The observation of neutral current of 500 kV power line and the application to the monitoring of the underground electrical conductivity

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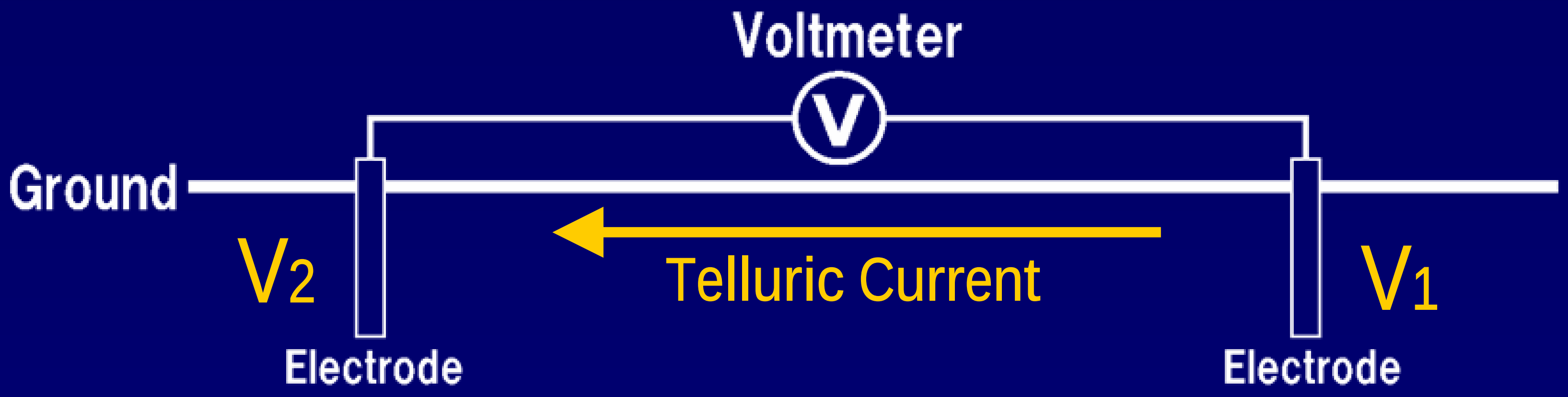
Telluric current measurement

Conventional telluric current measurement



- We use two electrodes and voltmeter.
- The potential difference is measured.

We measure the telluric currents by using already existing electric power line system.

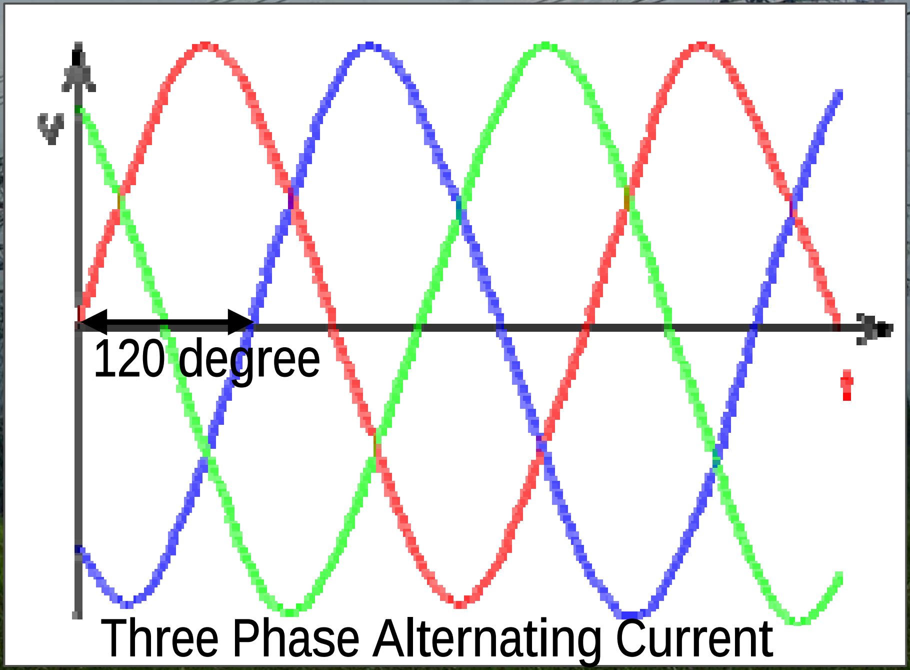
Super High Voltage Electric Substation

1

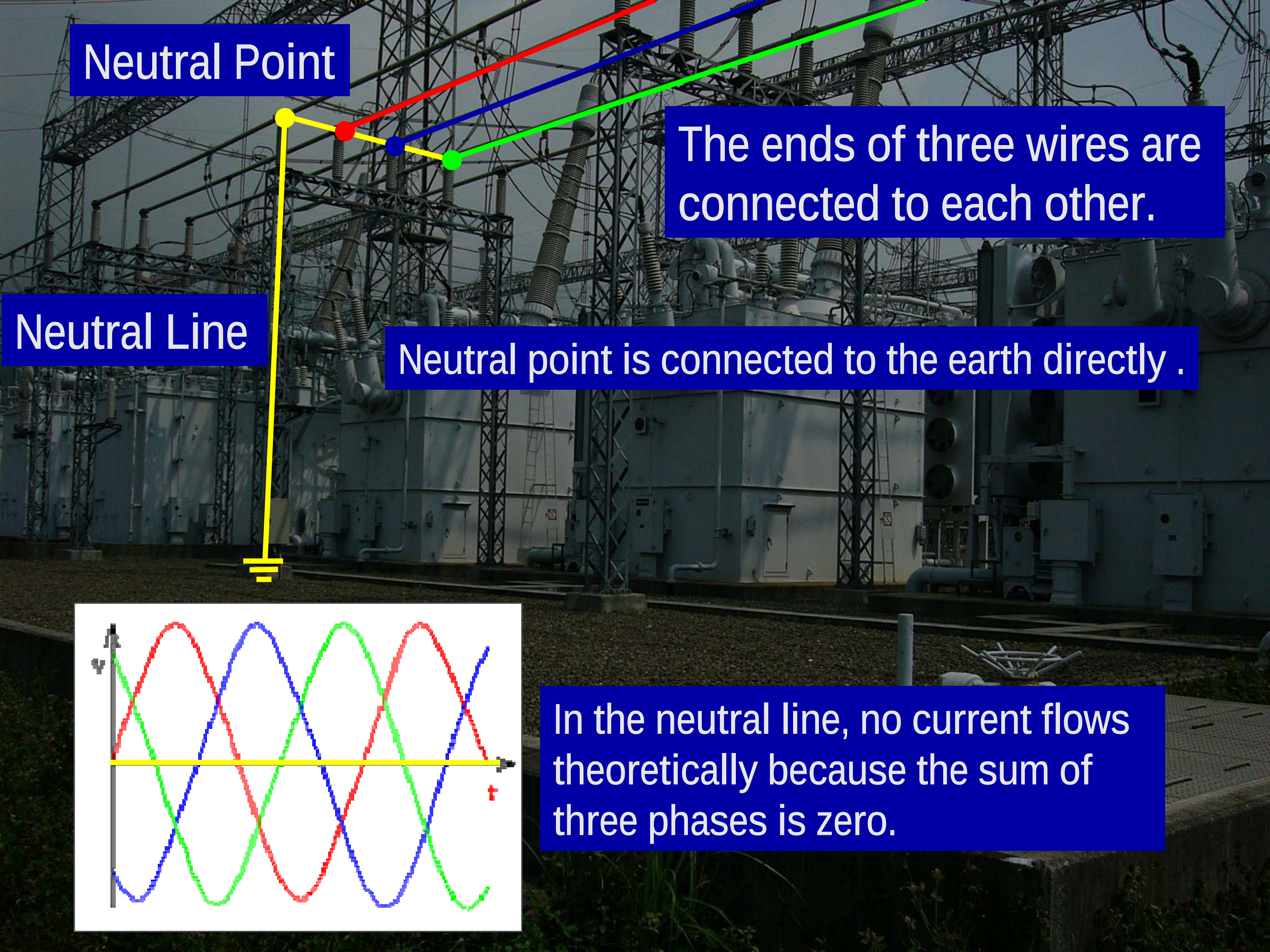
2

3

In each wire, 3 phase alternating current flow.

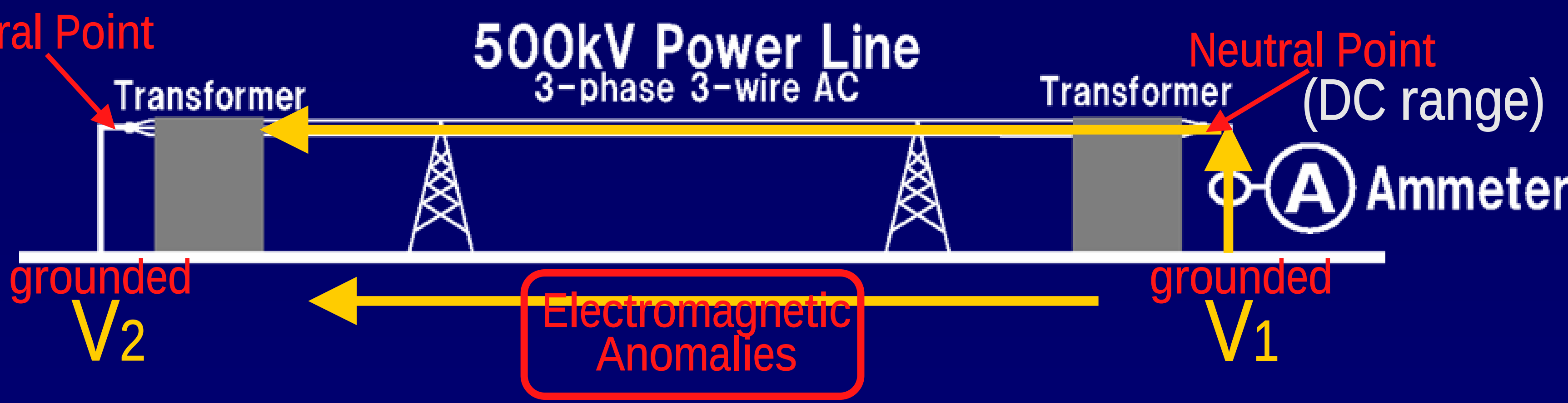


The electric power is usually transmitted by
3 Phase 3 Wire Alternating Current.


Neutral Point
The ends of three wires are connected to each other.
Neutral Line
Neutral point is connected to the earth directly .
v
t
In the neutral line, no current flows theoretically because the sum of three phases is zero.

Telluric Current

If there are electromagnetic anomalies, V_1 is not equal to V_2.



The potential difference $V_1 - V_2$ generates the telluric current.

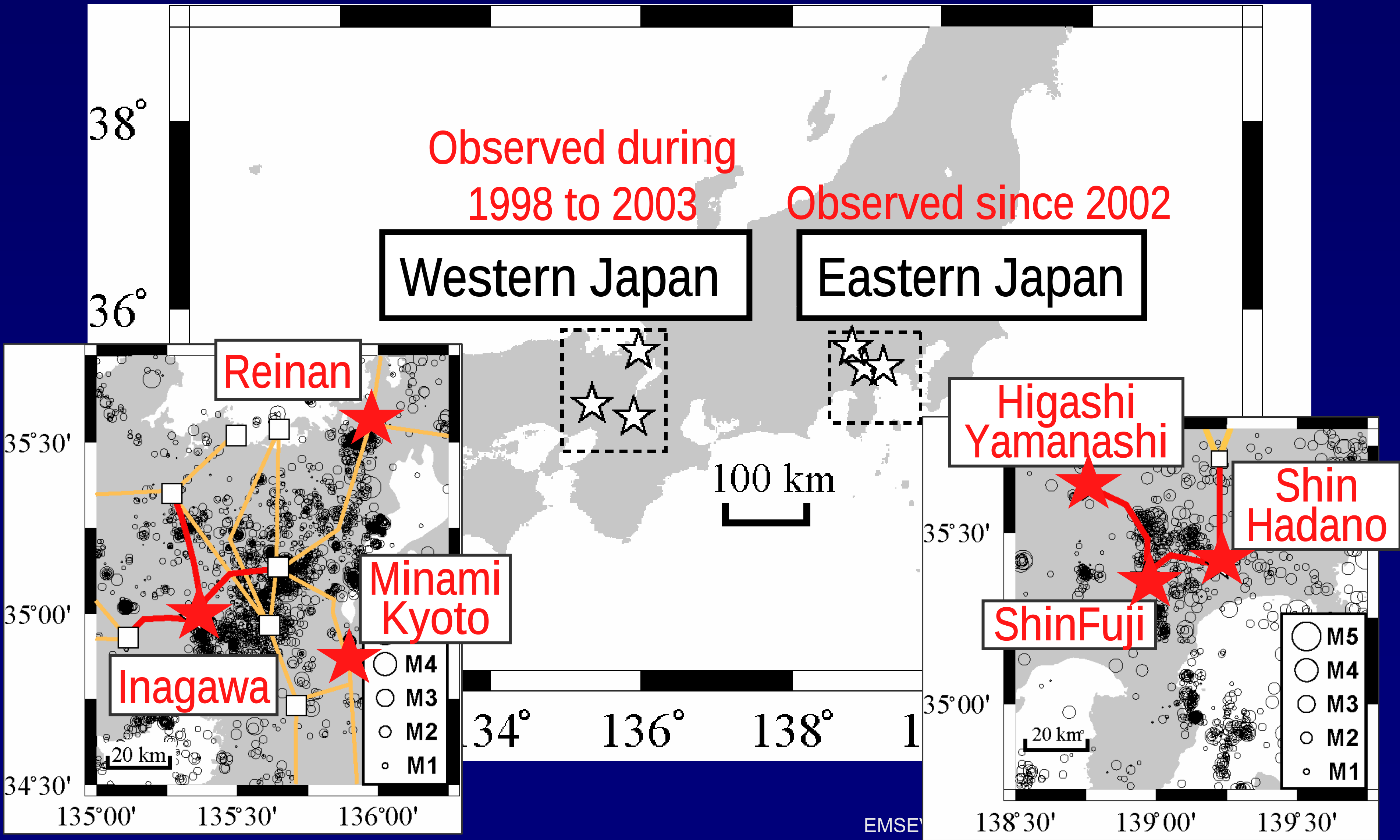
This current in the earth may be measured by the ammeter Ⓐ (DC range).

Neutral Current

This method has been used to measure GIC (Geomagnetically Induced Current).

Observation Area

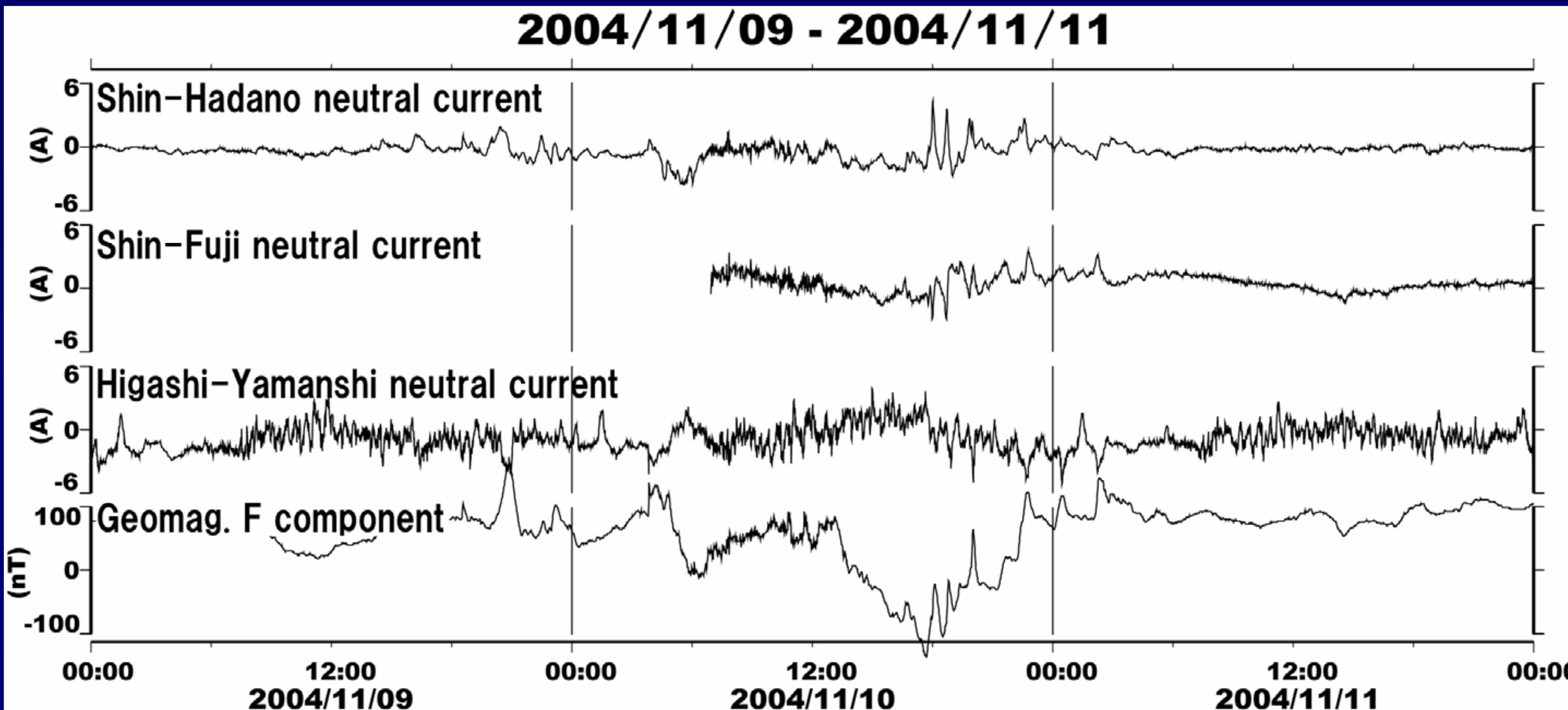
We choose some electrical substations in the high earthquake activity area.



EMSEV

Magnetic Storm

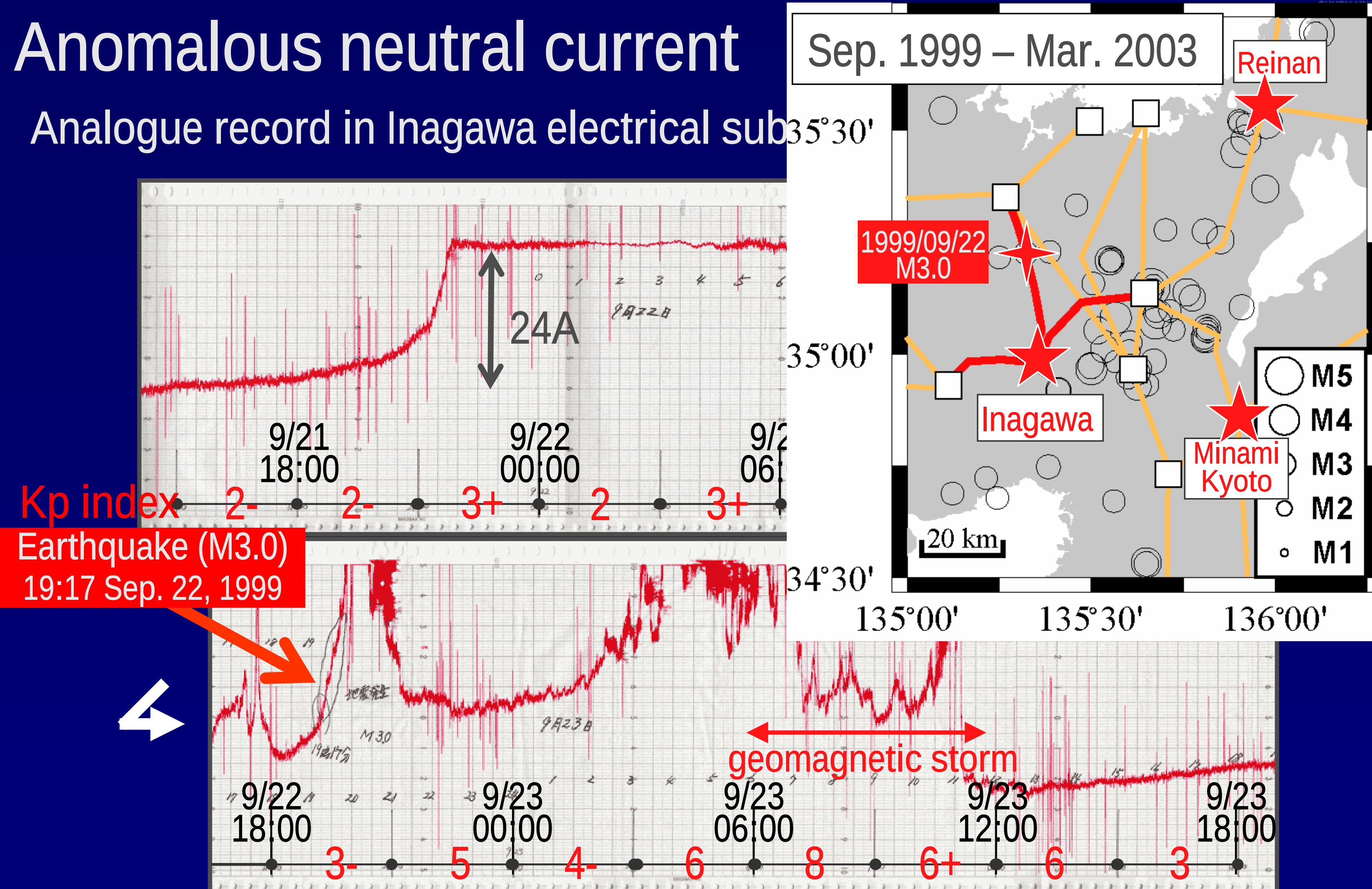
Neutral currents and geomagnetic components (Kakioka) during the large magnetic storm



Fluctuation range is at most 10A.

Anomalous neutral current

Analogue record in Inagawa electrical sub

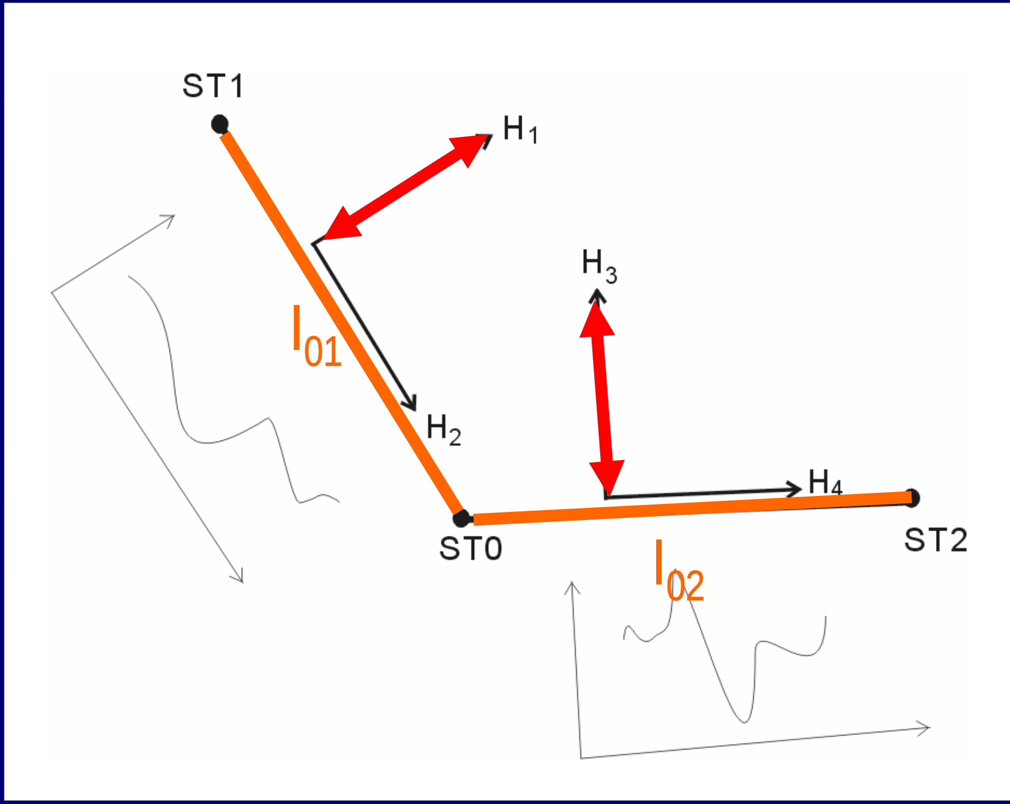


However, there are many earthquakes larger than this earthquake.
No other anomalous current has been observed.

Quantitative analysis

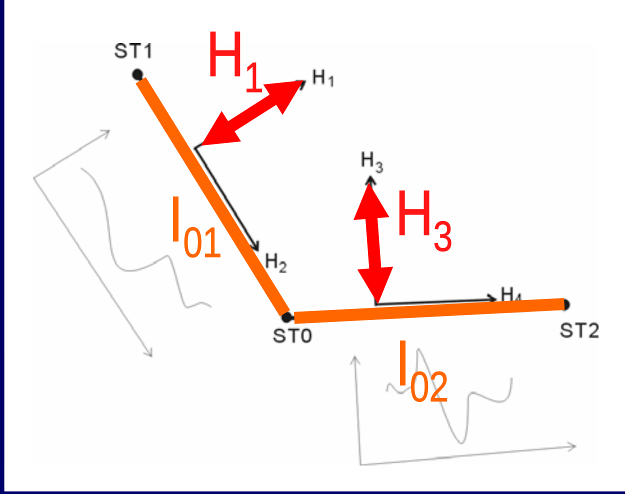
The observed neutral current at ST0 (I_{ST0}), can be considered as the superposition of current which flows between 2 sets of substations ($I_{ST0} = I_{01} + I_{02}$) .

We consider that induced neutral current are generated from the geomagnetic variations, of which variation are perpendicular to the direction of 2 substations.



Transfer Function

Relationship between neutral current and geomagnetic changes



$$I_{ST0}(\omega) = TF1(\omega) \cdot H_1(\omega) + TF2(\omega) \cdot H_3(\omega)$$

$I_{ST0}(\omega)$: Neutral current observed at ST0

$H_1(\omega)$: component 1 of geomagnetic field (Kakioka)

$H_3(\omega)$: component 3 of geomagnetic field (Kakioka)

$TF1(\omega),\ TF2(\omega)$: Transfer Function Coefficients

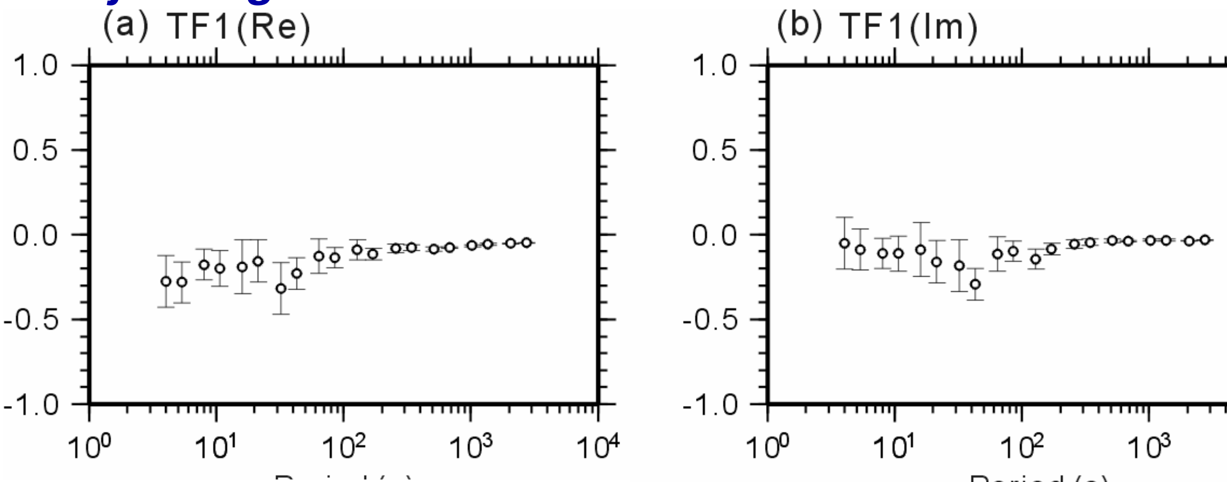
We calculated TF1 and TF2 using observed data.

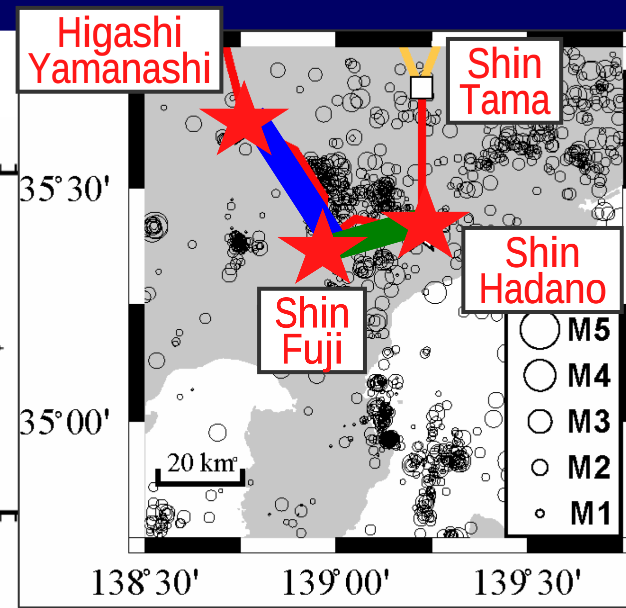
RRRMT (Robust Remote Reference MT) algorithm (Chave et al., 1987)

Transfer functions at Shin-Fuji

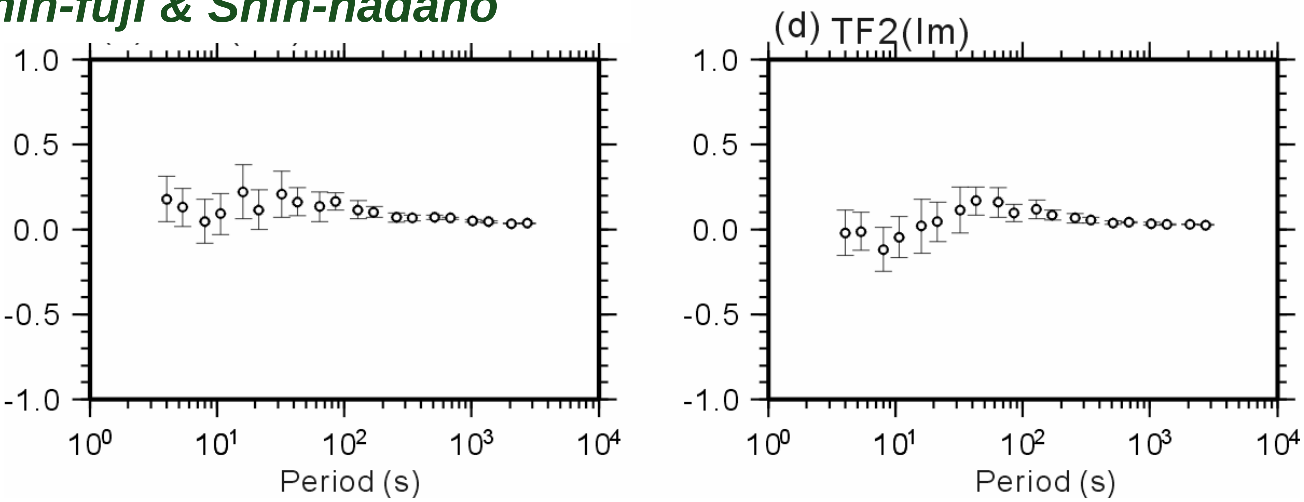
$$I_{ST0}(\omega) = TF1(\omega)\cdot H_1(\omega) + TF2(\omega)\cdot H_3(\omega)$$

Shin-fuji & Higashi- Yamanashi





Shin-fuji & Shin-hadano



Transfer functions at Shin-Hadano

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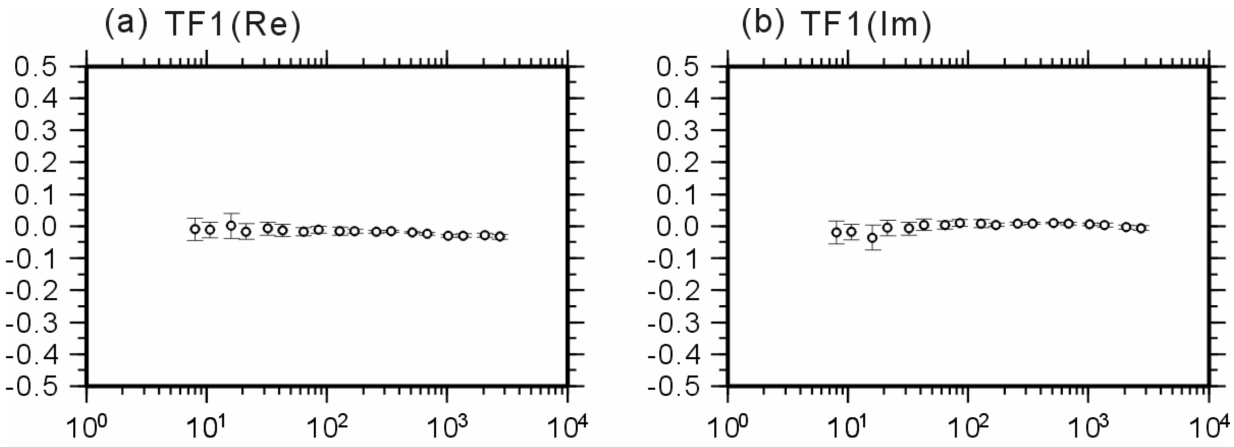
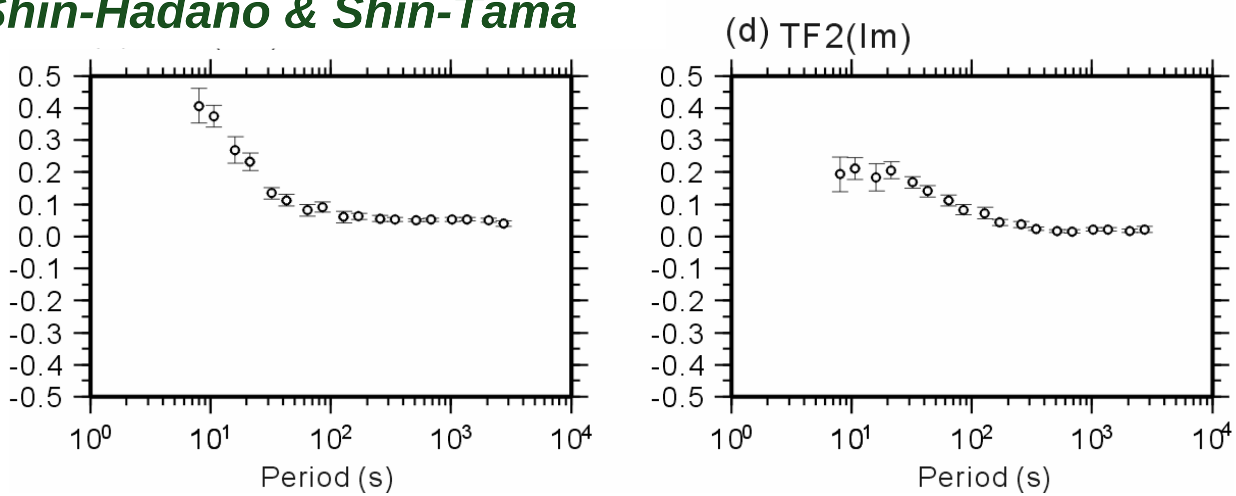
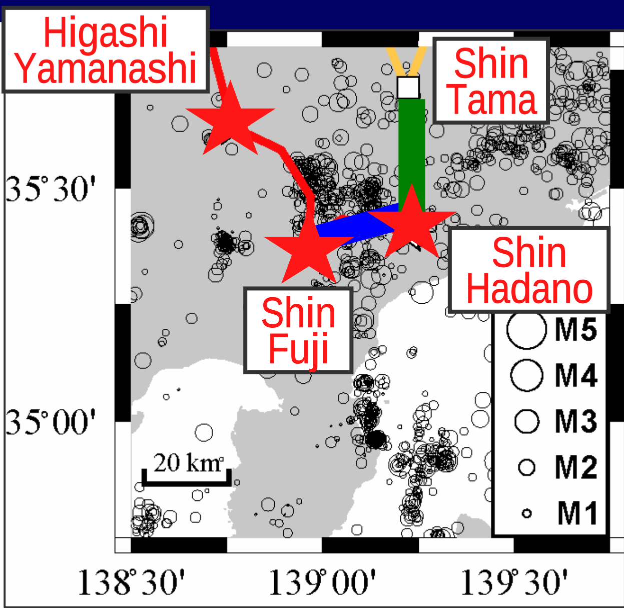
Shin-Hadano & Shin-Fuji



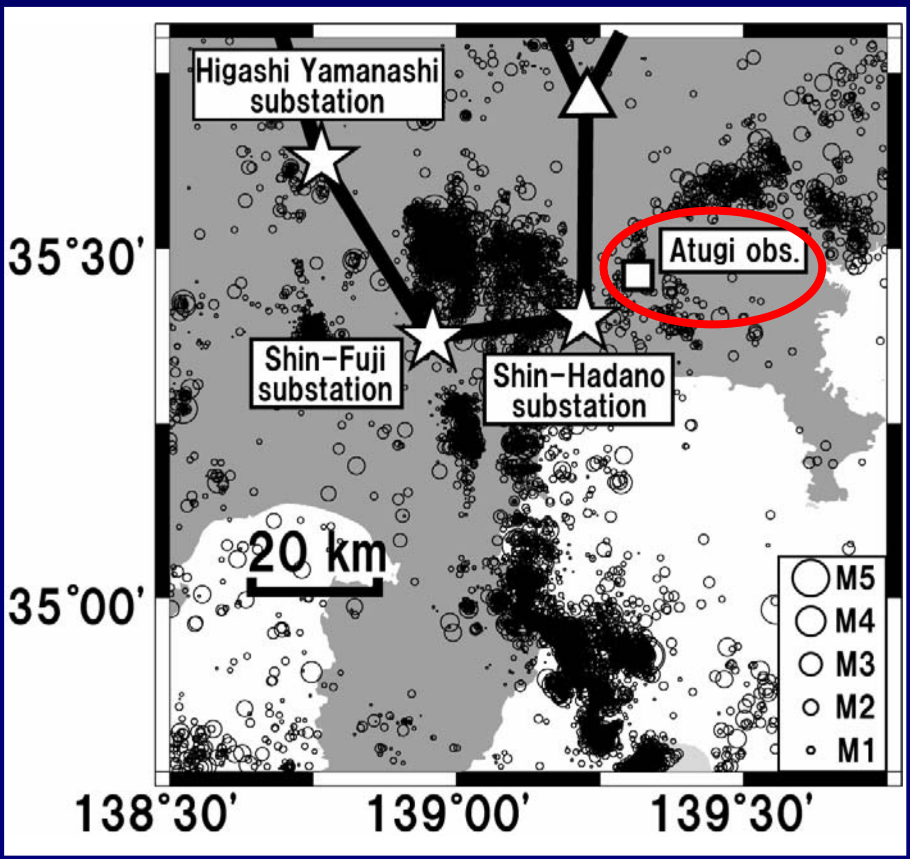
Shin-Hadano & Shin-Tama



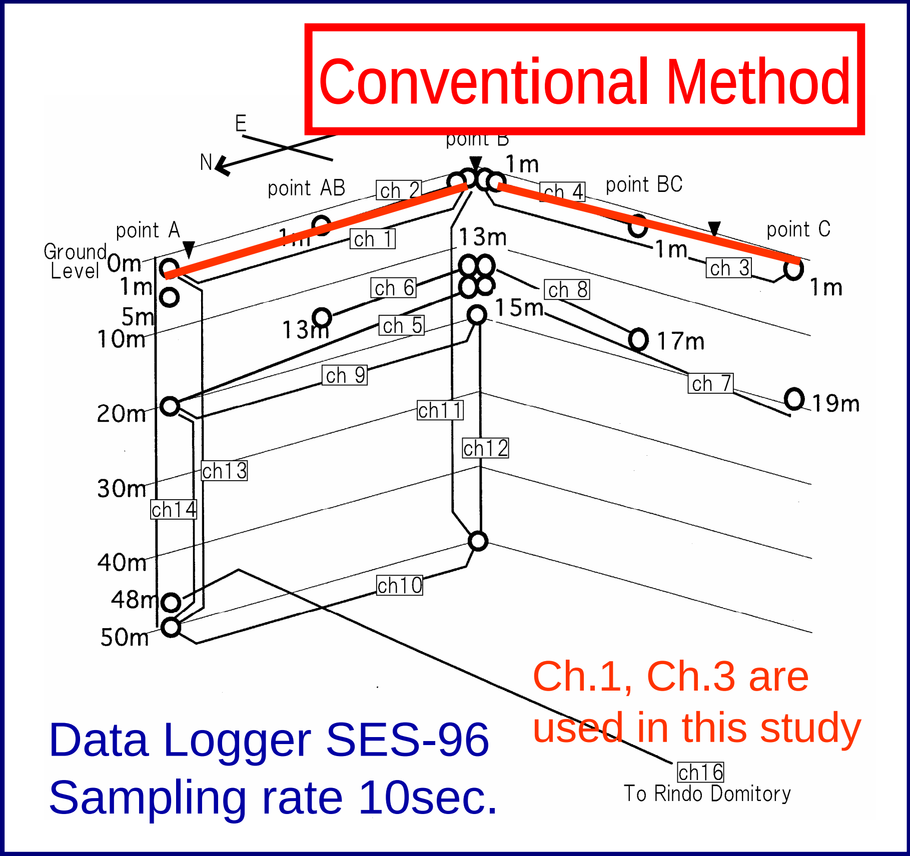


Telluric current measurement in Atsugi

We have observed telluric currents at Atsugi by conventional method.

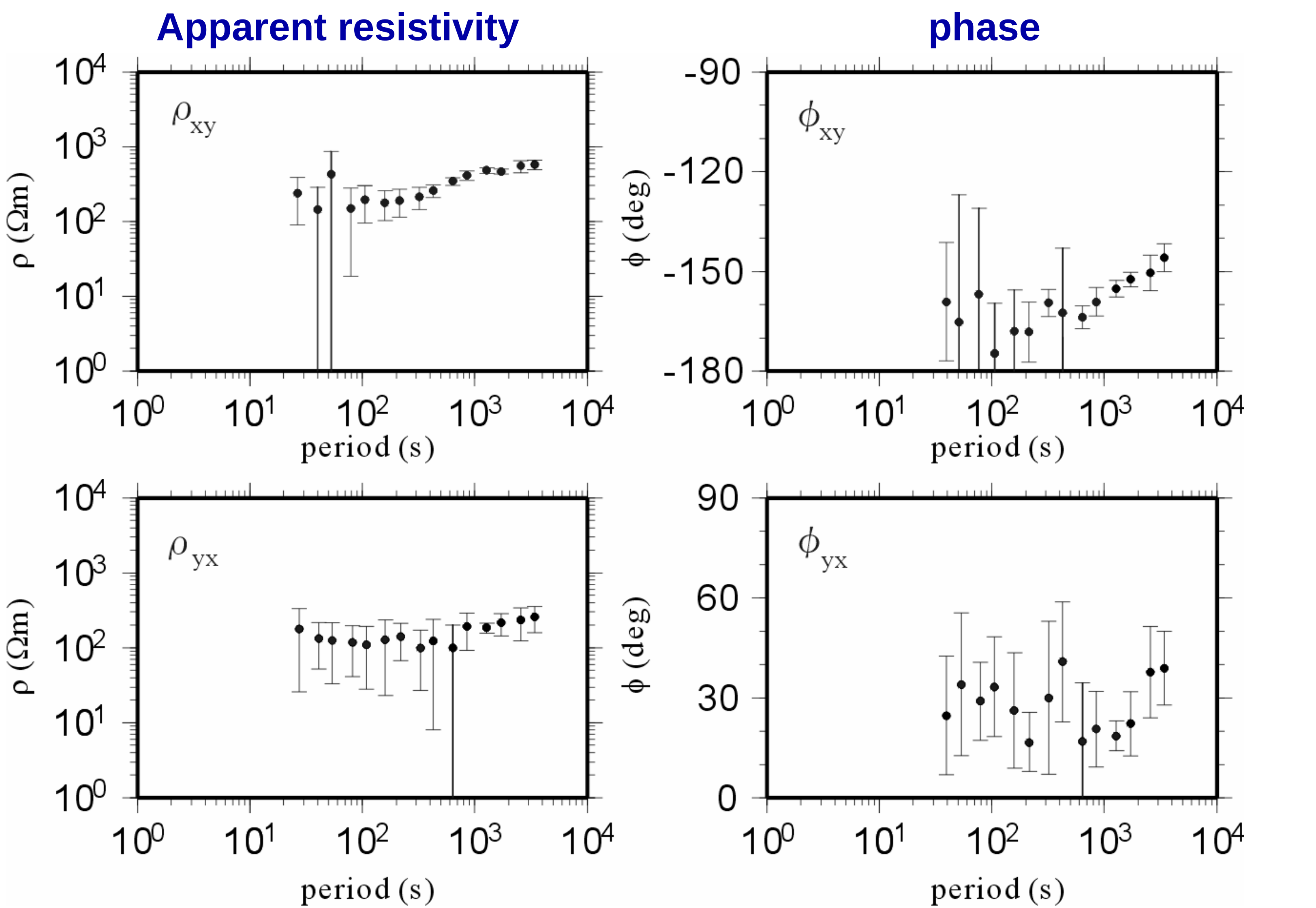


Configuration of observation points



Configuration of electrodes

MT parameters at Atsugi



Compare to MT method

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MT method

$$\begin{pmatrix} E_x(\omega) \\ E_y(\omega) \end{pmatrix} = \begin{pmatrix} Z_{xx}(\omega) & Z_{xy}(\omega) \\ Z_{yx}(\omega) & Z_{yy}(\omega) \end{pmatrix} \cdot \begin{pmatrix} H_x(\omega) \\ H_y(\omega) \end{pmatrix},$$

apparent resistivity

$$\rho_a(\omega) = \frac{1}{\mu_0 \omega} \left| \frac{\mathbf{E}(\omega)}{\mathbf{H}(\omega)} \right|^2$$

phase

$$\phi(\omega) = \tan^{-1}\left(\frac{\mathrm{Im}(\mathbf{Z}(\omega))}{\mathrm{Re}(\mathbf{Z}(\omega))} \right)$$

Transfer Function

$$I_{ST0}(\omega) = TF1(\omega) \cdot H_1(\omega) + TF2(\omega) \cdot H_3(\omega)$$

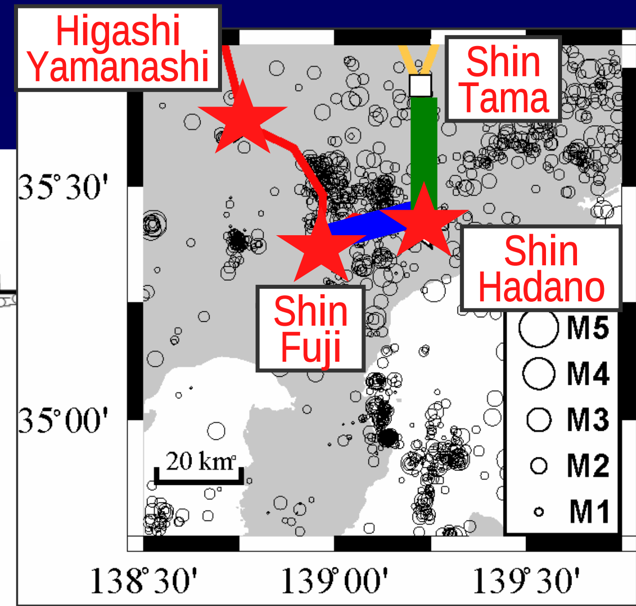
“pseudo-” apparent resistivity

$$Rs(\omega) = \frac{1}{\mu_0 \omega} \left| \frac{I_{ST0}(\omega)}{\mathbf{H}(\omega)} \right|^2 \cdot factor$$

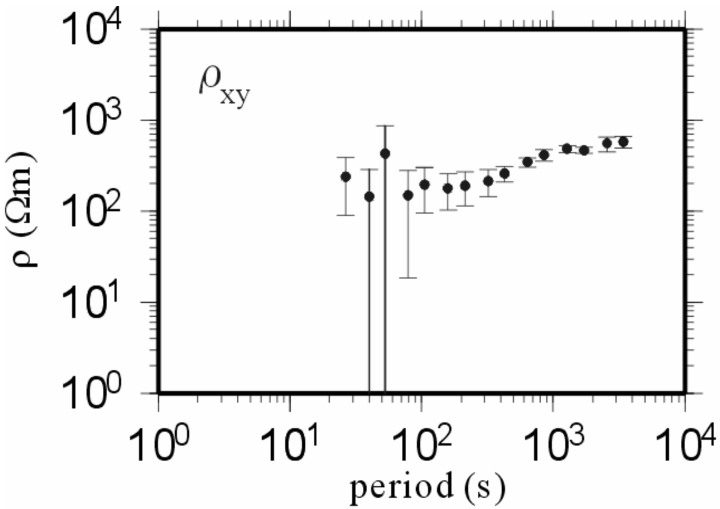
“pseudo-” phase

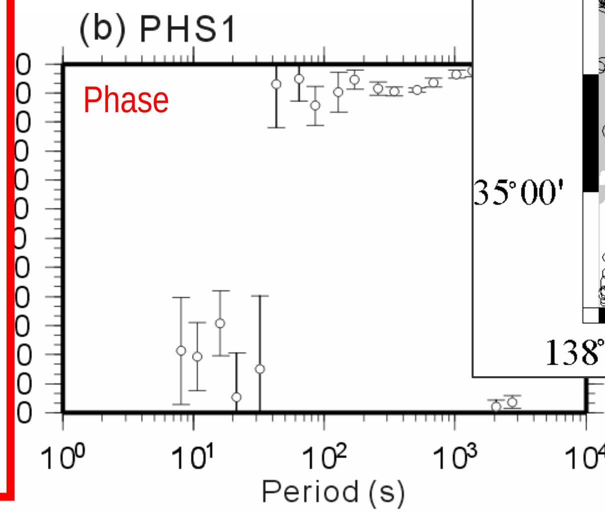
$$\phi s(\omega) = \tan^{-1}\left(\frac{I_{ST0}(\omega)}{\mathbf{H}(\omega)} \right)$$

"Pseudo-" apparent resistivity and phase at Shin-Hadano

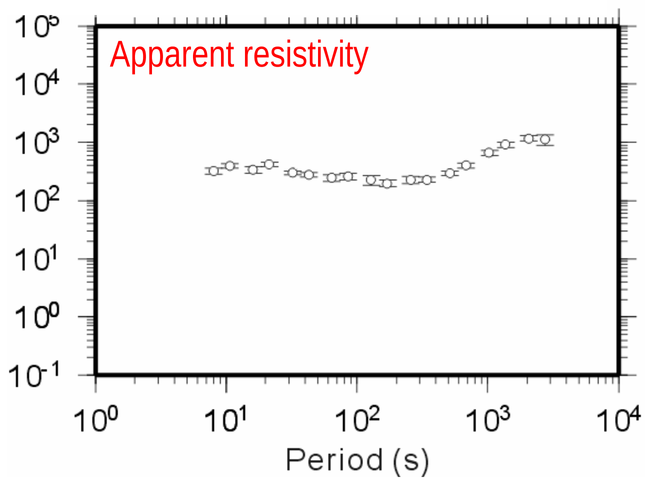


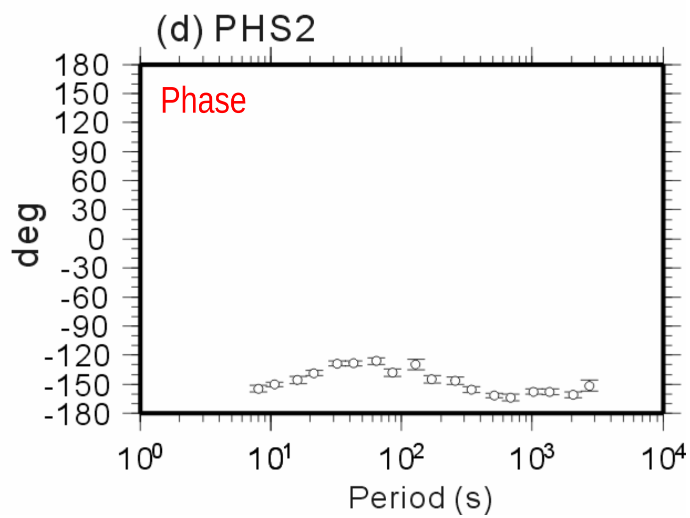
Apparent resistivity at Atsugi





Shin-Hadano & Shin-Tama





Time Variation of "Pseudo-" apparent resistivity and phase at Shin-Hadano

○ : Oct.& Aug., 2003

● : Nov.,2004

factor = 100

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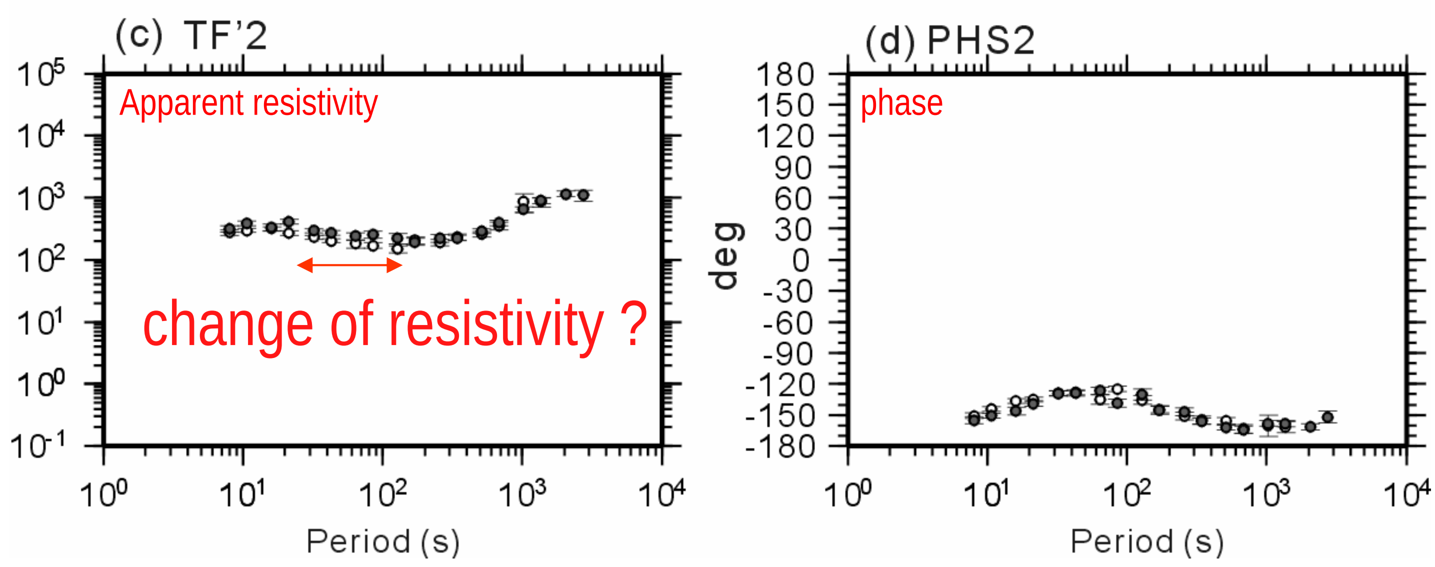

Conclusion

We observed telluric current between substations by using the power line system.

We observed the anomalous neutral current before and after an earthquake in 1999. However, We have never observed such anomalous neutral current after that.

We calculate the transfer function between a neutral current and geomagnetic changes.

The coefficients of this transfer function have the information of the underground conductivity.

Comparing with the result by MT method, we can estimate monitor the change of the under ground conductivity.