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Approach to Strengthening Power Company Networks in Japan

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Summary:

Power grid sites are spread throughout different regions hence the telecommunication network for grid operation has to be reliable at all times. They must remain unaffected by the change in environment due to natural disasters such as earthquake, rain, snow, lightening, etc. To provide stable and reliable power supply, the Japanese power companies have constructed their own private telecommunication network for operating between their power station and distribution facilities.
Microwave networks allow for faster recovery from effects of propagation of a natural disaster in comparison to wired telecommunication equipment. Preparing duplicate of the product which allows for swift switch and maximizes the effects of anti-earthquake measures to allow for high reliability and a disaster resistant network.
Since large capacity transmissions are possible through IP network, using LSP of the MPLS function; a network with swift switches and high reliability is possible.
In Tohoku EPCO, equipment that monitors communication network management system-has been strengthened and updated by adding data from earthquake by which the past is repeated and the Great East Japan Earthquake in 2011, information processing ability during breakdowns, human machine interface on the monitoring panel, business continuity plan (BCP), and functional training. Operations have been started since March, 2014.
To provide stable power even at times of natural disasters, power companies will construct a telecommunication network with disaster resistant facilities and high reliability.

Keywords:

[Business Continuity Plan]
[Resistant To Disaster]
[Telecommunications Network for Electric Power Systems]
[Communication Network Management System]
[Microwave Communication]
[Optical Communication]
[Multi-Protocol Label Switching]

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1. Introduction:

Telecommunications network for electric power systems must be stable at all times in various regions and at various times including disasters such as earthquakes, lightening, typhoon, rain, snow, etc.
Power companies in Japan requires a focus on anti-earthquake measures since it has regions with lots of earthquakes, but preventive measures are also necessary for lightening, flood disaster, and snow damage to keep the effects of disasters on operating systems to a minimum.
Historically, power companies in Japan were organized into 10 companies that generate, transmit and distribute power to their specified regions and 1 company that specializes in generation and transmission and many generators scattered around different regions in Japan. The 10 companies have since formed the Federation of Electric Power Companies in Japan (FEPC) to provide safe and stable electricity throughout the country.
The 10 power companies own the following telecommunications network for electric power systems (as shown in Figure 1) to keep the grid stabilized. The electric power network is divided into the generation and transmission network, transmission network and distribution network (from left to right). Of telecommunications network for electrical power system, core networks have high reliability and anti-disaster measures that are constructed of using microwave communication or Optical fiber composite overhead Ground Wire (OPGW). In recent years, IP networks are increasingly being used to reduce costs.

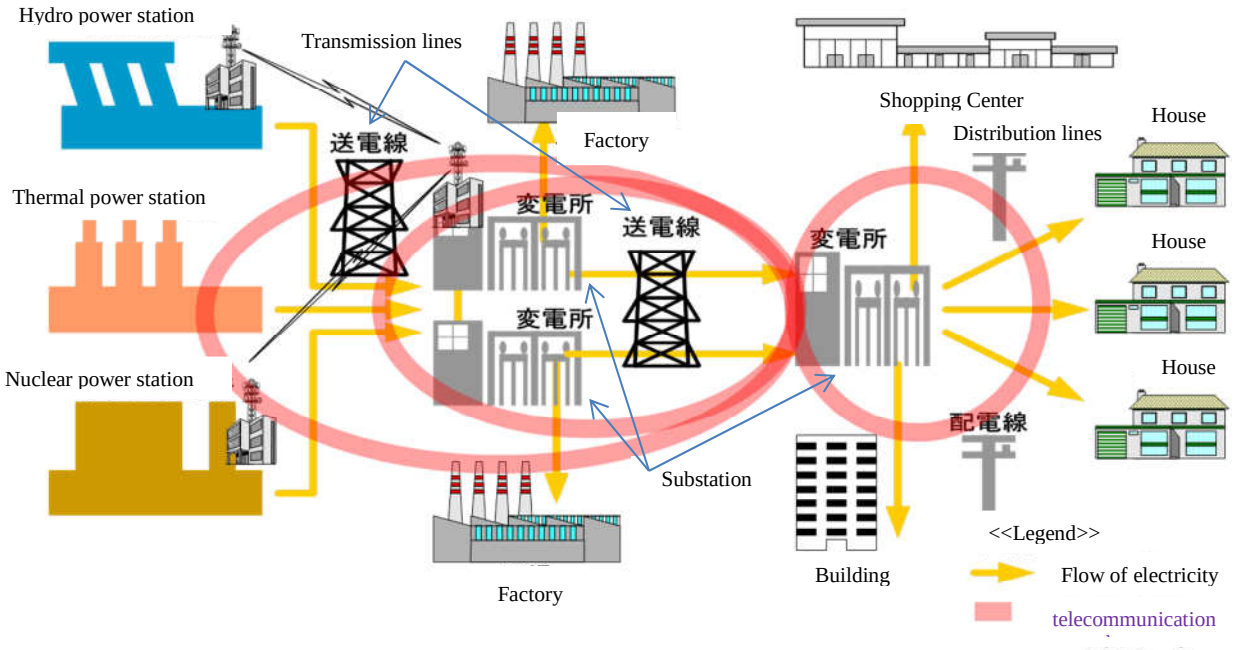

Figure 1 Overview of 10 Electric Power Company's Telecommunication Network

2. Overview of Approach to Anti-disaster Measures by Tohoku Electric Power Company (Tohoku EPCO):

Tohoku Electric Power Company is providing for the largest and geographically northern regions in Japan (Figure 2) and is number 5 in total amount of power generated in Japan.

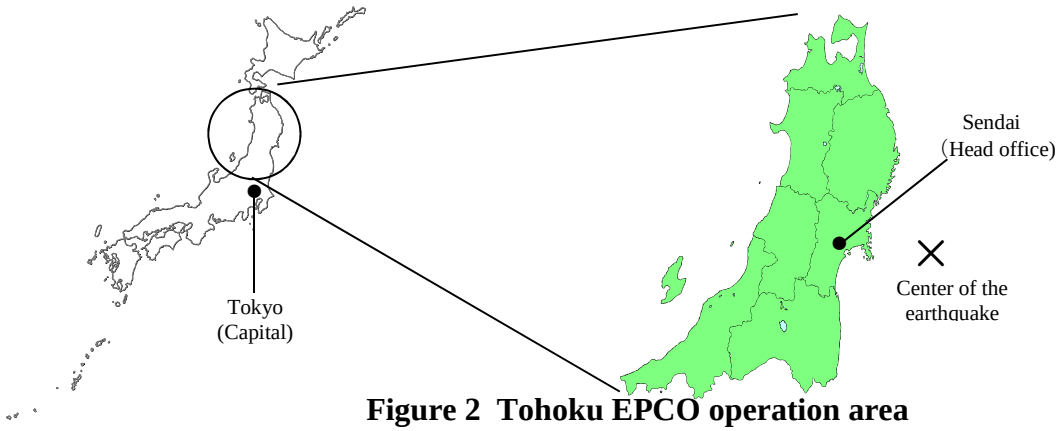

Figure 2 Tohoku EPCO operation area

The earthquake in 1978 offshore Miyagi Prefecture at magnitude 7.4 has been used as a base to strengthen the buildings, power equipment, communication equipment, etc. In March 11, 2011 at 2:46 PM (Japan time) offshore Miyagi Prefecture at 130 km, there was an earthquake of magnitude 9.0. During the Great East Japan Earthquake, due to the implementation of microwave communication and OPGW in the core network, the damage was minimized and the system was recovered within a short period of time.
The following is an explanation of the anti-disaster measures taken using microwave network, IP network and communication network management system-to control these networks.

2.1 Microwave Network:

Microwave networks, compared to wired communication networks, receive less effect from natural disasters and can recover at a faster rate at times of damage with strong anti-disaster measures, hence, they are used in the grid protective networks and for other important networks. It secures various routes and allows for redundancy of microwave communication equipment which brings a system with higher reliability. In Japan, both IP network and microwave network are used to transmit information so as to continuously check the networks for problems and to keep them in working order, in the case of an emergency. The following will introduce the structure of microwave communication equipment and the anti-earthquake measures taken.

2.1.1 Architecture of microwave communication

Microwave network has two parallel structures as shown below in Figure 3, as a way to transmit important information. Hence maintenance is simple and if there is damage in the grid when operating, it is designed to swiftly switch to the standby system and keep the effects of damage during operation to a minimum.

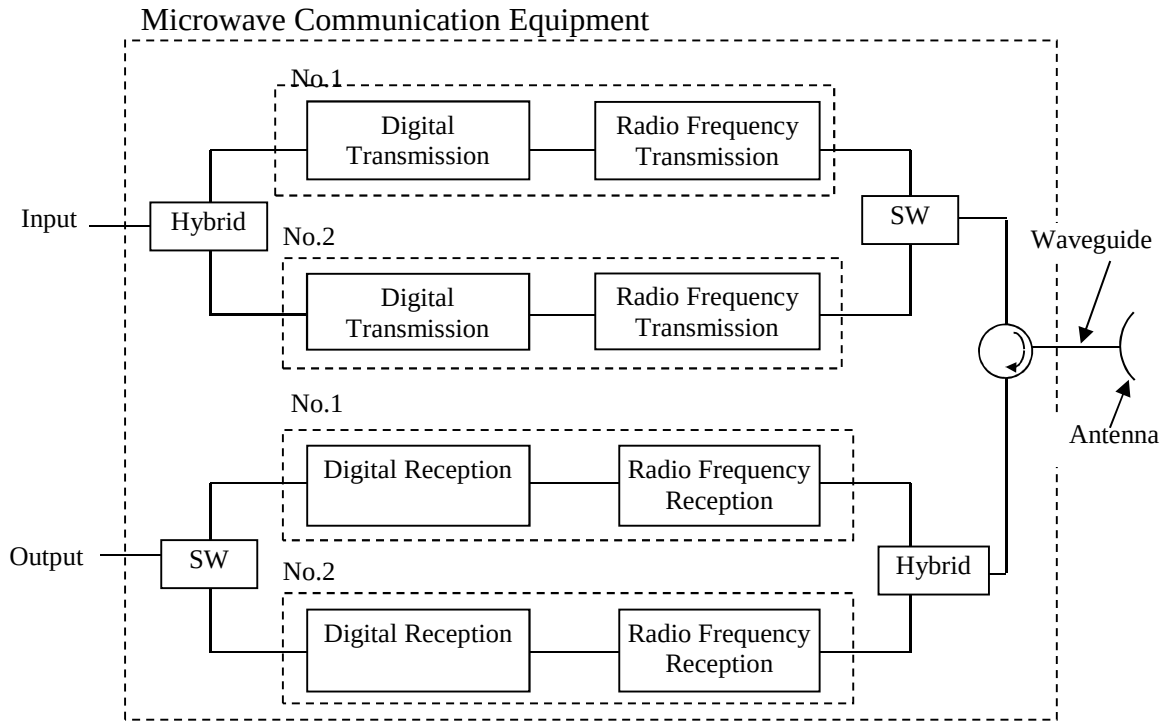

Figure 3 Example of microwave communication equipment structure

2.1.2 Anti-earthquake Measures

The earthquake in 1978 offshore Miyagi Prefecture (magnitude 7.4) caused racks to bend and packages to fall, affecting operations. Power companies analysed the effects of the Miyagi earthquake and put in new anti-earthquake measures the next year (1979) through the FEPC (Federation of Electric Power Companies in Japan).
Each power company will structure its anti-earthquake measures based on this base conditions which are; 1. Horizontal input acceleration 0.5 m/s^2, 2. Horizontal sine wave: 30^{th}.
It has been proven that these base conditions were effective during the Southern Hyogo earthquake in 1995 and the Great East Japan Earthquake in 2011.
During an earthquake a steel tower and base station building-will move differently due to the difference in structure, weight, etc. leading to damage to the waveguide and a flexible waveguide would make sure the damage is kept at a minimum. An example of measures taken would be changing the waveguide to a more flexible one. Another example is the packages used in microwave communication equipment and other transmission equipment that have fallen during earthquakes and hence to prevent it, have been locked to the racks for increased protection.
Other anti-earthquake measures have been put into effect, as given in Table 1. As a result, the effect on a power company's telecommunications network for electric power systems, including microwave network, has been minimized and in the case of microwave communication, there has been no damage despite damages to the network. Tohoku EPCO has also supported people (and government) in disaster struck regions where the public telecommunication lines have been disconnected by providing ways to communicate to their families.

Table 1 Extent of Damage and Anti-Measures taken for the Microwave Network after the earthquake offshore Miyagi Prefecture (1978)

Equipment	Extent of Damage	Anti-Earthquake Measures
Microwave communication equipment	Packages fall Racks get bent	Lock all packages to rack Strengthening the junction points of racks
Antenna	Damage to waveguide	Application of flexible waveguides
Telecommunication equipment room	Damage to waveguide Damage to cables when moving the racks	Reinforcement of building penetration, usage of cushioning Reinforcement of the installation method Rigid structure that does not resonant during earthquakes

2.2 IP Network

The Tohoku EPCO IP network consists of optical fiber and microwave communication together with MPLS (Multi-Protocol Label Switching) to provide high reliability.
Generally, IP networks take some time on changing routes during natural disasters and the exchange route cannot be specified, however, these problems can be solved using the MPLS function.
This thesis will introduce a highly reliable network construction using MPLS technology.

2.2.1 Specifying a route using LSP of MPLS

Optical fiber can send a large amount of data very quickly, however this means that it is a fixed network and the possibility of disconnection or damage due to a disaster is high. In the case of damage, usage of routing protocol like OSPF could lead to a data congestion in the microwave network. Meanwhile, the MPLS router allows for configuring LSP with service (data), hence it is possible to differentiate data; only data required for the power grid and disaster recovery are sent to the LSP that is through the microwave network. As a result, it is possible to prevent congestion in the microwave network.
MPLS uses LSP as a path for sending packets. Generally, routes within the IP network are decided by hop-by-hop router. However, LSP specifies route using the Ingress Router that is at its entrance and as shown in Figure 4, it uses not just the usual primary LSP but also secondary LSP (for when there is damage to the primary LSP) to specify routes. In this network, optical fiber is the primary LSP and microwave network is secondary LSP, hence when there is damage to the primary LSP then the system automatically switches to the Secondary LSP.

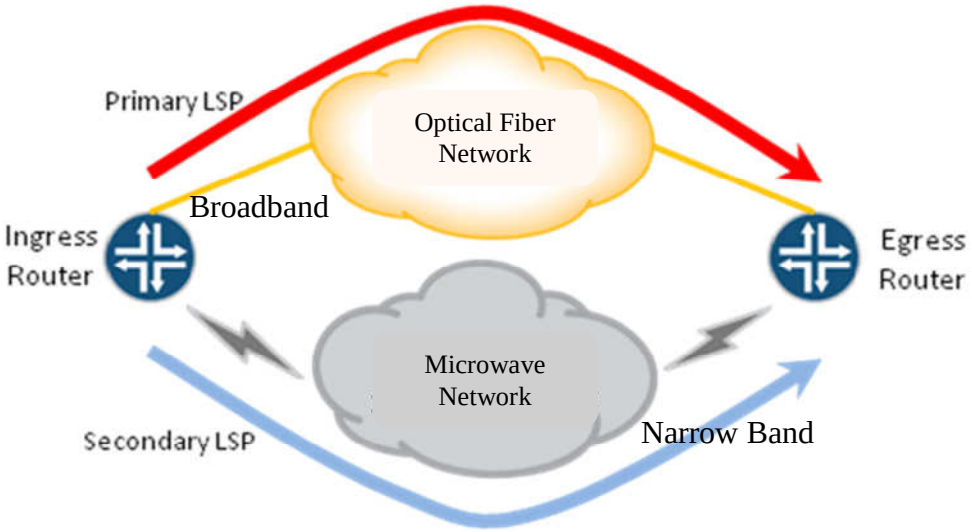

Figure 4 IP Network Structure

2.2.2 Swift switch during system failure

MPLS LSP not only allows for the route to be specified for each service but it can also switch from primary to secondary LSP within a few hundred milliseconds (which is fast in comparison to normal IP networks). It is designed to keep the effects of a natural disaster on operations to a minimum.

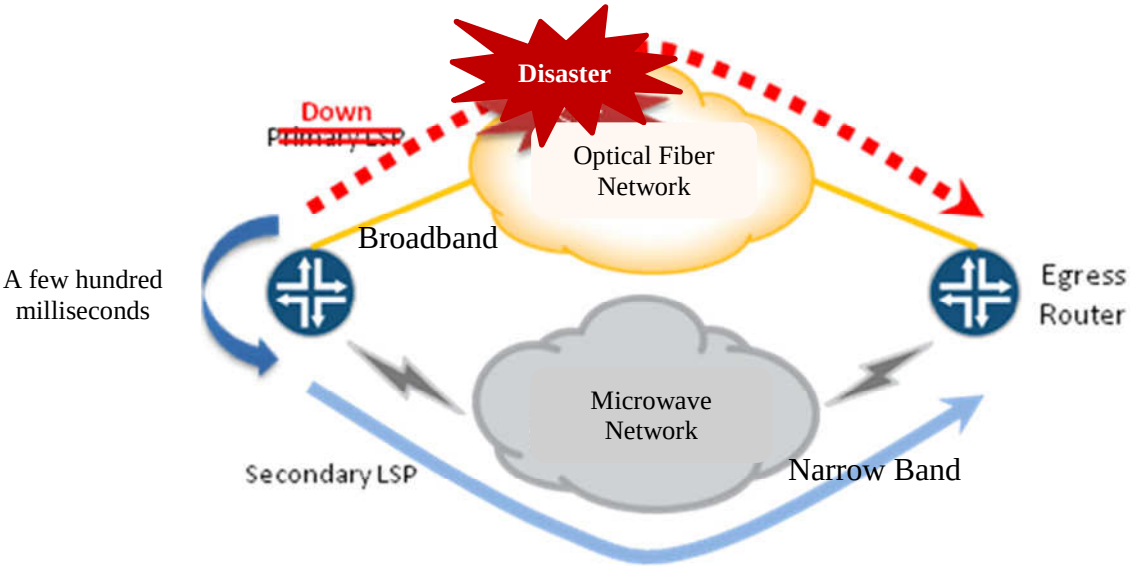

Figure 5 Route Switching at times of Emergency

2.3 Communication network management system

The communication network management system running at the time of the Great East Japan Earthquake was constructed of client servers installed at head office (in Sendai, Miyagi Prefecture) and a backup operation center (earthquake absorbing structure building about 10 km away) for redundancy. Although the center of the earthquake was close to where the system was, there were no damages and the system continued operating its telecommunication lines.

All the regions where Tohoku EPCO is providing power has been monitored by the communication network management system through installed telecommunication equipment and the damages were minor where most regions were able to continuously use their communication lines. However, there were cases of the equipment being taken away by the tsunami or equipment being flooded. Due to the earthquake the surrounding areas of Tohoku (65.5% of Tohoku EPCO area) had blackouts, and power equipment that were providing electricity to communication equipment had activated an alarm. The management system having received the signals then was left to process the large amount of data that was calculated to reach over 200 status changes / second. The data received during the earthquake was 158 status changes/ second so the equipment was able to completely process the information.

However, the information that was shown was 100 screens / minute (around 10 processing results / screen) so it was difficult for the operators to keep track of the damage received.

At Tohoku EPCO, in consideration of the expansion of IP network operation, reprisal and updating of the system is being done from 2008. The updating of communication network management system was also being considered until 2011. After the Great East Japan Earthquake, the updated contents are being rechecked and the following points and conditions have been added as of March 2014 as part of the anti-disaster measures.

(1) Reinforcement of-management system

Communication network management system-must have the processing capability to gather all of the data concerning errors that will be sent after a large disaster so that they can continue monitoring operations.

This includes the possible expansion of communication network management system due to increased usage of IP networks and alarm data from the Great East Japan earthquake. Hence, the requirement of processing capacity has been improved from 200 status changes / second to 500 status changes / second.

(2) Reinforcement of human machine interface for the monitoring panel

During the Great East Japan Earthquake a large amount of damage data results were displayed within a short period of time. Telecommunication network operators needed to do a detailed search function and data output function of electronic data and reports. As a result, operators can swiftly track the situation, analyse the damage and consider options for restoration. It also allows for reporting through forms which helps to speed up the process.

(3) Reinforcement of BCP (Business Continuity Plan)

During the Great East Japan Earthquake the communication network management system was proven to be a support for monitoring the damage to telecommunication equipment, form a proposal for restoration, etc. Hence, even in the case of another disaster the network management system must be recovered as fast as possible.

Tohoku EPCO has installed similar functioning servers in their head office as well as at a second place to keep redundancy. On the possibility that both places could be affected by a strong local earthquake in which case both operating HDD (Hard disk drive) will be damaged, Tohoku EPCO has also installed a NAS (Network attached storage) for data backup at 50 km away from the head office. Hence, even in the case of a local epicentral earthquake, it is possible to change the HDD to a cold standby server then download backup data from the NAS.

As a result, even if both system servers kept near the head office is damaged, it is possible to recover operations swiftly.

(4) Deployment training functions

With education and succession of technology, and reinforcement of correspondence to anti-disaster as an objective, telecommunication network operators are sending actual data of operated equipment data and examples or simulations of possible damages to the system for training purposes. Not all power companies in Japan have such training facilities that allow for employees to practice in the case of an emergency. Training is been conducted using past system error examples and simulations in such a way that it does not affect day to day operations. There is also training for equipment or pass database input, stimulation process registration for effect of a breakdown or breakdown procedures, and other system operation training that would be necessary in day to day operations.

3. Conclusion

This paper is an introduction to the reinforcements that Tohoku EPCO has added to the communication network management system-using microwave communication and IP network. The system has been consistently improved with each disaster that has hit Japan and having understood the importance of providing stable electricity, Tohoku EPCO will continue in its operations to reinforce communication equipment against disasters.

To flexible consideration that develops and maintains communication network management system, Tohoku EPCO, NEC and Juniper Networks will continue to improve conditions

through constant developments to communication technology, including reinforcements necessary for anti-disaster measures and swift restoration procedures.