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USE OF ELECTRIC POWER SUPPLY FOR DEVELOPMENT OF DISASTER MONITORING SYSTEM

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SUMMARY

This paper discusses the use of electric power supply data for disaster monitoring system. First, the method that the power demand in normal times can be classified into four typical patterns is explained. Second, as an example of the effectiveness of using the electric power supply, we show the relationship between power supply characteristics and the extent of damages at the case of the 1995 Kobe Earthquake and the 2000 Tokai Heavy Rain Fall. It results that the change of power supply before and after the disaster are correlated to the extent of the damages so that it can identify the location of the damaged area and evaluate how the area is affected quantitatively. The proposed methods have high potential to develop a seamless disaster monitoring system to evaluate regional characterizations in both disaster and non-disaster times.

INTRODUCTION

The purpose of this study is to propose a methodology to evaluate regional characterization at the time of usual and damages due to disasters in real-time using power supply. Since electric power is difficult to store, it has the feature of "Simultaneity of supply and consumption (demand)", therefore power demand reflects various activities of people in real-time. Moreover, since people's activity depends on the situation of the area during a disaster, the power supply during a disaster will indicate the disaster situation of the area that can be supplied electric power. Thus pinpointing of a stricken area and the evaluation of damage level during a disaster are possible.

This paper consists of the following two studies. First, the method that the power demand at the time of usual can be classified into four typical patterns is explained. The power demand curve of the power distribution can be expressed as the combination of four typical patterns (a residential type, an office type, an industrial (factory) type, and entertainment (pubs and restaurant, etc.)). Second, as an example of the effectiveness of using the electric power supply, we show the relationship between power supply characteristics and the extent of damages at the case of the 1995 Kobe Earthquake and the 2000 Tokai

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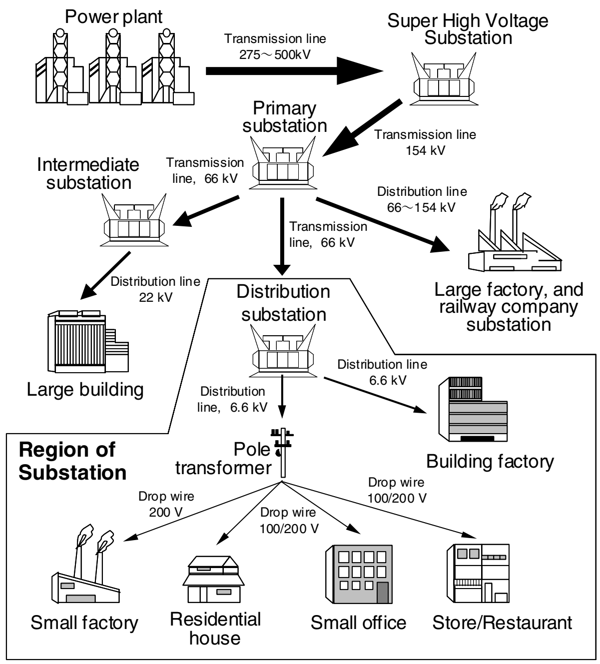


Figure 1 Electric power supply system

Heavy Rain Fall. According to the studies, we discuss the effectiveness and possibility as the disaster monitoring system for disaster related organizations such as the administration.

ADVANTAGES OF ELECTRIC POWER USE

Electric power supply (demand) is possible to monitor in real-time. The result using power supply is easy to provide feedback to the evaluation continuously. In this point, it is great different from real-time earthquake disaster reduction systems in operation at the present. The operation time phase of the current system is immediately after the event, and its operational opportunity is just a time after the event.

The proposed methodology has several strong points. First, there is no need to develop new facilities to implement a power demand monitoring system. All the facilities are already available and provided by the power supply company. Second, a real time monitoring is possible. Third, there is no need to collect a database of the structure strength characteristics or to develop fragility curves before the event. Finally, the observation is not affected by weather conditions or time.

POWER DEMAND CHACTERISTIC ANALYSYS METHOD IN NORMAL TIMES

Evaluation area

The power demand is monitored at a spatial unit denominated substation supply area. This unit consists of one substation for the transformation of the power for ordinary consumers (Figure 1). In this study substation supply area is discussed as analytical and evaluation area.

Calculation of the typical demand curves

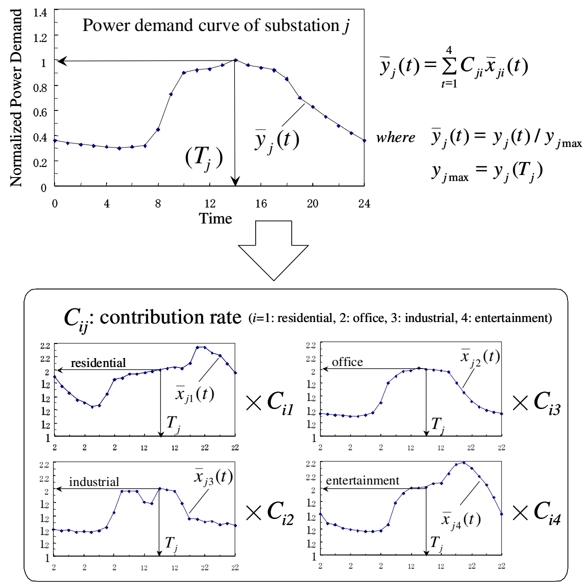


Figure 2 Calculation of the typical demand curves

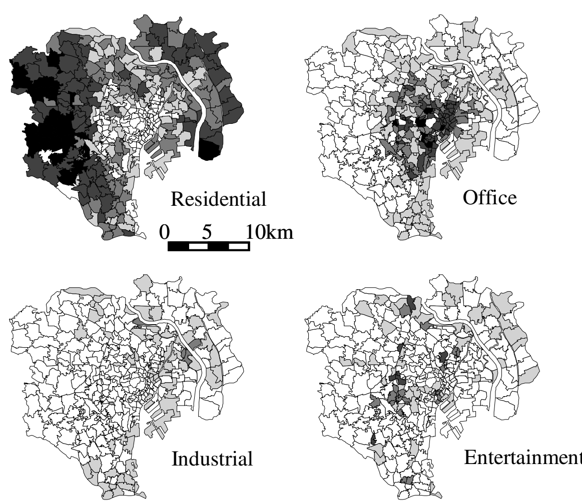


Figure 3 Distribution of power demand characteristic patterns in Tokyo 23 wards

The power demand and the substation supply area characteristics are strongly related. Meguro et al [1] proposed a classification of a region according to its power demand. Four categories were defined: 1) residential type, 2) office type, 3) industrial (factory) type, and 4) entertainment (pubs and restaurant, etc.) type. By using a stochastic analysis, typical demand curves for each type according to the season were developed for Tokyo 23 wards.

The substation power supply area is composed of not only one of the categories defined in four categories. It is rather a combination of them. Thus, the power demand at each area can be evaluated as the summation of the contribution of each category. In order to calculate the typical demand curves, the used spatial unit was the substation area.

Assuming that the typical demand curves of a distribution area *j* are expressed as the combination of four elemental demand curves $x_i(t)$, the demand $y_j(t)$ at time *t* is expressed as:

$$y_i(t) = \sum_{t}^{4} \alpha_{ji} x_i(t) \tag{1}$$

where *i* corresponds to the four typical areas (*i*=1: residential, 2: office, 3: industrial, 4: entertainment) and α_{ji} is the contribution of component *i* to distribution area *j*. The parameter α_{ji} is obtained from the spatial unit regional characteristics and the optimum $x_i(t)$ were calculated by multiple regression analysis. A normalized demand $\bar{y}_j(t)$ of a distribution area *j* at time *t* is expressed as:

$$\bar{y}_j(t) = \sum_{i=1}^{4} C_{ji} \bar{x}_{ji}(t) \tag{2}$$

where C_{ji} is the contribution rate (composition rate) and is normalized elemental demand curves $\bar{x}_{ji}(t)$. The contribution rate is the percentage of the power used in an area at peak-load time due to the residence, offices, factories or restaurant consumption (Figure 2).

Regional characterization using power demand

Figure 3 shows contribution rate (composition rate) of in each substation in Tokyo 23 wards on 1997. From this figure we can see the following, “residential type is mainly distributed in the suburbs”, “office type is mainly distributed around the imperial palace in central Tokyo”, “industrial type is distributed in coastal area and along the Arakawa river”, “entertainment type is distributed at shopping quarters, such as Ueno, Shinjuku and Shibuya, and along the railroad line”. These are well in agreement with an actual situation.

POWER CHARACTERISTICS BEFORE AND AFTER THE 1995 KOBE EARTHQUAKE

Change of power supply before and after the quake

We selected 69 substation areas in the affected region which were managed by Kobe branch office of the Kansai electric power company. Figure 4 shows the power demand variation on the day of the event, one and two weeks after and one month after for the 69 substations considered in the study. Figure 4(b) shows a white line surrounding the area where the seismic intensity was JMA7. The correlation between the power demand drop and the seismic intensity is very high.

Damage evaluation using electric power supply

Figure 5 shows that a model of power supply data at substation before and after a disaster and the concept of damage evaluation methodology. *a* which is the amount of decrease of power supply in the late night after the event, is equal to the power demand which would be consumed originally unless consumers are damaged to the extent of those who can not consume. Therefore we define that *a*/*b* is equal to building damage ratio. Figure 6 shows that the comparison between the damage ratio (collapsed or burned buildings) and the evaluated damage ratio calculated using the above mentioned method. If it waits till a predawn time zone, it is found that the whole picture of damage can be grasped in about one or a half day after the earthquake. In addition, about supply interruption area, since an electric power company can monitor per power distribution line, it can be said that it is removing the area concerned and presumption of the building damage ratio is attained.

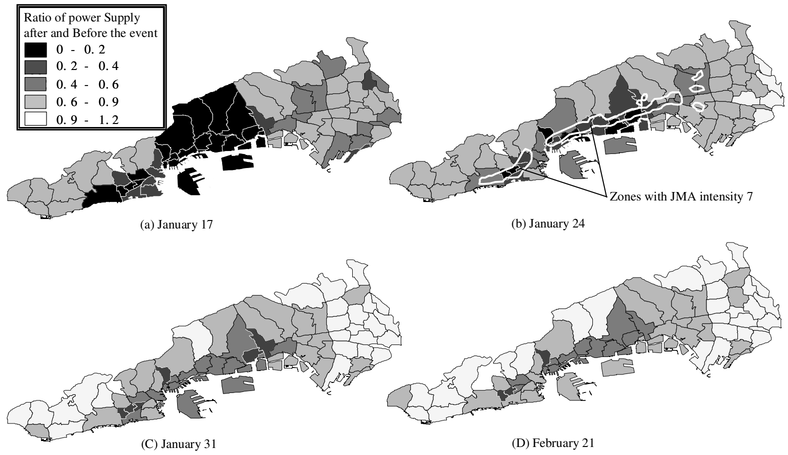


Figure 4　Distribution of power supply ratio in the affected areas (on the day, one- and two-week, and one-month later the earthquake)

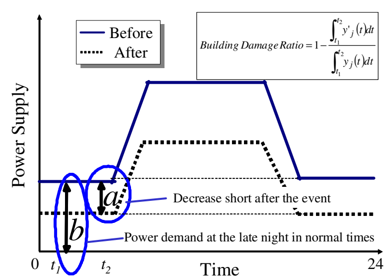


Figure 5　Calculation of building damage ratio

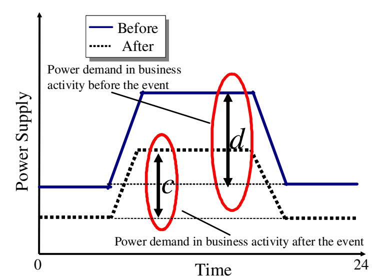
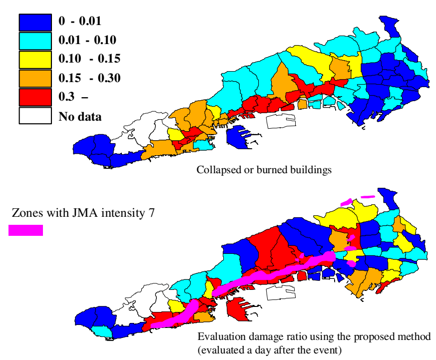
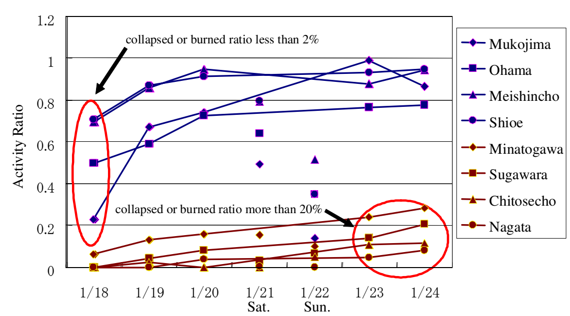


Figure 7　Calculation of activity ratio





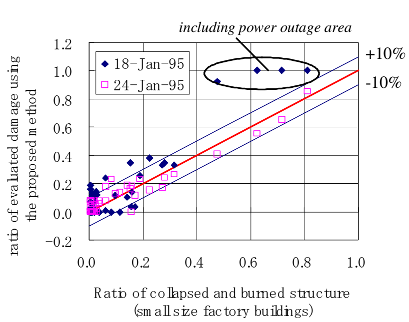


Figure 6　Relation between actual and evaluated damage

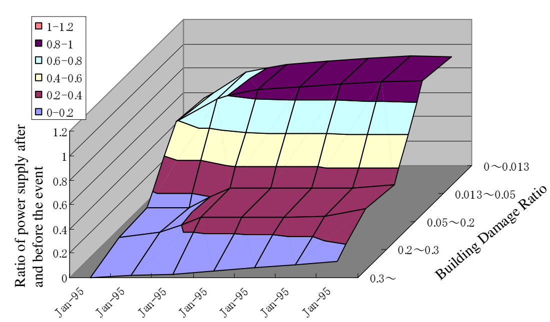


Figure 8　Change of activity ratio after the event

If it assumes that *d* which deducted the electricity demand of a predawn stable part in normal times from the amount of electricity demand of the stable part in the daytime in normal times is the amount of electric power used only for operating activities in Figure 7, the ratio of the amount of the daytime power supply before and after an earthquake, it can be defined as c/d = "operating rate". Figure 8 shows the transition of the operating rate in substations where demand composition rate of the business type is more than 50%. In the slight damaged area, although the level of operating activities is quite low on the next day, it has recovered in several days. On the other hand, even if supply interruption is restored in the area where the damage is serious, the operating rate is still low. Moreover, we see from this that the feature of transition of the operating rate changes a lot bordering around 5 % of ratio of collapsed and burned structure.

POWER CHARACTERISTICS BEFORE AND AFTER THE 2000 TOKAI HEAVY RAIN FALL

Introduction

Flood watching is done based on the record of hydrograph in general, and it is quite difficult to grasp the inundation damages in urban area on real-time and in detail. In recent years, lots of flood damage evaluation using remote sensing has been done [2]. Although this method is suitable for grasping the large flood damages, there are many problems for grasping urban flood disaster on real-time due to observation frequency, the influence of the weather condition and resolution under the present conditions. In this study, we attempted to accomplish the damage evaluation using electric power supply records and its possibility for usage is discussed.

Study area

One of the severest damage areas due to 2000 Tokai heavy rain fall is the Shin River basin, where a levee breach occurred, and this location is chosen as the study area in this research. Figure 9 shows the study area composed of 2 cities and 7 towns (Kita-ward and Nishi-ward in Nagoya city, Nishibiwajima town, Shinkawa town, Kiyosu town, Haruhi town, Nishiharu town, Shikatsu town, Toyoyama town and Kasugai city). This area has 9 substations as shown in Figure 10, which includes 3 inundated substations. We calculate the damage to the area using the data obtained from these substations.

Step of the study

The evaluation of inundation areas is done by the following steps. First, obtain the database and transform it for analysis on GIS. Second, smooth the elevation data above Mean Sea Level (MSL) and forecast electric power demand in time history in each substation. After these, the relationship between the change

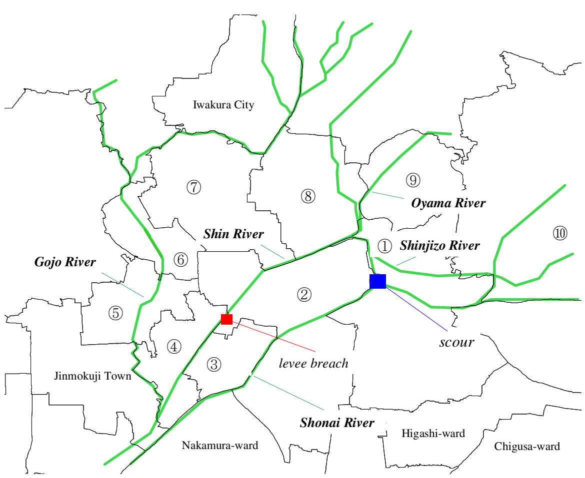


Figure 9 Study area

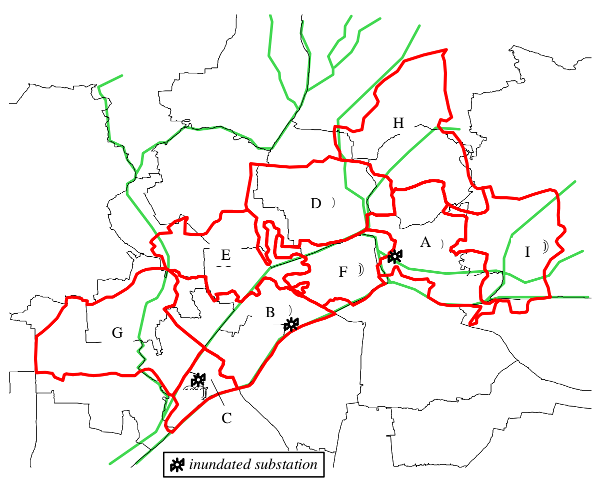


Figure 10 Substation area in study area

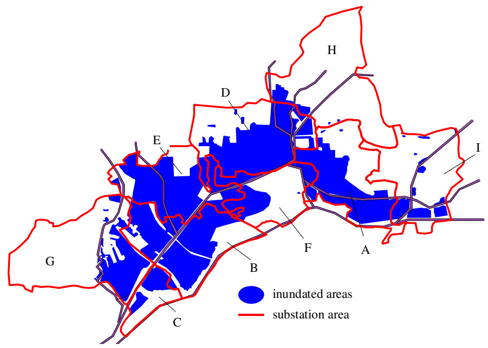


Figure 11 Inundation area and substation areas

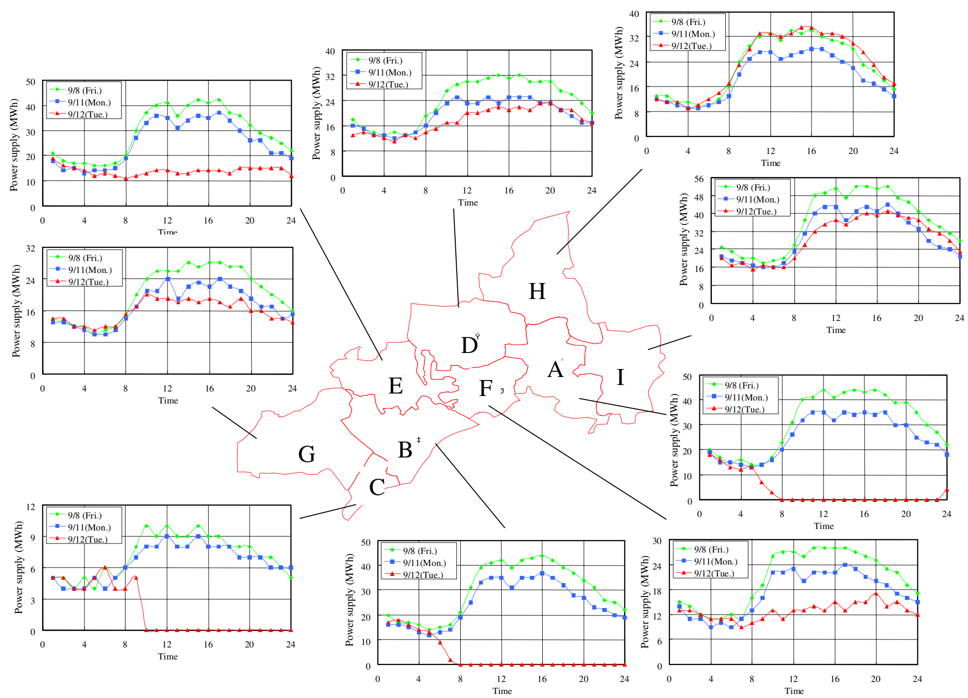


Figure 12 Power supply before and after the event (8th (Fri.), 11th (Mon.) and 12th (Tue.) of Sept. 2000)

of electric power supply and inundation area is discussed.

Data

The required data are, a) substation area, b) electric power supply records, c) 50m grid elevation data above MSL, and d) inundation area map due to the 2000 Tokai Heavy Rainfall disaster. Figure 11 shows both substation and obtained inundation areas. It can be seen from the figure, that the inundation areas are located not only in the left bank of the Shin River where the levee breach broke out but also in the Shin River basin.

Change of Power Supply

Figure 12 shows time change of the power supply of each substation in the study area September 8(Fri.), 11(Mon.) and 12(Tue.) 2000. It is understanding that the power supply records on the 11th and 12th are small compared with those 8th in almost all substations. In addition, it can be clearly seen that the power supply of substation A, B and C were reached to 0 in the morning. Actually those substation facilities were inundated and those functions were lost due to inundation. On observing the figure clearly, we can also see the areas where the demand was decreased largely compared with in usual i.e. areas E and F. These areas are indicated to be damaged and inactive due to inundation.

Evaluating Inundation Area using Electric Power Supply

Procedure to calculate inundation areas: Find out the minimum power supply ratio (PSR) from midnight to noon of 12th Sept. and then calculate the percentage of inundation area. Percentage of inundation area is IA (=[1-PSR] *100). After calculating the percentage, choose the number of lower elevation grids, whose total area is equal to IA percent of the whole substation area.

The above procedure for obtaining the inundation areas cannot be used for the areas A, B and C because the substations became dysfunctional. However it cannot be said how large area is inundated using PSR in such cases, it means that the inundation level is above the elevation at least, where substation is located. Therefore all areas below the area which each inundated substation is located are chosen as the inundated and the others are judged as the impossible to evaluate.

Figure 13 shows the comparison between the actual inundated data and evaluated data, which are obtained according to the proposed procedure. In this figure, white portion with light black lines indicates real inundated area, black areas indicate evaluated inundated areas based on PSR values, light shaded area indicates evaluated inundated areas below the substation elevation (at least whose substations are inundated) and dark black shaded areas indicate the areas above the substation elevation. It turns out that

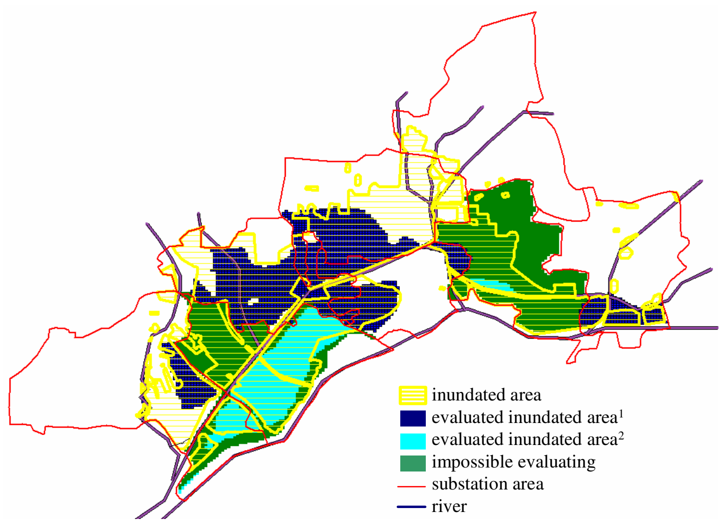


Figure 13 Actual and evaluated inundation area

Tables 1 Comparison between the evaluated inundation area and inundation area above floor level

Ratio of inundation above floor level	Inundation and non-inundation area evaluated using power supply		
	inundation	Non-inundation	Impossible to evaluate
20% -	26 (84%)	4 (13%)	1 (3%)
5% - 20%	10 (83%)	2 (17%)	0 (0%)
0% - 5%	14 (50%)	13 (46%)	1 (4%)
0%	11 (11%)	90 (87%)	2 (2%)

the inundation area evaluated from change of the power supply is well in agreement with an actual inundation area. Table 1 compares the inundation area evaluated using the change of power supply and the ratio of inundation above floor level which totaled per an administrative and/or a school district. The number in table 1 are the number of an administrative and/or a school district contained in the damage classification evaluated using the change of power supply. The area where inundation above floor level damage is more serious has brought a result evaluated as inundation area. Moreover, 87% of the area where the ratio of inundation above the floor level was 0% is evaluated as non-inundation area. Therefore the result of inundation evaluation using power supply shows its effectiveness for grasping inundation area during a flood disaster.

CONCLUSION

In this study, we reported the use of electric power supply data for disaster monitoring system for the use by disaster related organizations, from administrative organizations down. Though the idea is quite simple methodology to evaluate damages using the change of electric power supply, through the study at the case of the 1995 Kobe Earthquake and the 2000 Tokai Heavy Rain Fall, we can show that "the change of power supply before and after the disaster are correlated to the extent of the damages", "it can identify the location of the damaged area and evaluate how the area is affected" and "regional social activity can be discussed quantitatively". Moreover, the feature of the method that the others don't have is able to be clarified that even if the damage is slight, the method can pinpoint the area where a recovery has not been made. As mentioned above, the proposed methods have high potential to develop a seamless disaster monitoring system to evaluate regional characterizations in both disaster and non-disaster times.

Power outage information which Tokyo electric company manages has started to be provided to DIS (Disaster Information System) of the Cabinet office in every 15 minutes since November 6, 2003. An opportunity to apply power supply data in real-time for disaster reduction has been spleading. If monitoring the power demand in real-time at the smaller spatial unit such as distribution line in the future, the effectiveness of the method is getting larger. In the future we're going to utilize information other than electric power supply, such as earthquake motion information, and do advance examinations so that it is able to use under the situation that many power outage areas have occurred immediately after an earthquake.

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