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DISASTER-RESILIENT TELECOMMUNICATIONS SYSTEMS FOR SMART GRID IN JAPAN

by

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SUMMARY

Telecommunications systems with disaster-resilient features and the capability to support early recovery from disasters are likely to be needed for smart grid deployment.

The Great East Japan Earthquake spurred electric power companies (EPCOs) in Japan to start work on improving telecommunications systems and significant improvements have also been made in telecommunications systems to enable support early recovery from disasters.

This paper introduces the initiatives undertaken by Shikoku and Tohoku Electric Power Companies as part of the activities of EPCOs in Japan to tackle the issue of recovery from disasters.

Shikoku EPCO has replaced its private telephone network to ensure uninterrupted communications even during a large-scale disaster. Specifically, its private IP network is effectively used to realize a wide-area backup system by using a hybrid configuration comprising the IP network and existing communication lines to enhance reliability in the event of a disaster. CAPEX and OPEX have also been reduced by dramatic reduction of the number of PBXes (Private Branch eXchanges).

Tohoku EPCO has a VSAT (Very Small Aperture Terminal) system and TV conference system, and these played a significant role in early recovery from the Great East Japan Earthquake. Based on this experience, to reinforce support for early recovery from disasters, these systems have been combined into a new system which can communicate with locations such as disaster-stricken areas and isolated offices.

KEYWORDS

Disaster Resilience /Early Restoration, Early Recovery, Disaster Recovery, IP Phone, PHS, Cost Reduction for Private Telephone Network, VSAT (Very Small Aperture Terminal) System, TV Conference System, Emergency Line

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1. Introduction

Prior to the Great East Japan Earthquake, EPCOs in Japan were consistently trying to enhance measures for early restoration of telecommunications systems. The Great East Japan Earthquake has prompted reevaluation of the importance of early restoration of telecommunications systems and has proven that such early restoration also plays a significant role in the early recovery of electric power systems. This experience will prove useful for smart grid deployment.

This paper introduces the construction of telecommunications systems that factor in early restoration and support for early disaster recovery.

2. Steps to realize Disaster Countermeasures

2.1 Disaster Countermeasures for Private Telephone Network (Shikoku EPCO)

2.1.1 Purpose of New System

Shikoku EPCO has constructed and operated a private telephone network which interconnects power stations and substations. Operation, restoration and maintenance information is exchanged using this private telephone network. However, Shikoku EPCO has replaced this network with a new system due to aging and discontinuation of maintenance for its components. In building the new system, Shikoku EPCO took into consideration the following points to cope with the risk of future disasters such as earthquakes in the Tonankai and Nankai areas (60% to 70% probability of a magnitude 8 to 9 earthquake within the next 30 years).

1) Disaster resilience (Reliability)
   - The system should incorporate wide-area backup capabilities to ensure uninterrupted telephone service in the event of a large-scale disaster.
   - Increased reliability of the existing IP network used by the new system.
2) Cost Reduction (Economy: CAPEX and OPEX reduction)
   - The existing IP network must be used effectively to reduce the number of telephone exchanges (aka PBXes).
3) Enhanced Convenience (Functionality)
   - Expansion of the area covered by PHSs (Personal Handy phone System: A low power wireless phone developed in Japan) which are used as extension telephones.

2.1.2 Overview of New System

The problems of the existing system were identified and the new system built based on the policies detailed above.

(1) Existing System

The features of the existing telephone system are as follows:

- PBXes are deployed in offices of over a certain size to consolidate line and trunk connections.
- The system comprises up to 60 PBXes.
- Employees use analog phones, multi-function telephones and PHS terminals.
- PHS relay antennas (aka CS: Cell Station) are also deployed at the same location as PBXes.

- Each employee has an individual PHS terminal, making communication among employees more effective and convenient. An employee visiting another office can use the same extension telephone.
- For the trunk line between PBXes, ISDN trunk and analog trunk lines are selectively used depending on the purpose.

(2) New System

The new system adopts IP-based PBXes to conform with the policies detailed earlier. The features of the new telephone system are as follows;

- Change in network design: Consolidation of PBXes for each area and deployment of backup PBXes in two different prefectures to achieve a wide-area backup system.
- Realization of an IP terminal and PHS terminal backup system using a hybrid configuration comprising the IP network and ISDN trunk lines.
- Realization of a disaster-resilient IP network by adopting a microwave radio network which has powerful disaster-resilient capabilities.

The architecture of the new system network is shown in Fig. 2.1-1.

The IP-based PBX can manage and control IP terminals, IP-CS (LAN-based CS), PSTN (Public Switched Telephone Network) gateways, IP-RU (IP Remote Unit: A gateway for analog phone and CS) and IP multi-function telephones in addition to existing PSTN, trunk lines and legacy telephone terminals.

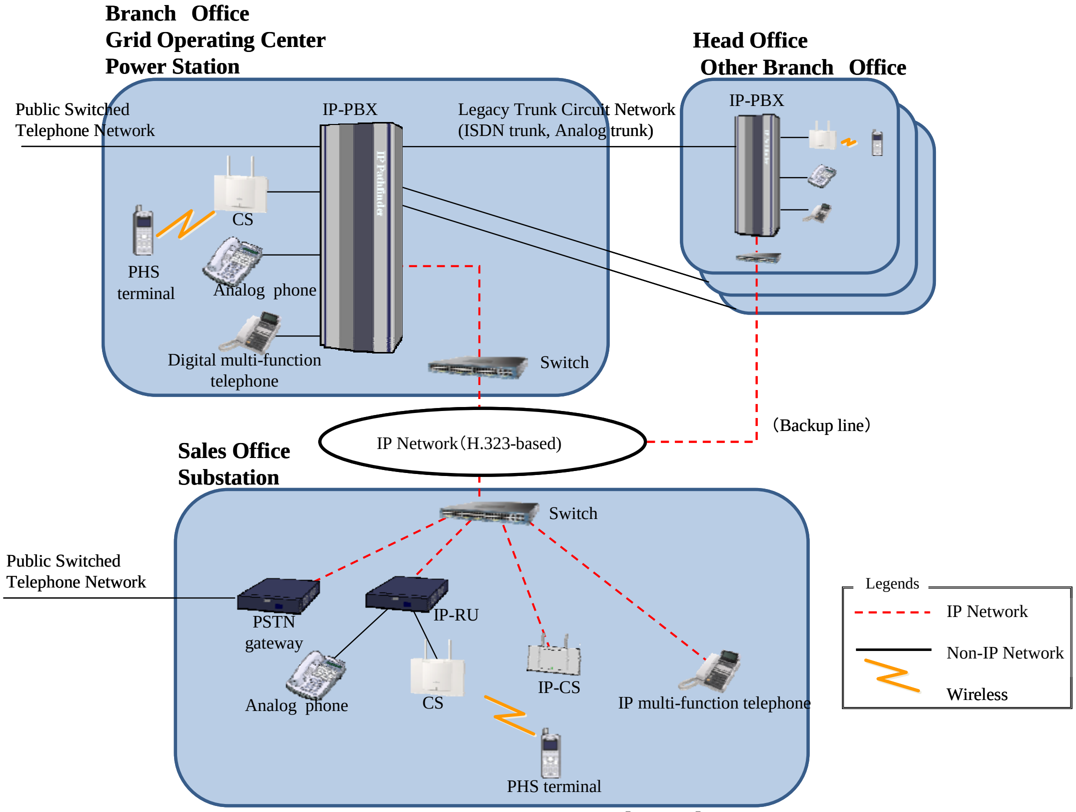
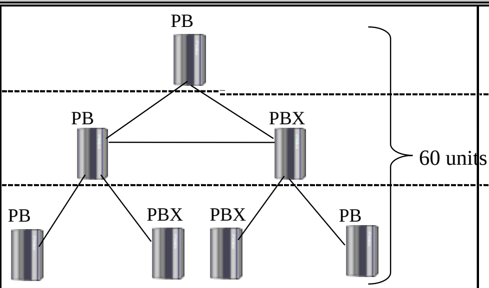
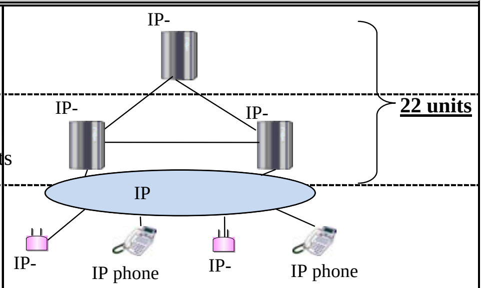


Fig. 2.1-1 New System Network Architecture

The new system has achieved remarkable improvements in reliability, economy and functionality compared with the existing system as shown Table 2.1-1.

Table 2.1-1 Expected Benefits of Deployment of New System

		Existing	New System (IP-based
Configuration (Logical Topology)	Head / Branch Grid Operating Power Station / Sales Office Substation	 - PBXes are deployed in offices and substations of over a certain size.	 - PBXes will be eliminated from sales offices and substations. - Lines will be extended from branch offices or grid operating centers by IP network.
Comparison	Disaster (Reliability	△ - Sales offices and substations only connect to one branch office or grid operating center (with no backup systems).	○ - Sales offices and substations can communicate with some branch offices using a wide-area backup system.
	Cost reduction (Economy	△ - Up to 60 PBX units are used.	○ - The number of PBXes will be reduced to 22 units, resulting in reduction in CAPEX and OPEX.
	Enhanced (Functionality	△ - The PHS coverage area is limited to offices which have PBXes and their surrounding areas.	○ - The PHS coverage area will be expanded dramatically.

2.1.3 Steps to achieve Disaster Resilience

The new system is provided with 2 important features aimed at achieving disaster resilience. The first is "a wide-area backup system" and second, "increased reliability of the existing IP network." These features will enable a communication system free of interruptions even in the event of a major earthquake or problems on the IP network.

(1) Wide-area Backup System

In the new system, terminal extension of telephone equipment in offices where existing exchanges have been abolished is provided through the IP network from the upper-level office. For this reason, a wide-area backup system is provided to ensure uninterrupted call functions even in the event of failure at the upper-level office. In the wide-area backup system, IP terminals (e.g. IP-CS) select other PBXes automatically to ensure continuity of call control (call connect/disconnect) in the event of failure of normal connections.

An overview of the wide-area backup system is set out below.

a) Deployment of Backup Stations

To cope with wide-area disasters such as major earthquakes, backup stations are located at sites distant from master stations.

In the case of Shikoku EPCO:

Master: Ehime prefecture, Kochi prefecture, Backup: Kagawa prefecture;

Master: Kagawa prefecture, Tokushima prefecture, Backup: Ehime prefecture

(See Fig. 2.1-2.)

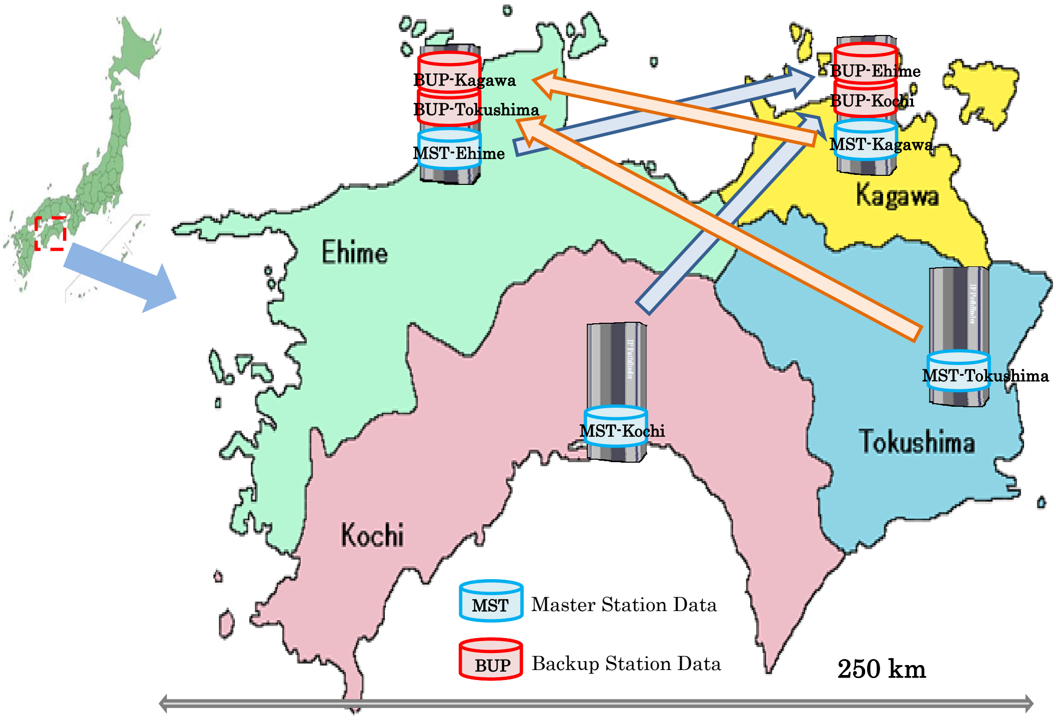


Fig. 2.1-2 Configuration of Backup System

b) Backup Target Terminals

- IP terminals: IP-CS, IP multi-function telephones, IP-RU, PSTN gateways
- Non-IP terminals: PHS terminals

c) Data Management for Backup Target Terminals

- Data from "target terminals for backup" are registered in the backup station.
- For IP terminals, the IP addresses of master/backup stations are registered in advance.

d) Overview of Operation

<Backup Operation>

- IP terminals are re-connected to the backup station automatically and retain call control when the master station is down or the IP network has failed.
- For PHS, the backup station takes over charge of call control when the master station is down. Other stations will detect stations that failed due to ISDN trunk line disconnection and automatically change call routes to the backup station.

<Post-recovery Operation>
- IP terminals connected to the backup station send reconnect messages to the master station periodically and automatically re-connect to the master station.

(2) Improved Reliability of the Existing IP Network

The following measures have been taken to improve the reliability of the existing IP network.

- Alternative routing using a microwave radio network

  The new system uses the IP network comprising optical fiber lines and this presents the risk of line severance in the event of a major earthquake. To overcome this problem, a microwave radio network that provides greater disaster resilience than optical fiber lines is employed as the alternative route. Because the bandwidth of this network is very small, QoS techniques have been applied to implement prioritized transmission of voice packets.

- Redundancy of IP network components and distributed accommodation of IP phone terminals

  By installing additional devices (layer 2 switches) at locations where IP network components were not provided with redundancy and implementing distributed accommodation of IP phone terminals, a configuration has been realized that would prevent total telephone blackout in the event of device failure.

2.2 Configuration of TV Conference System using Satellite Communication Links (Tohoku EPCO)

2.2.1 VSAT System (Very Small Aperture Terminal System)

(1) Overview of VSAT System

Tohoku EPCO has built telecommunications systems such as telephone and TV conference systems that employ a combination of carrier lines and private communication lines using microwave radio or optical fiber lines. In addition, the VSAT system has been adopted as an emergency line for locations that would be left with no means of communication in the event of disasters and that are not provided with backup lines.

The VSAT system is a bi-directional small wireless communication system that enables satellite communication between any two locations. The VSAT system at Tohoku EPCO comprises 2 types of VSAT stations: a transportable type and a fixed type installed at important offices that connects data transmitted by transportable VSAT stations to the internal communication network.

An outline of the configuration of the VSAT system is shown in Fig. 2.2-1.

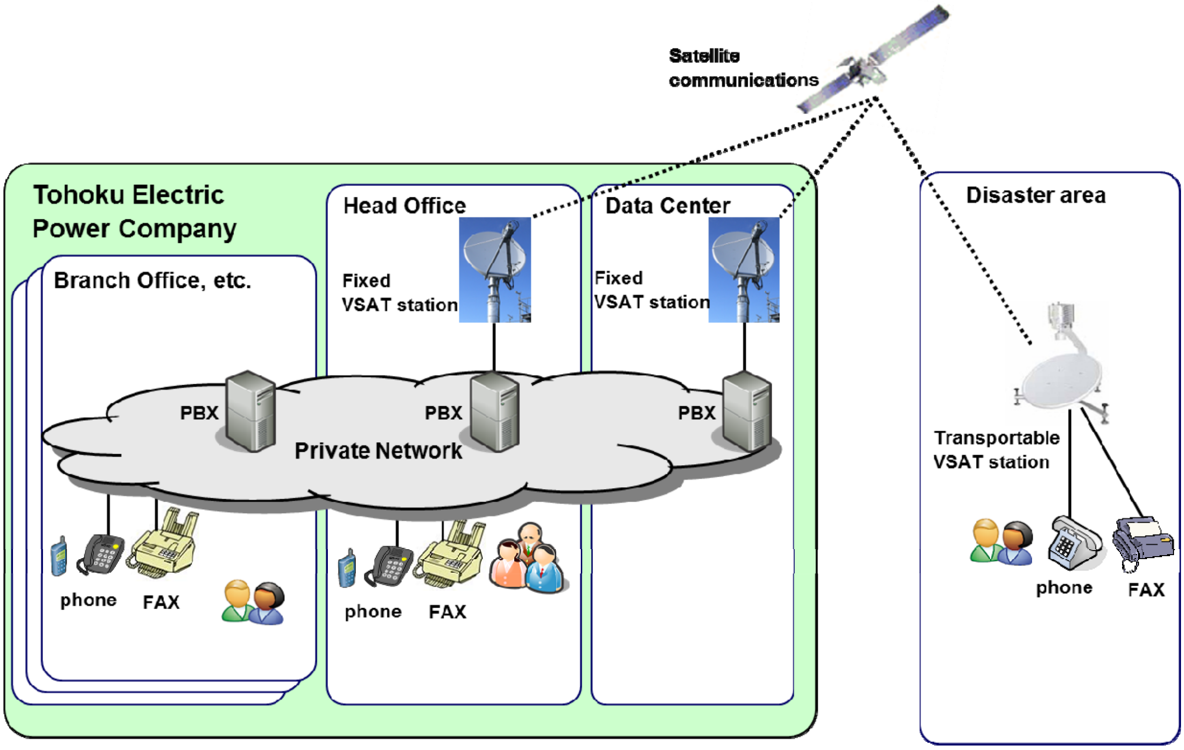


Fig. 2.2-1 Outline of VSAT System Configuration

(2) Use of the VSAT System during the Great East Japan Earthquake

The Great East Japan Earthquake that occurred on March 11, 2011 caused a wide-area blackout that brought thermal power plants and nuclear power plants to a halt and created huge tsunamis that toppled substations and transmission lines, resulting in destabilization of power systems.

Communication was lost in some offices and electricity plants and private communication lines were also damaged by the huge tsunamis. In order to restore communication lines, Tohoku EPCO used transportable VSAT stations for telecommunications and FAX systems. In addition, the VSAT system was also applied to remote monitoring and control lines for substations in need of manual operation.

Other power companies cooperated in the preparation of the necessary transportable VSAT stations.

As a result, telephone lines were restored within 3 days after the earthquake and remote monitoring and control line restoration was achieved in 2 weeks, realizing a contribution to early recovery from disaster.

2.2.2 TV Conference System

(1) Overview of the System

Tohoku EPCO has built a full HD TV conference system that uses the internal communication network to realize rapid information sharing and real-time decision-making. A total of 183 TV conference terminals have been deployed at 113 offices, comprising a stationary type to be used in manned offices and a portable type to be used outdoors in the event of a disaster. The use of multipoint control units (MCU) installed at important offices makes it possible to hold 1-on-1 TV conferences as well as simultaneous multi-point conferences.

(2) Use of the TV Conference System during the Great East Japan Earthquake

Because, with the exception of offices the communication lines of which had been destroyed by the tsunami, the TV conference system were available for use in offices, it was used to aid disaster recovery actions from the very day the Great East Japan Earthquake struck.

The TV conference system enabled not only high-definition TV transmission, but also sharing of images such as data summarizing the disaster situation and pictures of affected sites. Thus, the TV conference system was used for information sharing between emergency centers established in locations such as branch offices, the head office, technology centers and sales offices. The system was used 360 times for a total of 434 hours between March 11 and 31.

Furthermore, the system made it possible to share the sense of crisis and the reality at affected sites, creating a sense of unity that aided the disaster recovery process.

[Transportable VSAT Station deployed at Ootsuchi Substation]

[TV Conference held during the Great East Japan Earthquake (Emergency Anti-disaster Headquarters in the Head Office)]

(3) Linkage of the VSAT System and TV Conference System

The earthquake brought about renewed recognition of the worth and importance of the VSAT system and TV conference system in terms of their ability to facilitate early recovery and provide an understanding of the disaster situation.

Therefore, to make greater use of these systems, transportable VSAT stations and portable TV conference terminals have been combined to create a new system that enables TV conferencing with affected sites or branch offices where communication has been disrupted.

a) System Configuration

In order to connect the VSAT line to the TV conference system, a fixed VSAT station is connected to the TV conference system. The portable TV conference terminal is connected to the transportable VSAT station deployed at the site, enabling communication with the TV conference terminal at a desired location via the fixed VSAT station.

This configuration that only requires deployment of transportable VSAT stations provides teleconferencing capability quickly in emergencies and disasters.

The system configuration is shown in Fig. 2.2-2.

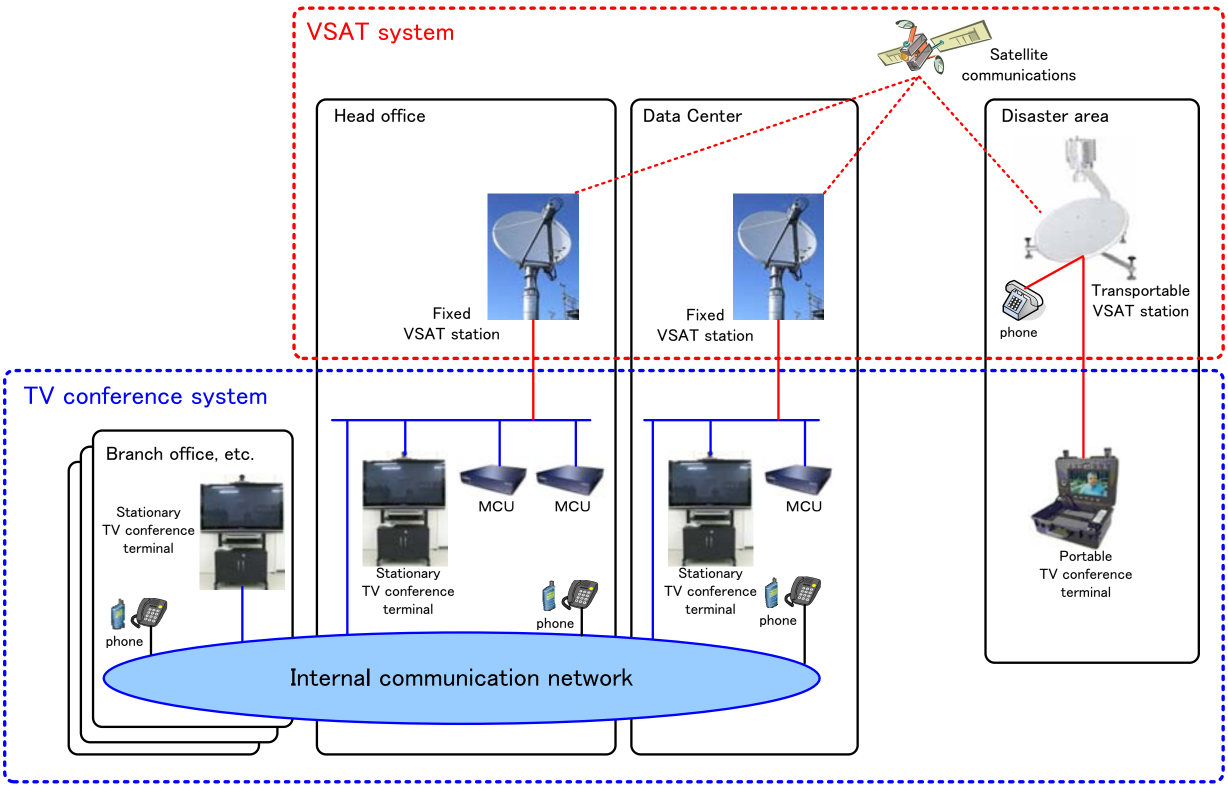


Fig. 2.2-2 System Configuration

b) Image Quality and Required Bandwidth

Since the bandwidth of the VSAT system is only 32 kbps which is suitable for FAX and telephone but not for TV conferencing, investigations have been conducted to identify the optimum line speed for connection of the TV conference system. The maximum transmission speed of the transportable VSAT station is 384 kbps and the bandwidth of the portable TV conference terminal is between 64 kbps and 2 Mbps.

As a result of connection testing in multiple patterns, the 192 kbps communication band has been adopted for portable TV conference terminals.
This is the minimum bandwidth required to produce clear images of drawings and other documents used during TV conferences.

c) Expected Benefits
The expected benefits of the combination of the TV conference and VSAT systems are as follows.

*The ability to view images directly from disaster sites at the emergency anti-disaster headquarters provides more accurate information.
*Setting up the system at disaster sites as an image monitoring unit cuts down on monitoring work.
*Images of disaster sites needed to report to locations outside the company and other entities can be rapidly acquired.
*Technical support can be provided for affected facilities and work instructions can be transmitted directly to disaster sites.
*Use of the system as a backup line for the stationary TV conference terminal improves the reliability of the TV conference system.

3. Conclusion

This paper introduced telecommunications systems used by EPCOs in Japan that are based on disaster resilience and support to achieve early recovery from disasters. The Great East Japan Earthquake underlined the importance of these systems and their applicability in coping with possible future disasters such as major earthquakes in the Tonankai and Nankai areas.
We believe that undertakings such as those outlined in this paper will be further reinforced by telecommunications systems in the future and will also be utilized in the future deployment of smart grid.