4-4km	0.5-10km
	rural area	-25km	0.6-7km	10-15km

Country	Poland	India	Norway	
the distribution voltages	HV	230kV-400kV	---	45kV-420kV
	MV	10kV-110kV	---	11kV-22kV
	LV	230V-400V	---	230V-400V
the typical type of distribution line	urban area	mainly underground	overhead and underground	mainly underground
	rural area	mainly overhead	mainly overhead	mainly overhead
usual transformer capacity	urban area	200-630kVA	250-1600kVA	200-500kVA
	rural area	50-200kVA	10-500kVA	100-200kVA
The number of circuits of distribution line from a transformer	urban area	4-10cct	widely varies	3-7cct
	rural area	2-4cct	widely varies	2-4cct
a length of distribution line	urban area	0.1-0.8km	5-25 km	5-10km
	rural area	0.1-1.0km	5-40 km	10-30 km

As a result, distribution system can be defined as follows.

- A system that supplies electric power to medium and small-sized customers.
- The network, which supplies electricity to customers on comparatively low voltage (35kV or less).
- Network configuration is typically radial.

On the other hand, transmission system can be defined as follows.

- The voltage class of transmission system is usually higher than that of distribution system.
- Transmit high amount of power to another load centre.
- The capacity of customer facility is large.

These points are distinguished from distribution system.

2.2 Dispersed Generation

Next, we clearly defined “Dispersed Generation”, which is to be interconnected to distribution system. Since the definition of DG was also expected to vary in different countries similarly as that of distribution system according to the configuration and regional character, we also surveyed member countries to identify the view of them on the following topics.

- (1) The kind of DG actually applied (capacity in the utility interactive operation)
- (2) The minimum voltage class that the load-dispatching centre operates DG

The following is the results of this investigation

(1) The kind of DG actually applied (capacity in the utility interactive operation)

Table 2.2.1. The generation capacity of DG applied individual countries

Country		Canada	Germany	Japan	India	Poland
Solar Photovoltaic	Capacity of single generation	0.8-15 kVA		1.0-125.0 kVA		
	Capacity on one customer		1.0-10.0 kVA	1.0-125.0 kVA	15.0-239.0 kW	
Wind power	Capacity of single generation	0.004-0.01 MVA		0.004-1.5 MVA		0.25-1.5 MVA
	Capacity on one customer		0.6-4.0 MVA	0.004-1.5 MVA	0.5-1.94 MW	
Small hydraulic power	Capacity of single generation	0.07-14.0 MVA		0.035-1.1 MVA		0.1MVA
	Capacity on one customer		0.01-1.0 MVA	0.035-1.1 MVA	0.05-25 MW	
CGS	Capacity of single generation	0.7-7.0 MVA		0.001-7.1 MVA		0.6-49.0 MVA
	Capacity on one customer		0.005-50.0 MVA	0.02-0.975 MVA		
Waste	Capacity of single generation	4.0-6.0 MVA		0.8-4.1 MVA		
	Capacity on one customer		10.0-50.0 MVA	0.8-3.8 MVA		0.38 MVA
The other	Capacity of single generation	3.6MVA (Batteries)				

	Capacity on one customer					
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The survey result shows that the view varies very greatly ranging from small-capacity photovoltaic power generation intended for installed at house to such energy sources utilizing a large-scale electricity generation from waste materials in terms of type and installing position of DG and, in terms of capacity, from a limited capacity by a single power generation system to a capacity guaranteed under a single contract.

The DG we covered are classified according to resources as follows in a similar manner as in the way of WG C6.01 report.

- (i) The power supply using natural energy
 - Solar Photovoltaic
 - Wind power
 - Small hydraulic power
- (ii) The power supply using a fossil fuel
 - CGS
 - Micro gas turbine
 - Fuel cell
- (iii) The power supply using unused energy
 - Waste
 - Biomass
- (iv) The others (Electric power storage equipment etc.)
 - Rechargeable battery
 - -Flywheel etc.

(2) The minimum voltage class that the load-dispatching centre operates Dispersed

Generation

With the interconnection of DG to HV or MV line, a communication system may be installed in some cases between the load-dispatching centre of the electric utility in the power grid side and the installer of the power generation unit in order to allow the bi-directional transfer of information required for the operation of the power system. Not centrally dispatched means that the operator of the power system cannot instruct the shutdown of DG unit or control output power (both active and reactive) from DG. The minimum voltage classes in different countries, which the load dispatching is done for operating DG, are listed in Table 2.2.2.

Table 2.2.2. The minimum voltage class that the load-dispatching centre operates DG

Country	Australia	Canada	Finland	Germany	Italy	Japan	Norway
minimum voltage	66kV	24kV	110kV	20kV	132kV	66kV	22kV

3. Present status of DG in individual countries

3.1 Data on the number of DG interconnecting to the power-grid in individual countries

We conducted a survey regarding the present status and future prospects for penetration of DG in each country (April thru May 2004). Table 3.1.1 provides an outline of the results. Some data are based on the WG C6.01 Report.

Table 3.1.1. The maximum demand and the amount of introduction of DG in individual countries

Country	Australia*	Denmark	Germany	Greece**	Israel*	Italy
maximum demand (GW)	31.5***	3.8	70.9	10.7***	7.9	47.9
CGS (MW)	2,015	1,415			6	10,618
Wind power (MW)	34	1,387	4,450	12	5	282
Solar Photovoltaic (MW)	29		64	0.3	7	19
Small hydraulic power (MW)		11				2,191
Waste (MW)	150	Included to CGS	522			170
Biomass (MW)	790	Included to CGS	448			490

Country	Japan	South Korea	Netherlands	Norway	Britain	U.S.
maximum demand (GW)	167.4	37.3	20.7***	27.9***	62.5	681
CGS (MW)	4,974	835	5,182		4,239	7,587
Wind power (MW)	83	3	409	14	350	2,300
Solar Photovoltaic (MW)	209		9		1	400
Small hydraulic power (MW)	-	32	37		64	44,052
Waste (MW)	900	5	424		468	4,300
Biomass (MW)	80		26	30	176	6,800

(*:2000, **:1997, ***: Power generation equipment capacity)

Country	Canada	Poland	Finland	India
maximum demand (GW)	88			
CGS (MW)		407		484
Wind power (MW)	124	58	38	1,870
Solar Photovoltaic (MW)	6	0.15		54
Small hydraulic power (MW)	1,423	51		1,509
Waste (MW)	282	16		2.5
Biomass (MW)	1,216			

Notes:

- These data were obtained through the survey that was conducted in 2004; therefore, this table may not reflect current data.
- The collection of data is not the object of the WG. They are only reported to give some qualitative indication about the existing and expected role of DG.

Table 3.1.1 indicates that the most widespread at present among the various types of DG is the CGS. This may be explained by the fact that an increasing number of consumers have been pushing forward these installations mainly to reduce electric energy costs. This trend is especially noticeable in Denmark, Italy, and the Netherlands because of high proportion comparing with peak demands in these countries. In addition, introduction of wind power generation is also increasing and is prominent especially in European countries such as Germany, Denmark and the U.S.

3.2 Factual survey on rules for grid-interconnection in individual countries and the identification of potential problems

We surveyed the rules for grid-interconnection in their countries (April through May 2004). Table 3.2.1 shows the results.

Table 3.2.1. Rules on Grid-interconnection in Member Countries

Country	For grid-interconnection		
	Established rules	Rules established by:	Rules enforced by law?
Australia	(1) National Electricity Code (Not focused on DG, but mainly focused on the generation and electricity network operation) (2) Various guidelines. (3) Technical Guideline for Connection of Renewable Generators to the local Electricity Network (4) Report on issues and barriers to DG.	(1) National Electricity Code Administrator (2) Various electricity distribution network service providers (3) Australian Business Council for Sustainable Energy (4) Independent Pricing and Regulatory Tribunal of New South Wales	(1) Yes (2) Rules are delegated to various state jurisdictions. In some states, rules are mandated (Victoria, South Australia), in other states more voluntary and code of practice (New South Wales, Queensland)
Canada	Each utility's own guideline	The utilities	Some utilities might, but the other majorities are not: these are considered guidelines. There are, however, safety related items that exist in the National Electrical Code (CSA) that are referenced in the guidelines. These are considered law.
Finland	No national rule, just a very general recommendation	Association of Finnish Electric Utilities	No
Germany	(1) Guidelines for the interconnection of DG to the LV and MV level (2) Transmission Code for large wind farms	(1) VDEW (the roof organization of German utilities) (2) VDN (the organization of network operators)	No
Italy	Different rules are present. (1) DG connected to HV networks (CEI 11-32) (2) DG connected to MV and LV networks (CEI 11-20) (3) DK 5740 for DG connected to MV networks, (4) DK5740 for DG connected to LV networks (5) DK 5750 for photovoltaic generators (6) DK 5540 was operating, concerning DG connected to HV	(1), (2) Italian Electric Standard Committee (CED): general rules (3)-(6) ENEL DISTRIBUTION S.P.A. CEI general rules becomes well-defined connection criteria for DG connected to MV and LV networks by means of the rules of the main Italian Distribution Electric Company, ENEL. (*) At the moment, the rules	Yes. The Standards of the National Electric Standard Committee have automatic value as a law.

	networks (*)	are stated by the National Grid Operator (TERNA), however, these are not very detailed.	
Norway	There is no national standard, however, there are several types of non-mandatory guidelines and recommendations for connection of DG (1) Guidelines (2) Company-specific requirements	(1) Issued by Independent bodies (interest organizations, research institutes): these are available for all network companies and owners of DG unit. (2) Issued by the issuing company, usually a distribution system operator, to assess the impact of connecting DG	No.
Japan	(1) Guideline of Technical Requirements for Gridinterconnection to maintain power quality (2) Interpretations of technical standards for electrical facility (Prescriptions for safety)	(1), (2) The Ministry of Economy, Trade and Industry	(1) The rules are not mandatory (2) This rule is regarded as almost forcible; however, it is the “Interpretations” of the law, “Technical standards for electrical facility”, so it is admitted if one can technically prove another way, which is out of interpreted rules, to comply with the law.

Many countries have rules for grid-interconnection. Some of them are mandatory or enforced by the national governments though others only have guidelines. Grid-interconnection is typically promoted via talks between distribution network operator and DG owners. When the interconnection rules have no legal force, the rules are taken solely as technical guidelines and the parties involved are expected to deliberating amongst themselves in good faith. When interconnection incurs costs, however, problems may arise in allocating the cost burden and determining governing laws in the absence of rules with legal force.

Broadly speaking, the rules for grid-interconnection apply to almost all of the types of DG units now popular in the member countries.

Table 3.2.2. Content of Rules on Grid-interconnection in Member Countries

(O = mentioned, X = not mentioned)

Country	Prevention of DG islanding	Capacity of DG connections	Coordination with power lines	Voltage control	Communication system
Japan	O	O	O	O	O
Switzerland	-	-	-	-	-
Italy	O	O	O	X	X
Poland	-	-	O	O	O
Finland	O	X	O	X	X
Canada	O	O	O	O	O
Germany	O	O	O	O	X
India	X	X	O	X	X

Country	Harmonics	Power factors	Cost bearing	Other
Japan	O	O	X	-
Switzerland	-	-	-	-
Italy	X	O	X	-
Poland	O	O	X	-
Finland	O	X	X	-
Canada	O	O	O	Power Quality monitoring
Germany	O	X	X	Flicker
India	X	O	-	-

Load-dispatching is not done in most of the countries below the MV level. While this may not pose a problem with grid-interconnection rules, the lack of instructions for DG can affect the sound operation of the networks as a whole.

As the table 3.2.2 indicates, the rules include stipulations on the prevention of DG islanding, DG connection capacity, coordination with grid, voltage control, voltage harmonics, and power factors. The rules related to power quality such as voltage flicker and power quality monitoring are established in a certain country. In contrast the rules in many countries contain no provisions on communication system, cost bearing, or other issues involving direct contact with the customers.

In the absence of any international rules governing grid-interconnection for the present, the rules are enacted individually and tailored to the circumstances at home. Many types of generator, however, are marketed worldwide. When a power producer purchases a generator and tries to install it at home, the generator may fail to meet the specifications required for conformance with the domestic grid-interconnection rules. This may necessitate the installation of additional equipment at considerable expense and cause troubles between network operators and DG owners.

The rules in some countries have remained effective through the early stages after

their introduction. In case that excessive amount of DG are interconnected later, they are required to make modification and amendment of their rules at each time at each time when an unexpected fault or like problem impairs the voltage or power quality of the grid.

Some countries lack rules on cost bearing when problems occur during later stages (i.e., after the first connection goes smoothly without problems involving line overload, excess voltage outside the suitable range, excess burden on the line short-circuit capacities, etc.). This can lead to disputes or force the parties involved to handle the matter on a first-come, first-served basis. This is considered to be a problem.

4. Forecasting the future diffusion of Dispersed Generation and identifying potential problems

4.1 Estimated future growth of Dispersed Generation

We conducted a survey to estimate the future growth of DG (April thru May 2004). Table 4.1.1 shows result.

Table 4.1.1. Estimated Future Growth of DG by Type

Country	Japan (2010)	Poland (2010)	Finland (2010)	Canada (2014)	Germany (?)	India (2007)
Solar photovoltaic (MW)	4820			0.1	250	5
Wind power (MW)	3000	1,412	200	10	14,000	1,500
Small hydraulic power (MW)	157.7 (For 1,000 kW or lower)	227		300	4,780	6,000
CGS (MW)	5,020	410		20	10,000	7,000
Waste (MW)	417	50		30	500	80
Biomass (MW)		5			800	

Notes:

- These data were obtained through the survey that was conducted in 2004; therefore, this table may not reflect current data.
- The collection of data is not the object of the WG. They are only reported to give some qualitative indication about the existing and expected role of DG.

When compared with the data in Table 3.1.1, the forecast data in table 4.1.1 indicates higher projected power production in 2010 or so: CGS (1.1 to 2.5 times higher), Waste

Generation (1.9 to 3.1 times higher), and Small Hydraulic Generation (2.1 to 4.5 times higher). Though priority differs from country to country, plans for the successful introduction of various types of power generation are already in place. India, for example, is planning to dramatically increase the scale of its CGS and waste generation operations relative to the levels at which they have been introduced.

In a view of using RES, introduction of a large amount of Wind power Generation is scheduled in every country that cooperated with this survey. Germany is the most outstanding for the present. Germany also has the most ambitious, large-scale plans for further introduction, followed by Japan, India, and Poland. Japan has the most ambitious plans for the introduction of solar photovoltaic power. Though these types of generation are expected to diffuse to other countries, the output will be highly dependent on geographical and meteorological conditions due to the features of the generation system. Thus, the diffusion of this type of generation may vary considerably from country to country.

4.2 Identifying problems with the diffusion of Dispersed Generation

As DG becomes popular, an increasing number of DG units will be connected to a single distribution system. The current rules may not be able to cover this situation. The paragraphs below address expected issues to occur in the future though some of them have already existed.

(1) Increased short-circuit capacity

Synchronous and inductive generators and other alternate current generation facilities serve as supply sources for short-circuit current during short circuits of lines necessitated by the characteristics of the rotating machine. If a short circuit occurs at a point where many generators are interconnected to distribution line, short circuit current may therefore exceed the instantaneous allowable current capacity of the distribution line or the rated capacity of the circuit breaker at the customer's site. As the circuit breaker is rendered inoperable when this occurs, the breaker fails to break the short-circuit current continuously flowing in through faulty points. Eventually, the facilities may break as a result.

In the case of a generation facility connected with an inverter in-between, a short-circuit current fed from the inverter in the event of a line short circuit is inhibited to a level 1.1 to 1.5 times greater than the rated current due to the characteristics of the inverter. As a result, the short-circuit current has no serious influence on increases in the short-circuit capacity.

(2) Deteriorated sensitivity in the detection of islanding

For the detection of islanding based on the voltage or frequency relay, it is difficult to detect it in case of balanced condition between the total load and the total output of the generation facilities within a grid.

Some countries require that grid-interconnections have the capability to detect islanding by the passive or active method. In the passive method, islanding can be detected by a rapid change in voltage phase due to load in non-equilibrium, etc. In the active method, islanding can be detected by continually injecting a line with a micro-disturbance signal designed to be detectable when amplified.

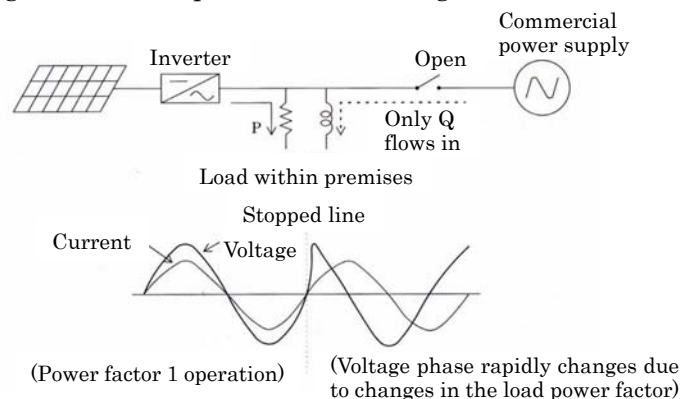
However these methods are effective only when relatively few generation facilities are involved. As the number increases, many DG will be installed within the same line. As a consequence, the amount of load and the output of generation may balance each other, effectively nullifying the passive method due to the disappearance of necessary factors for detection like phase difference as well as the active method due to the mutual interference of the disturbance signals from each DG.

For reference, here describes some explanations about those methods with issues of islanding.

(i) Passive method

(a) Voltage phase jump detection

A method to detect a rapid change in the voltage phase, etc. due to non-equilibrium between the generation output and load during transition to islanding.



(b) Frequency change rate detection

A method to detect rapid changes in frequency, etc. due to non-equilibrium between the generation output and load during transition to islanding.

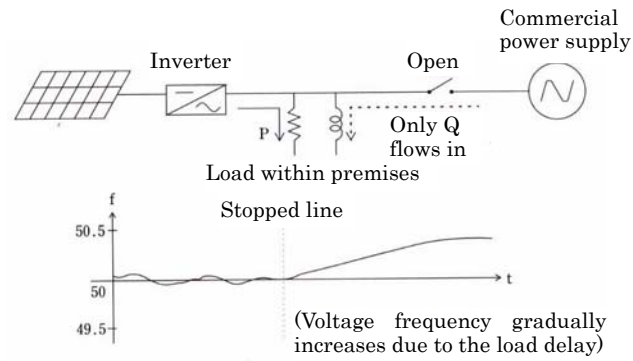


Figure 4.2.2. Frequency change rate detection

(ii) **Active method**

(a) **Reactive power fluctuation method**

This method detects periodical voltage or current fluctuations, etc. that appear during transition to islanding in cases where the generation output is continuously subjected to periodical reactive power fluctuations.

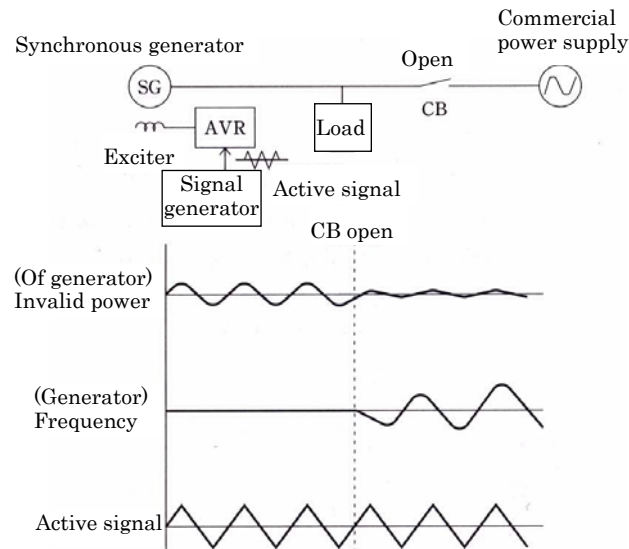


Figure 4.2.3. Reactive power fluctuation method

(b) **Frequency shift method**

A method to detect islanding based on the shift of frequency towards a value determined by the frequency characteristics of the generation facilities and the load characteristics of the individual line during transition to islanding. This is accomplished by setting a bias, etc., in the characteristics of the frequency output of the generation facilities in advance

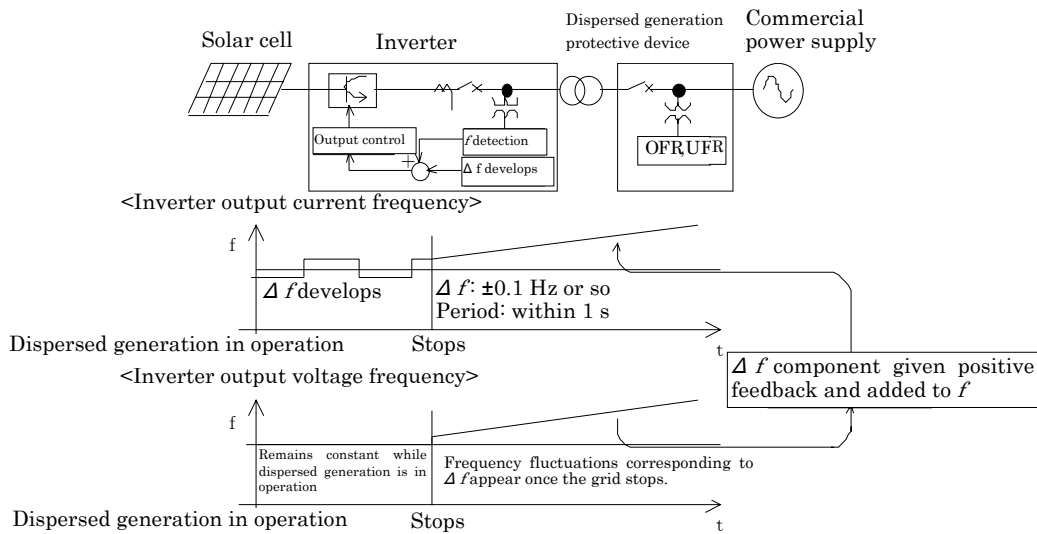


Figure 4.2.4. Frequency shift method

(iii) Issues of islanding

(a) Public electric shock

As power is continuously supplied to a faulty point, there is likelihood that the public at large near the faulty point will suffer electric shocks, etc. A longer period of islanding translates into a longer period of power supply to the faulty point and increased likelihood of even more damage.

(b) Damaged equipment due to asynchronous turn-on

When a circuit breaker is re-closed or interconnected switch to adjacent line is automatically operated while maintaining islanding, the grid and DG units are interconnected asynchronously. This is likely to produce an overcurrent and voltage dips in the grid and thereby damage the equipment of other connected customers.

(c) Increased risk of electric shock of power utility's workers searching for faulty points

A worker searching for the faulty point of a grid faces an increased risk of electric shock if a grid that must be discharged in power failure turns out to be charged.

(3) Simultaneous disconnection of DG units

When turbulence such as voltage dips due to lightning in the grid, then voltage relays

and other equipment may undesirably make, depending on their settings. This, in turn, may cause many DG units to be disconnected all at once, thereby affecting the maintenance of the voltage and frequency throughout the grid.

(4) Deteriorated power quality

There is a worry that the diffusion of DG may affect power quality such as supply voltage, voltage dips, voltage fluctuations (flicker), voltage harmonics, etc. as follows.

- Built-up voltage due to a reverse power flow makes it difficult to maintain the grid voltage within an appropriate range.
- When using wind power generators of the cage inductive type: A rush current will flow when DG joins the grid, resulting in voltage dips in proportion to the line impedance.
- When DG interconnects to grid via a reverse converter of the separately excited type: A voltage dip will occur since the reverse converter is incapable of inhibiting a rush current.
- When DG interconnects to grid via a reverse converter of the self-excited type: A large excitation rush current may flow into the transformer if the converter is unable to synchronize automatically. The probability of this occurring depends on the line configuration (transformers, filters, etc.) and the arrangement of parallel connections.
- When using a wind power generator: Rush currents will flow in response to changes in the wind velocity, output fluctuates due to the tower shadow effect, or frequent separations of DG units. This may cause voltage flicker.
- When more generation facilities with inverters in-between are installed: If harmonic current flows out of a generation facility, the distortion rate of voltage harmonics of the grid may increase.

(5) Voltage adjuster

When the connected condition of DG differs among distribution lines within the same bank, the voltage profile of the distribution lines will be somewhat diversified. This will make it difficult to maintain the voltage of all distribution lines within an appropriate range with the bank taps alone. When the reverse power flow from DG is oversized, the bank current will become light-loaded or subject to a reverse power flow, eventually hindering the grid voltage maintenance by Line Drop Compensator (LDC) at distribution substations.

5. Surveys and considerations on the efficacy of ICT usage

Electricity plays an increasingly important role in supporting our social activities. To maintain the convenience and prevalent supply of electricity, utilities must maintain power quality, system stability and system reliability at stable levels on the diffusion of DG. In view of this, previous chapters have confirmed that DG will diffuse at a much higher pace in the future. However, unless revising the current rules of grid-interconnection or the existing electric facilities, the number of interconnected DG probably has to be limited to maintain the soundness of the power grid. Such a state of affairs would certainly hinder the diffusion of DG.

One of the possible means to avoid this situation is to rapidly expand the field of ICT.

In the following sections we will present the results of surveys on the status of ICT usage in the member countries, and a number of research projects based on ICT. Both types of research help us address the issues expected to be encountered during the transition, until DG gains full popularity.

5.1 Survey on the present status of ICT use in distribution facilities

First of all, we surveyed the purposes of ICT and communication media now in practical use in existing distribution systems. The results are shown in Table 5.1.1.

Table 5.1.1. Status of ICT USE in Distribution Systems

	Purposes	Methods (communication media)
Australia	DG metering Power Quality monitoring	
Poland	Voltage control Monitoring (voltage and current)	Optical fibers, Metal cables, PLC
India	Metering	Optical fibers, Metal cables, PLC, Wireless
Norway	Voltage control Voltage and current monitoring Water level in reservoir	Metal cables, PLC, GSM
Canada	Metering Voltage control Monitoring (voltage and current)	Optical fibers, Metal cables, PLC, Wireless
Finland	Distribution control system Voltage control Monitoring (voltage and current)	Optical fibers, Metal cables, PLC, Wireless
Germany	Energy management Voltage control Monitoring (voltage and current) Availability Fault ride-through	Optical fibers, Metal cables, PLC, Wireless

Italy	Transfer cut-off Metering Monitoring (voltage and current) Switch remote control	Optical fibers, Metal cables, PLC, Wireless, GSM
Japan	Automated Distribution System Voltage control Monitoring (voltage and current) Metering DG metering Transfer cut-off	Optical fibers, Metal cables, PLC, Wireless, Mobile phones

On the basis of the survey data, we surmise that ICT is used chiefly for metering at the customer's side and for monitoring the voltage and current at the sending feeders in substations. In addition, it is also used for voltage control, power quality monitoring, distribution automation system, transfer cut-off, energy management, and so on. The communication media in use include metal cables, optical fiber cables, radio, and Power Line Communication (PLC). PLC, metal cables and optical fiber cables are popular media among surveyed countries. As for PLC, though its capacity is somewhat limited, it has been widely adapted because it does not require the installation of new communication lines. Metal cables were formerly used as dedicated lines. Recently, however, optical fiber cables have replaced them as the mainstream. Both metal and optical fiber cables coexist in the present facilities.

5.2 Deliberations on the application of ICT to distribution systems

Table 5.2.1 shows the status of deliberations on the application of ICT to distribution systems. From the results, we can see that every country recognizes ICT as a means of realizing higher technologies in system operation and management, as well as improving the efficiency and quality of their work by developing distribution automation system, automatic metering system, power quality monitoring system, demand side management, and so on. Many national or private projects are on the move.

Table 5.2.1. Deliberations on the Application of ICT to Distribution System

Australia	<ul style="list-style-type: none"> • Demand management strategy • Market prices under conditions of restraint IPART (the Independent Pricing and Regulatory Tribunal) is encouraging the Market Network Service providers in New South Wales to establish an integrated service responsive to the market.
Finland	<p>Researching the following areas in the TESLA Program, a project funded by the TEKES (Technology Agency of Finland)</p> <ul style="list-style-type: none"> • Automated distribution system Improved efficiency in using the distribution network; monitoring of system status; and new application of instruments to measure the status of equipment components. • Industrial power line management Optimization of the consumption and supply of energy; monitoring of the current status of electronic transactions, risk control, and industrial power lines. • Demand-Side Management IT solutions, terminals, and control systems for communications between electric utilities and electricity users (a new service concept for electric utilities). • Applying new communication technology to distribution networks.
Germany	<ul style="list-style-type: none"> • Energy management Power measurements, metering data, information on status, and target values for generation in time rows in 15-minute rasters and for online control with single values at 1 min intervals. • Enhanced involvement in network operations Different kinds of reports, measurements, and methods for the control of DG (e.g., for starting operations after faults) • Application to voltage and power control • New protection devices for medium and low voltage levels
Italy	<ul style="list-style-type: none"> • Reduction of GSM network costs • Real-time metering of customer electricity consumption About 30 million electronic new metering devices, based on PLC, are being placed in the field. The activity is in progress and it is quite near to the conclusion.
Poland	<ul style="list-style-type: none"> • Communication technology development CEIDS project: Integrated Energy and Communications System Architecture (transmission system) Solution for distribution companies: SCADA, Substation Control Systems
Canada	<ul style="list-style-type: none"> • Automation ICT is in use not only as a means of communications, but also for remote control of circuit breakers, capacitors, distribution system switches, and the re-closing of circuits. • Metering ICT collects data on power quality from measuring instruments installed at distribution substations. • Power quality measurement • Source transferring
Japan	<ul style="list-style-type: none"> • Management of power consumption via enhancements in automated meter reading. • Innovation to ensure higher reliability and higher power quality for specific customers.

5.3 Measures to use Dispersed Generation through the application of ICT

The fluctuation of output power from the generator depends on the type of generator and leads to fluctuations in the system voltage and frequency. Especially, RES has a stronger tendency because its output power depends on meteorological conditions. For this reason, DG, generally non-dispatched, may deteriorate the stability of voltage and frequency in the system.

The following section presents the results of surveys on technologies for the appropriate operation of distribution systems interconnected with DG.

(1) Present status in the surveyed countries

Here we describe the present status of R&D on the use of ICT for DG. The results are summarized in Table 5.3.1.

Table 5.3.1. R&D towards the use of ICT for DG in the countries surveyed

Australia	<ul style="list-style-type: none"> • Integration of DG R&D funding is generally limited. The Commonwealth Scientific Industrial Research Organization (CSIRO) funds the Energy Research Centre in Newcastle.
Canada	<ul style="list-style-type: none"> • Remote tripping of customer DG facility The University of Alberta is developing a thyristor-basis transfer cut-off scheme that uses PLC for DG interconnected with a distribution system. <ul style="list-style-type: none"> • Manitoba Hydro is researching wind conditions to investigate the feasibility of wind generation at a number of potential sites. • A load-dispatching centre for DG interconnected with a distribution line. • Understanding the operation of the current DG.
Finland	Carrying out the DENSITY Program (2003-2007), a national project funded by the TEKES (Finland Agency of Technology). The program focuses on the following priority areas. (The goal is to make their products and market world-class via technological innovation.) <ul style="list-style-type: none"> • System solutions • System integration • Industrial production • Business concept • Application of ICT • Demonstration

Germany	<p>Test project on dispersed energy management</p> <p>A new project, Energy and Communication, is now just starting. The research objectives are to make use of the existing communication infrastructures to manage and control DG, and to integrate PLC, their telephone line network, radio communications, optical fiber cables (installed in aerial facilities), and line communication media into the IEC 61850 communication standard.</p>
Italy	<ul style="list-style-type: none"> • Remote tripping to avoid islanding. • Management and control of DG. <p>Centrally controlling DG by installing supervision systems at control and distribution substations.</p>
Japan	<p>The following R&D programs are underway.</p> <ul style="list-style-type: none"> • Optimum voltage control based on information from voltage and current sensors installed on distribution lines • Operating and separating services for DG to provide the optimum state for both distribution lines and DG, based on information from voltage and current sensors installed on distribution lines. • Research to implement the operation of an optimum loop of distribution lines in order to improve supply reliability, to minimize power loss, and to maximize the capacity of interconnecting DG based on information from voltage and current sensors installed on distribution lines.

These R&D topics can be categorized into the following themes.

- (i) Technology to detect and avoid islanding.
- (ii) Optimum voltage control based on integral control of all the voltage-controllable equipment in the system.
- (iii) Technology to use DG as a reliable source via centralized control.
- (iv) Optimum system configuration to use DG.

It can be said that all topics deal with the issues in the prevalence of DG. When engaging in R&D on (iii) and (iv), researchers generally focus on (i) as an essential component of the technologies concerned. The following paragraphs introduce practical examples to provide more concrete descriptions.

(2) Examples of research and practices

(i) Technology to detect and avoid islanding.

Title: Method to Transfer Trip Customer-owned Generators from the Utility Substation (R&D by the University of Alberta/Manitoba Hydro – Canada)

Purpose: To develop and field test a power-line-carrier-based anti-islanding scheme for transfer-tripping distributed resources connected to a utility distribution system.

General Description: One of the barriers to interconnecting DG to power distribution systems is the technical challenge of disconnecting the DG when the distribution system is isolated from the supply substation during faults, etc. If the DG is not disconnected in a timely manner, the power will continue flowing to the islanded portion of the system. This could lead to unpredictable conditions in the system and damages to the DG and other customers. A common industry practice is to disconnect all DG after the occurrence of islanding. To achieve this goal, each DG must have the ability to detect whether it is islanded. The development of methods for the reliable and timely detection of islanding has become one of the main technical hurdles facing both the DG industry and utility companies.

In response to the needs of industry, the University of Alberta has developed an innovative islanding detection scheme. After more than two years of research in collaboration with the Canadian power industry, a field assessment of the technology is ready to be conducted in collaboration with Manitoba Hydro.

The technology invented at the University of Alberta involves a new concept for anti-islanding protection. It uses a power line as a signal carrier to check the connectivity of power line. The basic idea is shown in Figure 5.3.1.

The scheme includes two devices: a signal generator installed at the feeder side of the substation and a signal detector installed at each DG site. The signal generator continuously broadcasts a signal to all distribution feeders with a preset protocol. When a signal detector fails to detect the signal interruption for a certain period (e.g., 200 ms), the system assumes that an island condition has developed and immediately trips the DG. The signal generator has several auxiliary inputs. Any one of the inputs can stop the broadcast and thereby trip all of the DG in the system. This feature is particularly useful when transmission system operators need to trip the DG. It is also useful when a transmission system island has formed. The transmission system is well equipped with SCADA capability and can therefore send a stop signal to the signal generator.

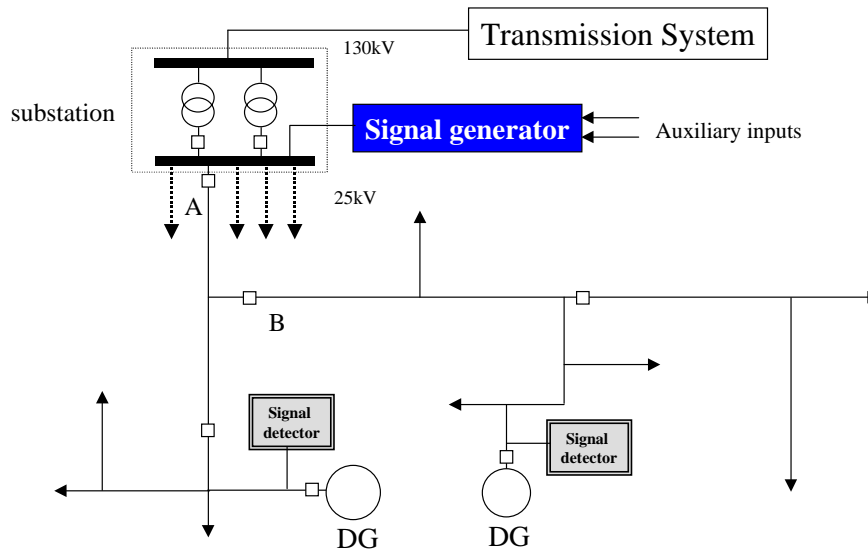


Figure 5.3.1. The proposed anti-islanding scheme

The proposed scheme is fundamentally different from the existing schemes. It combines the advantages of the transfer-trip and the local-detection-based schemes. The power line itself is used as the communication medium. Another important advantage is the ability to test the scheme without actually breaking up the distribution feeders. The tests can be performed by simply stopping the signal generator.

Another significant feature of the proposed technology is the creation of a unique signal that can be reliably detected by the signal detectors with only minimal impact on the power quality. The scheme injects harmonic signals to the system in selected cycles. Every second cycle in these waveforms contains a small distortion to indicate the presence of a signal. When a slower response time is acceptable, this distortion can be produced in every third cycle or every fourth cycle. The signals are extracted by digitally subtracting two consecutive cycles of the measured waveform, because the signals are present in only one of the cycles, at most. This subtraction will eliminate background waveform distortion. In theory, the signal is the only quantity left in the differential waveform. The differential waveform is then used to determine the presence of the signal.

The University of Alberta has developed a concrete method to generate such a signal. The signal is generated by short-circuiting the supply voltage around its zero-cross point through a transformer and thyristor. The firing angle of the thyristor is controlled to maintain a level of the signals power large enough to be detected while ensuring that the distortion caused by the short-circuit never compromises the power quality. The voltage signal can be injected on one or more of the three phase-to-ground voltages and one or more of the three phase-to-phase voltages. When all are employed, a total of 6 signal channels result. There are also two zero-cross instants to use. This brings more options

for the design of signal patterns that can be more reliably detected.

Field tests are now underway in Alberta and Manitoba. Preliminary results show that the system works.

(ii) Optimum voltage control by integral control of all distribution equipment

Title: Advanced voltage control system (Research: Tokyo Electric Power Co., Ltd., Japan)

Purpose: In conventional systems, the proper voltage is maintained by designing and operating distribution lines configured with a radial structure in which the power always flows in one direction. With the prevalence of DG, a method of generation requiring a reverse power flow, voltage distribution becomes more complicated and the proper voltage becomes more difficult to maintain. The purpose of this research is to establish a method of voltage control consisting of centralized control of load ratio control transformers (LRTs) at substation banks and the taps of step voltage regulators (SVRs) installed on distribution lines, based on measurement data from voltage and current sensors in the distribution network. These measures are believed to be capable of maintaining the distribution system voltage at a proper level even when large-scale DG or substantial numbers of smaller DG are interconnected.

General description: Figure 5.3.2 presents a conceptual diagram of the centralized voltage control system. Switches equipped with voltage and current sensors are installed at three to five locations per feeder on a distribution line, and all measurements are sent into the centre server via a communication network. These sensor-equipped switches have the same remote-control function provided by conventional automatic switches, as well as a function to monitor and clearly display the level of power quality (voltage harmonics, voltage unbalance, flicker, voltage dips/swells, fault current, etc.). The centre server periodically carries out computations using data on the tap position of each LRT and SVR and sends out control signals to the subject equipment and devices.

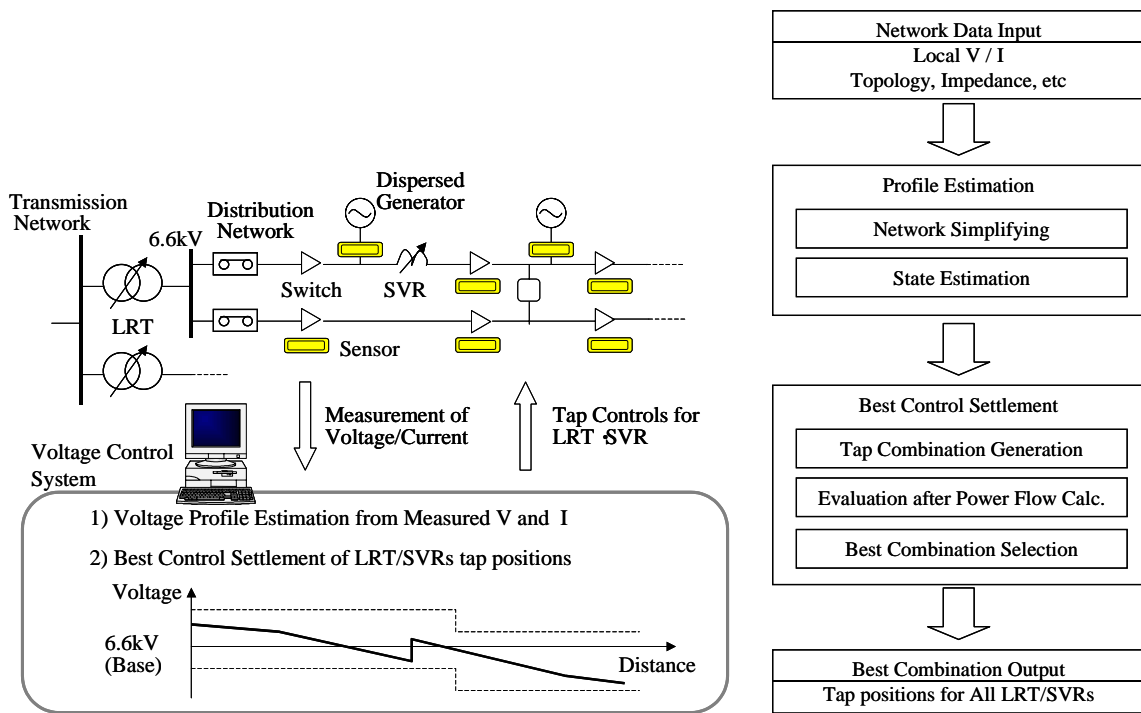


Figure 5.3.2. Outline of Advanced Voltage Control System

Information communication system: Figure 5.3.3 illustrates the structure of the switch with several built-in sensors. Figure 5.3.4 shows the configuration of the optical fiber network. The switch is equipped with three-phase Potential Devices (PDs) at each end of the contact. One end is equipped with a three-phase Current Transformers (CTs) and the other end is equipped with a Residual Current Transformers (RCTs). With these sensors, the remote terminal unit (RTU) measures the data, edits it, saves it, and sends it to the computer. Measurement data and the results of data-editing are sent at fixed intervals of 1 min. The saved data are designed to be transmitted on demand from the computer system. These sensor-equipped switches have the same remote-control function provided by conventional automatic switches. In addition, it also has a function of monitoring power quality (voltage harmonics, voltage unbalance, flicker, voltage dips/swells, fault current, etc.). The centre server periodically carries out computations using data on the tap position of each LRT and SVR and sends out control signals to the subject equipment and devices.

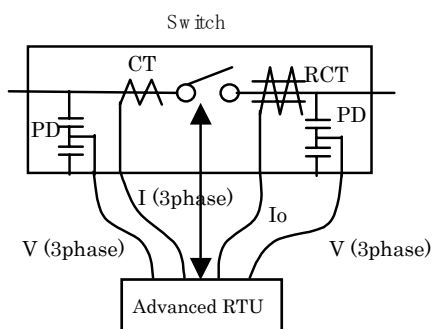


Figure 5.3.3. Structure of the switch with several built-in sensors

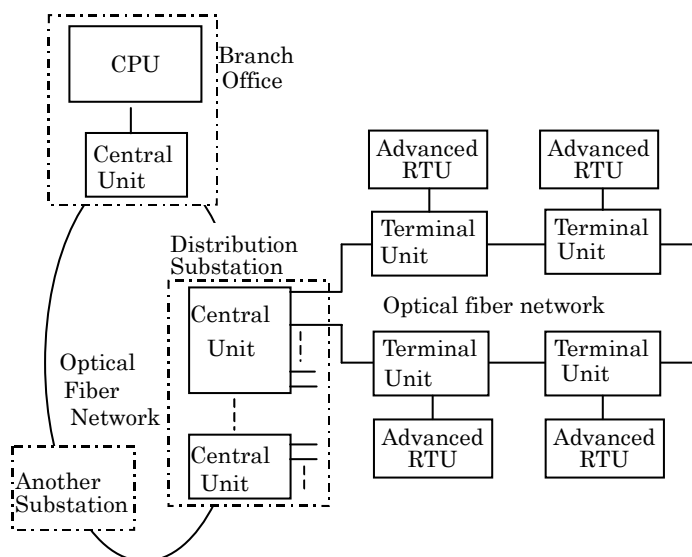


Figure 5.3.4. Configuration of the optical fiber network

(iii) Technology to use DG based on the centralized wholesale control of DG

Title: EDISON Project (Electricity Distribution Integrating Systems Of New generation, storage and coupling technologies using advanced information and communication systems for the dispatch) (Research: Federal Ministry for Economy and Technology, Germany)

Purpose: National programs inside the European Community are now directed to increase the share of RES and the efficiency of power generation by CHP. The output of most of the RES depends on meteorological conditions and the CHP output is driven by

the demand of heat. Therefore, it seems quite difficult to operate network with large share of today mostly undispachable power sources, and to limit the reserve power be limited which is required for compensation of power fluctuations and ensuring a safe network operation.

Thus, it is considered that advanced planning and energy management approaches have to be introduced to ensure the today existing high level of power quality in the future as well.

In this context, a vision sees the power system of the future consisting of a number of microgrids. In each of these microgrids a significant share of the power demand will be covered by DG. However, the power balance of the microgrids shall be planable and dispatchable in such a way that the import or export of power from or into the higher level network has to follow a schedule which can be predicted with a high level of accuracy in advance.

The purpose of this project is to investigate the operational behavior of a distribution microgrid with a large share of RES and CHP units.

The targets were defined as follows:

- the development of methods to analyze the conformity and reliability of large-scale DG in existing networks;
- to realize a fully dispatchable microgrid with significant shares of DG and storage via decentralized power generation and load management (also referred to as “DEMS” (Decentralized Energy Management Systems)), and the practical use of related communication channels;
- to gain experience in the operation of new technologies such as Fuel Cell CHP, innovative battery storage units, and Medium Voltage Direct Current (MVDC) couplers, and to define the requirements for operation in the future.

General description: A part of a 20 kV distribution network in a rural area was selected to verify a microgrid concept. The principle features of this microgrid are summarized below.

- The microgrid serves a village with 3, 200 inhabitants. The peak load is 3.5 MW.
- The microgrid is connected to the main network parts solely by one overhead line spanning a distance of 4 km. In addition, however, the dead-end feeder of a neighboring network supplies a farm located about 200 m from the border of the village. Inconveniently, the thresholds exceed the residual currents in both neutral compensated networks. This makes it impossible to connect the two networks to obtain a second infeed.
- As a result of the remote location of the microgrid from the feeding substation, the voltage level drops to 95% in the worst case.
- The reliability assessment targets are unacceptable: records indicate an annual outage time of 1.14 h and a failure to supply 3.1 MWh/a of energy on time.

- Three 20/ 0.4 kV transformers are overloaded to up to 126% capacity for 2 hours on winter nights due to a high concentration of night heating units in the related 0.4 kV networks.

In an analysis of the potential for establishing DG, the connection of innovative components was foreseen in accordance with figure 5.3.5.

The microgrid was equipped with the following dispersed components:

- MVDC network coupler for 2 MVA transfer power between the microgrid and a second supply infeed from the neighboring network;
- 1.2 MW wind power plant on a hill;
- 800 kW batteries connected in four low-voltage networks with partial transformer overload;
- 50 kWel fuel cells for household CHP; (ten 5 kW units);
- 200 kW photovoltaic units with ratings of 10 kW distributed in the whole microgrid;

The following units are foreseen for the supply of a new thermal spa:

- fuel cell CHP of 212 kWel and 230 kWth;
- diesel CHP of 310 kWel and 520 kWth;
- 2.3 MWth. heating station.

With the aforesaid specifications, the DG and storage units can generate a maximum power of 2.77 MW. In addition, another 2 MVA of power can be supplied via the MVDC coupler. As a result, the microgrid can fully serve the village during the outage of the feeding line (branch A-C).

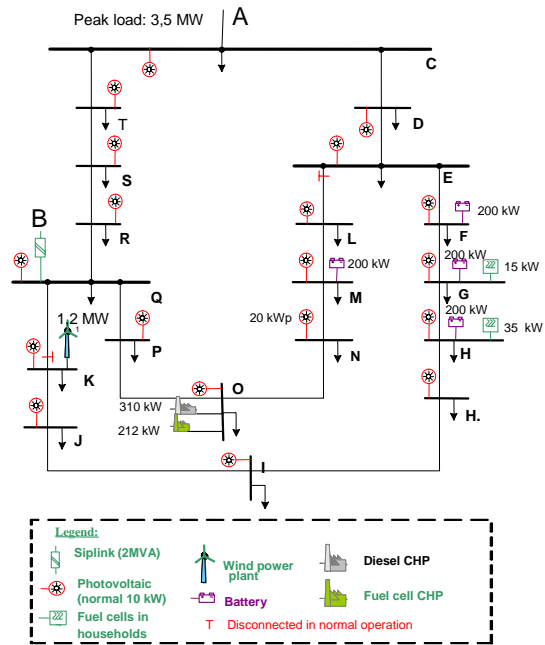


Figure 5.3.5. Scheme of the 20 kV microgrid with dispersed units for generation, storage and MVDC network coupling

Information communication system:

First of all, it was necessary to develop and use advanced network planning tools to investigate the conformity with criteria for network connection and reliability of the network, restructured with DG, Storage, and Coupling (DGSC). The detailed network analysis requires simulation models for the new technologies reflecting their steady state and dynamic behaviour. From this viewpoint, DGSC models for long and short-term simulation have been developed.

Secondly, the dispatching of the DGSC within the microgrids is also major requirement for future stable and cost effective operation of the power system when the market share of DGSC increases significantly. A DEMS is required to enable the planning and dispatching of the power balance in the microgrids and thus to ensure a widespread integration of dispersed generation into the system operation. The functionality of a DEMS is presented in figure 5.3.6.

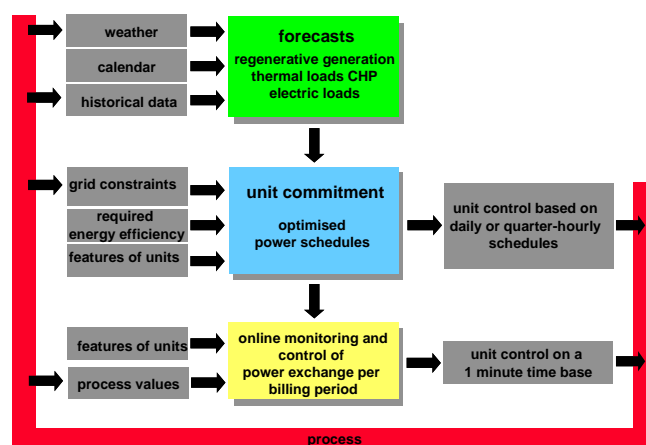


Fig.5.3.6 Functions and features of DEMS

Finally, regarding communication technology, the DGSC dispatching will be spread over a wide area. For economical reasons, the existing infrastructure has to be used for communication purposes. Figure 5.3.7 demonstrates the devised communication solutions that are based on the existing communication capabilities of the suitable equipment.

The DEMS and the SCADA PC of the MVDC Coupler are both based on the WINCC PC software for industrial control and monitoring.

The internal WINCC data exchange is performed via a dedicated telecommunication channel by means of integrated OPC services.

The wind power plant uses mobile phone services to transmit the measured power output and power target values when restrictions of power output are requested.

The load management is based on the existing ripple control system in combination with the metering data communication capability of the specially equipped meters.

All other DGSC units employ a Data Service Controller (DSC) developed for the gateway, for the COM server, and for the SCADA functionalities. The DSC is a PC-based system that principally functions as a gateway between the DEMS PC and the PLCs controlling the technical processes. Most of the PLCs have no interfaces for connection with PC-based control systems. As a solution, the DSC is configured with the ability to connect the PLC over the installed field bus in the manner of a Modbus TCP or industrial Ethernet. To enable communication with DEMS, a java-based web service that understands XML-formatted enquiries is enveloped in the Simple Object Access Protocol (SOAP) and exchanged over HyperText Transfer Protocol (HTTP) within the DSC. The DSC serves as a COM server that essentially functions as a service provider for the DEMS and all involved units.

The integrated web server can create dynamical web pages containing self-refreshing

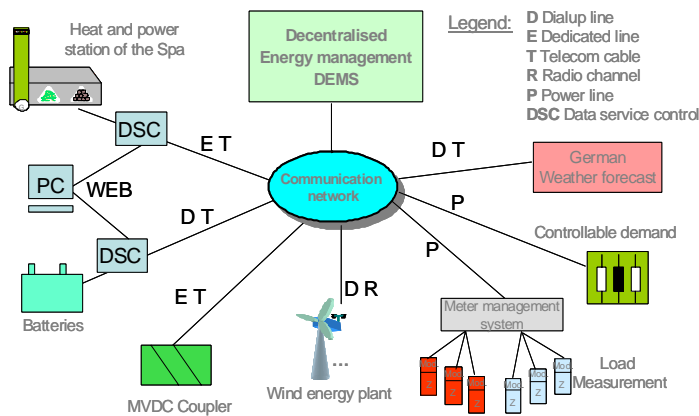


Figure 5.3.7. Communication network for DEMS dispatching

objects that display the latest data on the process. The server can also be configured with functions to generate trending diagrams for the retrospective process data development. This SCADA functionality can be used locally or remotely via the web.

Title: Information Communications Technology for Distributed Generation Connections
(Practice: BC Hydro, Canada)

General description:

(a) BC Hydro System

The BC Hydro (BCH) system operates at 60 Hz with an A-B-C counter-clockwise phase rotation. BCH's primary distribution system is a three-phase four-wire multi-grounded common neutral system. In limited locations, a 3-wire ungrounded system is used as an exception. Figure 5.3.8 shows a typical DG interconnection system.

device. A separate communication medium is used to transmit data on the DG operating status to the Area Control Centre.

ICT for Existing DG (<10MVA)

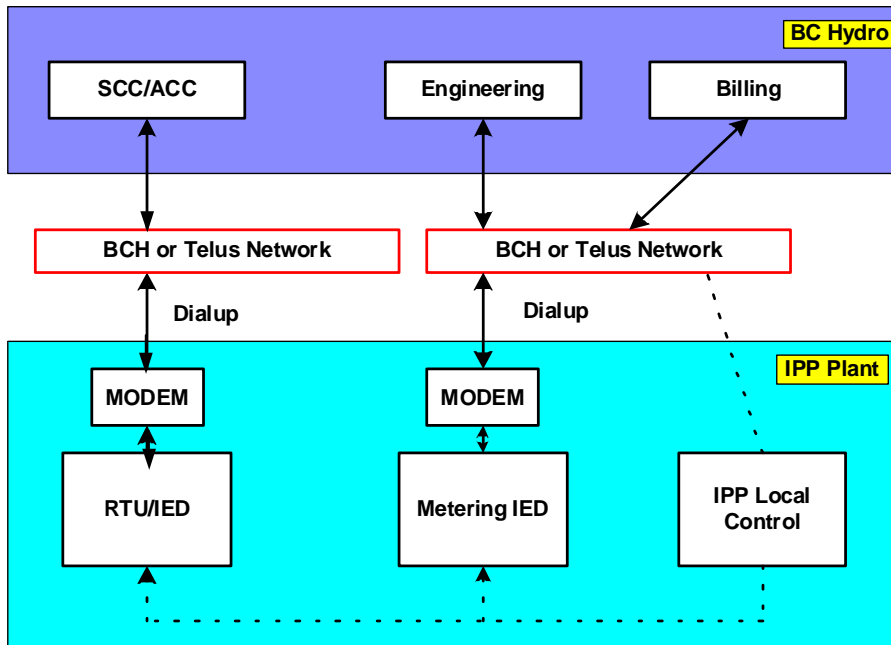


Figure 5.3.9. ICT for Existing DG < 10 MVA

ICT for Existing DG (>10MVA)

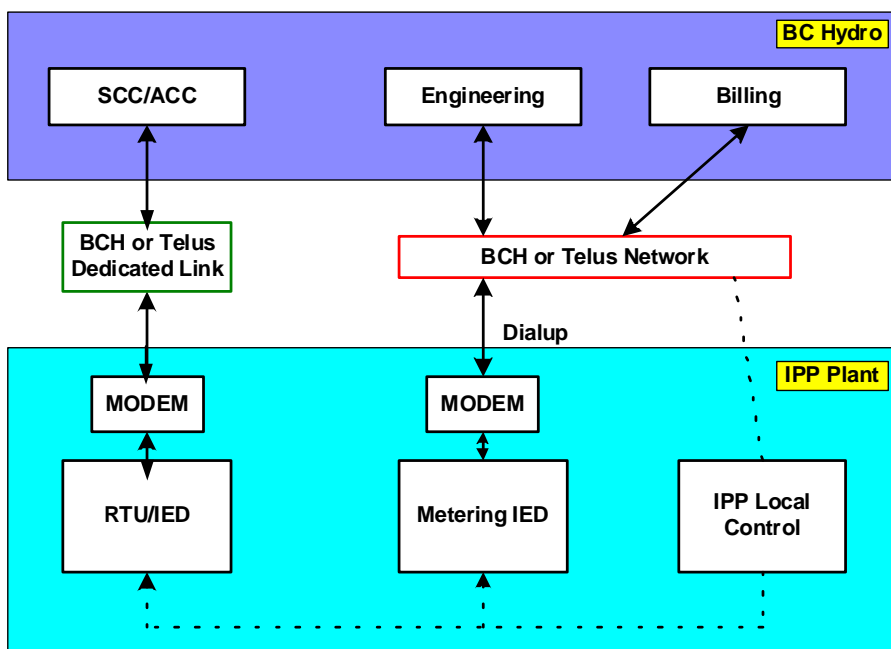


Figure 5.3.10. ICT for DG > 10 MVA

(c) Information Communication Media

Telecommunications media alternatives between the DG and BCH, and within BCH, to transmit data on the operating status may include dedicated or leased metallic wire line circuits, Power Line Carrier, microwave radio, optical fibers, UHF/VHF radio, and satellite. Full duplex (4-wire or equivalent) circuits will generally be used when two-way telecommunications media are required (except for standard voice telephone circuits on wire lines, where 2 wire circuits are used).

Appropriate telecommunications entrance protection must be provided whenever metallic pairs are used. This is a necessary precaution to minimize danger, as the DG station ground potential can rise to hazardous levels above remote ground potential during a power system fault. Telecommunications entrance protection improves safety for personnel, prevents damage to equipment, and allows continuous use of the telecommunications media and attached equipment during and after power system faults. This equipment should be designed to meet public carrier and BCH safety and protective requirements.

(d) Information Communication Data Points

BC Hydro requires telemetering equipment for DG plants rated 1.0 MVA and up. Some or all of this data may need to be supplied continuously or via dial-up from the Area Control Centre or System Control Centre. The specific requirements depend on the size of the plant and other generation in the area. Telemetry information requirements are shown in Table 5.3.2.

Table 5.3.2. Generator Operating Data/Status Telemetry Summary

PLANT RATING	LARGEST GENERATOR RATING IN PLANT	DATA	DESCRIPTION
1.0 –10 MVA	≤ 10 MVA	Plant MW, Mvar, MWh & kV. Plant interconnection status.	<ul style="list-style-type: none"> • Unsolicited (DG initiated) report by exception using a dial-up IED with DNP 3.0 protocol; 2-minute maximum to establish connection for BCH interrogation on demand; reports to Area Control Centre. • Telus analog business line with entrance protection; no other telecom uses in DG plant
>10 MVA	< 30 MVA	Unit MW, Mvar, MWh & kV. Unit connection status & unit running status.	<ul style="list-style-type: none"> • Real-time report by exception using an IED with DNP 3.0 protocol reporting to Area Control Centre. • Single dedicated (always on) communication link, i.e., Telus lease, PLC, optical fibers, microwave, satellite, etc.

Notes:

- Three types of IEDs (Intelligent Electronic Devices) are to be used: RTUs (Remote Terminal Units), digital meters, and programmable logic controllers.
- Each IED is to be capable of providing all required data to the System Control Centre or Area Control Centre at a one-second polling frequency.
- This table applies to all DG, regardless of whether they export electricity across the revenue meter into the BCH distribution system.

(e) Future development of Information Communication Technology

BC Hydro has no operational control for DG in the integrated distribution system. In one proposed plan targeting more efficient operation of the DG interconnected distribution system, a DC plant is controlled directly by the BCH control centre, as shown in Figure 5.3.11 (in other words, the DG generators in the distribution system can be dispatched from the BCH control centre).

ICT - Proposed for BCH DGs

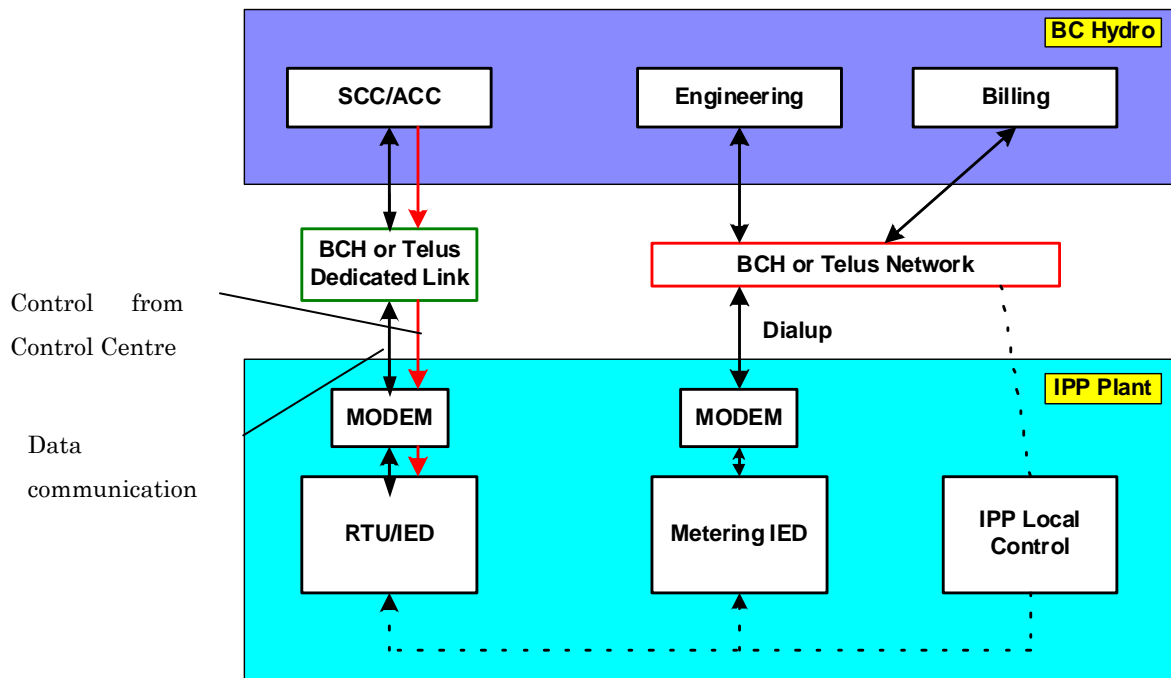


Figure 5.3.11. Proposed ICT for DG

(iv) Optimum system configuration for the use of DG

Title: Autonomous Demand Area Power System (ADAPS) (Research: Central Research Institute of the Electric Power Industry, Japan)

Purpose: To build an electric power supply system which permits the smooth introduction of DG in spite of the various existing problems, and to maximize the advantages to be gained by popularizing DG (e.g., saved energy, leveled load, and minimized energy cost).

General description: The system is assumed to be arranged in a loop structure that inhibits voltage fluctuation and ensures a uniform power flow to make it possible to disseminate DG (Figure 5.3.12). The central operating system gathers voltage and current information from sensor-equipped switches installed in the distribution system, uses the gathered information to control the power flow and voltage with the aid of loop controllers (based on the BTB method) installed at each loop node on the line, and exchanges information with a so-called “demand-supply interface” device installed at each customer site or alongside the DG unit. This configuration enables the control of DG based on ample reference information from both the supply and demand sides, in order to optimize economy and other operational aspects (Figure 5.3.13).

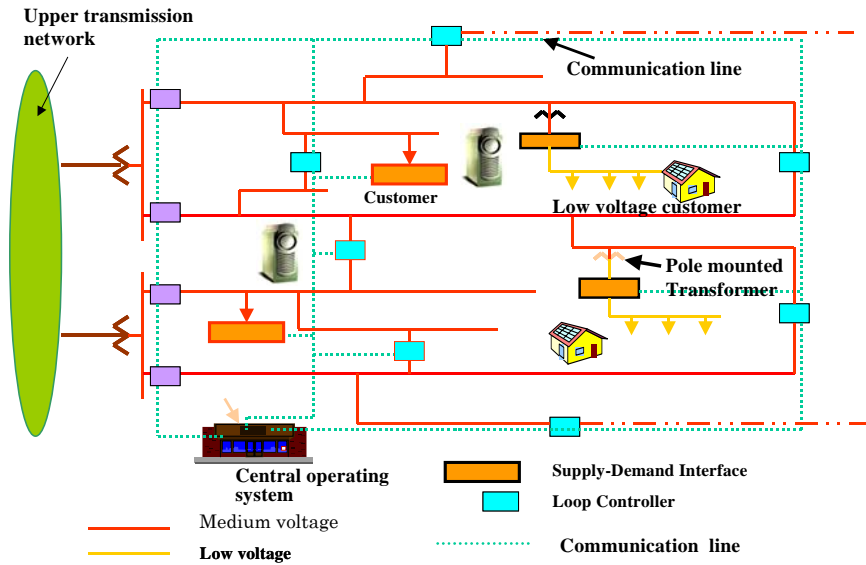


Figure 5.3.12. Configuration of Autonomous Demand Area Power System

Information communication system: This information and communication system for ADAPS must be both adaptive and autonomous if it is to reliably cope with the dynamic changes in the states of ADAPS. It also must perform quickly enough to isolate fault sections from other sections in ADAPS. The mobile agent technique promises to make a system both adaptive and autonomous. The mobile agent platform, a.k.a. MAFADAPS (Mobile Agents for ADAPSs), is used to provide priority controls and object classes in order to secure an adequate degree of flexibility. This is essential, given that the existing platforms for mobile agents neglect to account for real-time performance to cope with isolations of fault sections, etc. Figure 5.3.14 gives an overview of the mobile agent system for ADAPS. A prototype MAFADAPS system has been designed with Java™. The results from this prototype system indicate the applicability of MAFADAPS to ADAPS operations.

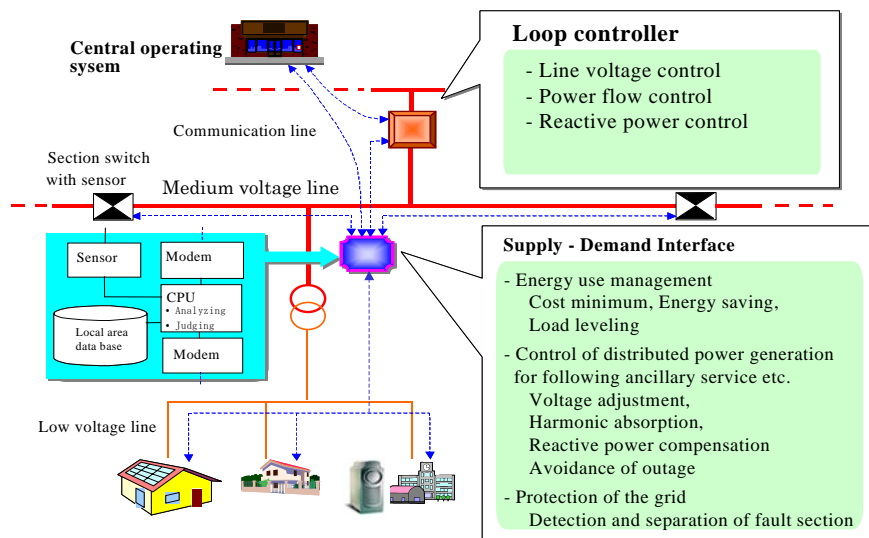


Figure 5.3.13. Configuration of a section

(3) Function of ICT in these examples

Table 5.3.3 shows the features of each ICT adopted in these examples.

Table 5.3.3. Features of ICT in examples

Examples	Electricity Data	Intervals of transmission	ICT tools	Protocols
(i) Transfer trip	Signals from SG (at SS) to Detectors (at DG)	In selected cycles (3 or 4)	PLC	Original
(ii) Advanced voltage control system	-V, I, P, Q (Network) -Status of Switch	1min.	Optical fiber	TCP / IP
(iii) Edison Project	-Metering, -P, Q (DG) (Weather forecast)	1min.	-Metal -Radio -PLC	-SOAP (Single Object Access Protocol) -HTTP (Hyper Text Transfer Protocol) etc.
(iii) ICT for DG connection	-Metering, -P, Q (DG) -Status of interconnection		Optical fiber, PLC, Metal, Microwave, Satellite	Dial-up IED with DNP 3.0,
(iv) Autonomous Demand Area Power System	-V, I, P, Q (Network, DG, Load) -Status of switch, Loop Controller	5–10s (normal) 100ms (fault)	Optical fiber (PLC adoption is now being researched)	TCP / IP

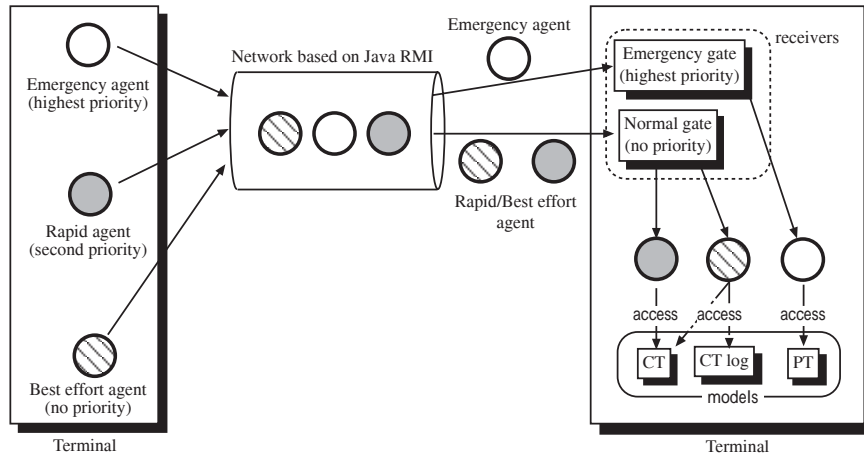


Figure 5.3.14. An overview of mobile agent system for ADAPS

6. Potential applicability of ICT for purposes other than Dispersed Generation

6.1 Applicability of ICT to use other than Dispersed Generation

Our survey results have confirmed that a full range of communication networks has not yet been built. All countries, however, accept that ICT is eminently important for the rapid prevalence of DG. Utilities are therefore expected to steadfastly install communication networks as a means of ensuring that DG can be applied more widely in more stable and reliable systems with adequate power quality.

Given that communication infrastructures generally have a high value-added, they can be used for purposes other than operating DG. Table 6.1.1 presents the results of assessment on their expectations on the extent to which they plan to use the communication infrastructures.

The results show that these countries are directing for making distribution network operations more active to keep in pace with the expansion of switch control, power quality monitoring, and other areas of ICT application.

Table 6.1.1. Applicability of ICT to use other than DG

	Voltage and Current monitoring and control	Automated Power Distribution	Customer services	Power quality monitoring	Other
Japan	0	0	0	0	
Italy	0	0	0	0	
Poland	0	0	0	0	Diagnosis of substation equipment and line facilities
Finland	0	0	0	0	
Canada	0	0	0	0	
Germany	0	0			
India	0	0	0	0	Metering
Norway	0	0	0	0	

6.2 Issues to address when applying ICT

We also surveyed how these countries assess the significance and priorities of the various issues for applying ICT in the future. According to survey results, the two biggest obstacles are the cost of constructing the communication network and the absence of any institution to define the cost-bearing structure and shoulder the administrative responsibility for network operation, etc. The assurance of information security is a crucial factor when applying ICT.

7. Discussion

7.1 Summarizing survey results

WGC6.03 conducted a survey to assess the spread of ICT and progress of R&D on the application of ICT to DG. The survey results confirmed that some countries have already engaged in various types of ICT research in anticipation of the problems that may arise during the rapid adoption of DG. ICT is already in use in many areas, but the communication networks have yet to be fully installed. This stands to reason, as the sizable cost of building communication networks hinders the introduction of various technologies.

Various countries are studying technologies expected to be important in the near future for applications such as the integral control of DG and voltage control. They are also researching technologies to achieve optimum distribution system configurations for DG in the future. We have presented details on these studies in this report to give examples of these technologies. ICT is expected to be a particularly important technical component for implementing these plans.

It will be crucial, in applying ICT, to find optimum ways to fuse the conventional technologies with future technologies. Our success in promoting the widespread use of DG hinges on our ability to achieve this fusion.

7.2 Proposals on the widespread dissemination of DG through the use of ICT

The following paragraphs summarize the conditions that, according to the results of our surveys so far conducted, will have to be met in order to disseminate ICT in the future.

(1) Building economical high-speed, huge-capacity communication infrastructures

The sizable cost for installing facilities for ICT hinders its prevalence. This, as mentioned above, will require effective steps to maximize the advantages not only for the utilization of DG but also the versatile use of communication infrastructures.

Moreover, as shown in the R&D example (iv), if the distribution system configuration is to be changed from the conventional radial structure to loop structures, it will thus be necessary not only to install ICT to exchange information in usual operation, but also to develop a technology to remove only faulty point momentary in the event of faults. The main challenge to be tackled here will be to build economical huge-capacity, high-speed, reliable and secured communication infrastructures for the distribution system.

(2) Standardization

The functions of output control, protection, etc. are now developed as modules independent of each other. When using a single set of communication infrastructures in versatile ways, it will be necessary to unify the information interfaces to be applied.

A unified information interface based on the plug-in method may help to facilitate cooperative operations, such as connection and disconnection, between distribution networks and various types of DG. A standardized interface and a stratified set of standardized core algorithms for control and protection on the respective layers will make it easier to connect devices produced by different manufacturers. Though research on ICT should certainly be promoted as a means of improving network operation, it will also be necessary to define requirements of information transfer and to coordinate with the standardization of DG interface.

(3) Information security

The versatile uses of communication infrastructure will allow the network to receive a steady incoming flow of control signals for the control of system operation, distribution line information at the respective nodes, and information on the status of use and conditions of electricity on the customer side. Reliable information security will therefore be critical. It will be essential to secure the secrecy of the information and signals transmitted, and to build networks capable of giving and receiving information rapidly and smoothly.

The various methods considered effective for ensuring security are listed in Table 7.1.1, together with their respective advantages and disadvantages.

Table 7.1.1. Methods to Ensure Information Security

	Advantages	Disadvantages
Encrypting signals	Encrypting technology has been established and is thus easy to introduce. Encryption is possible in existing infrastructures such as IP networks.	Encryption can be cracked with enough time. Data “bugging” is also possible.
Applying communication protocols by type of information	The existing infrastructures can be used. Protocols can be customized for each type of information.	New protocols and accompanying software and hardware can be freshly developed. Additional security measures, such as encrypting for each protocol, become necessary.
Building communication networks based on the type of information	Provides robust safeguards against bugging and intrusion.	High facility investment is required. An alternative communication route in the event of a fault with facilities is difficult to secure.

8. Acknowledgments

The present WG conducted a number of factual surveys on DG and edited the findings obtained in an effort to elucidate and grasp the future trends. We, the authors, will be happy if the results of these surveys help to pave the way toward the formation of other WGs in SC C6. We would like to express our deep gratitude for the help and advice we have received during the surveys.

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