Characteristics of the Voltages between the Communication Lines and Ground Induced by the Adjacent Artificial High-Voltage or Current ELF Source

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Abstract

The measurements were performed to verify experimentally that the voltage arising on a telecommunication line by a power line is due to the induction phenomena because there has been an opinion that the arising voltage on a telecommunication line is not by induction, but by other causality. The voltage appeared on the telecommunication line by way of an electric field or magnetic field generated by the source apparatus that had been artificially made to provide intentional constant high-voltage or current in ELF, that is, 60 Hz as an emulated commercial power.

Key words : Induction Phenomena, Induction Voltage, Source Generator, Electromagnetic Field.

Ⅰ. Introduction

The electromagnetic induction has been acknowledged by theory and experiments, especially Faraday's law, etc. Such an induction phenomenon has been applied for implementation to various things necessary and useful in mankind's life.

In the field of telecommunication, the power line, which generates an electromagnetic field, may interfere with transmission signals. The magnetic field generated by the power line gives rise to induced current in nearby communication lines. So, protection measures are taken according to legal provisions[1],[2]. The measures are carried out when the induced voltage calculated with the formulas provided by the national legal notice[2] is equal to excess over the limited voltage prescribed in the technical regulation rule[1].

But there has been a questionable point as to whether the voltage onto telecommunication cables by power line or electrified railway line is really caused by induction. We are used to measuring the induced voltage with the technical regulation notice method[3]. But there is an opinion that just a potential difference between the two points of the ground is measured by the method.

Having made an EMI source generator emulating the commercial power operating at 60 Hz as an ELF, we experimented with whether the voltage generated onto a telecommunication cable by a nearby power line is due to an induction.
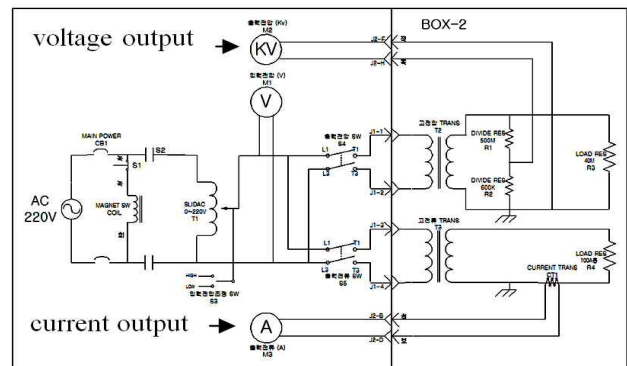

Fig. 1. Circuit diagram of source generator.

Ⅱ. Source Generation Circuit

The high currents and voltages are generated by the artificially made apparatus from the 220 V/60 Hz as the commercial power. The 220 V from the commercial power source is routed into the current- or voltage- generating section of the apparatus, and whether it can then be enhanced up to 15 kV for high voltage or 100 A for high current. The circuit of the source generator is shown in Fig. 1.

Ⅲ. Experiment and Analysis

3-1 Measurement Configuration

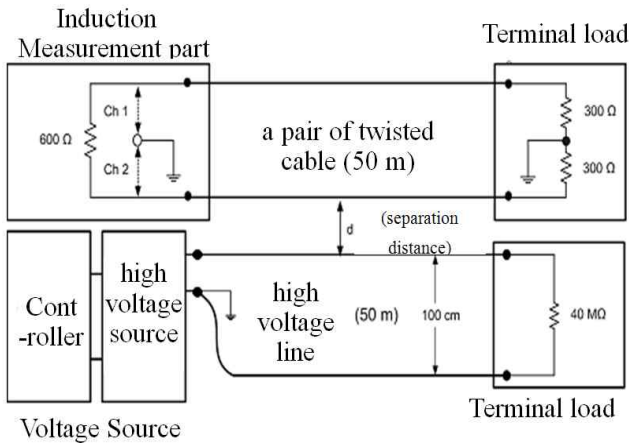The installation configuration of components for mea-

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Fig. 2. The configuration of measurement.

surement is shown in Fig. 2. Basically, the distance between the feeder line and feedback line of the power line is set as 1 m. And the distance between the communication line and the power line(this is separate distance: d) varies by 0.3 m from 0m to 0.6 m, which results in three measurements as to each distance change: measured at 0 m, 0.3 m, 0.6 m. The parallelized length of both the communication line and power line is 50 m. And for the high current source case, the terminal load is put as 0.2 Ω.

In addition, as the communication line is composed of a pair, which means having two core lines in a pair, two induced voltages(one is for CH1; the other for CH2) are measured to confirm that they are practically the same. This is an important factor because just a tiny difference of induced voltages between the core lines may give rise to noise voltage on the pair caused by the voltage difference between the core lines.

3-2 Characteristics of the High-Voltage Source

3-2-1 0 m Separation Distance(d=0)

The measured voltages induced onto communication cable are shown in Table 1, including peak-to-peak values and RMS values, and the CRO displays the waveform shown in Fig. 3 when the voltage source level is off(0 kV): Fig. 4 /5 kV, Fig. 5 /10 kV, Fig. 6 /15 kV. The values of CH1 and CH2 are not completely the same, but show slightly different values.

We see that as by increasing the source voltage level, the induced voltage also increases proportionally, and that the default voltage exists when no source is provided(0 kV). It is presumed that there exists stray current in the ground or one that is caused by another unknown factor that can generate the voltage onto the cable. Some voltage can be usually checked between two

Table 1. Measured voltage at d=0.

Source voltage (rms)	CRO-CH 1		CRO-CH 2	
	$V_{p\text{-}p}$(V)	V_{rms}(mV)	$V_{p\text{-}p}$(V)	V_{rms}(mV)
0 kV	1.06	373	1.07	383
5 kV	1.76	488	1.76	495
10 kV	4.16	696	4.42	724
15 kV	11.01	840	10.94	865

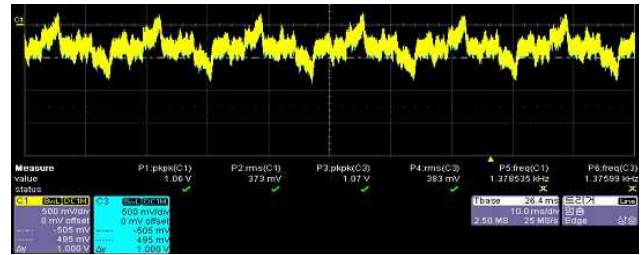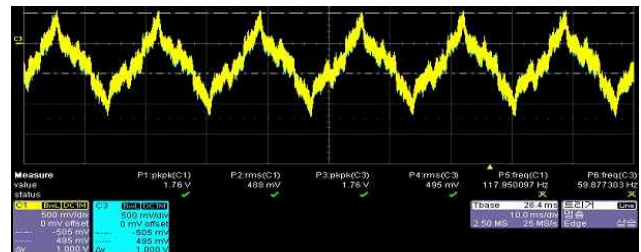Fig. 3. Waveform at d=0 in 0 kV(500 mV/div, and 10.0 ms/div).

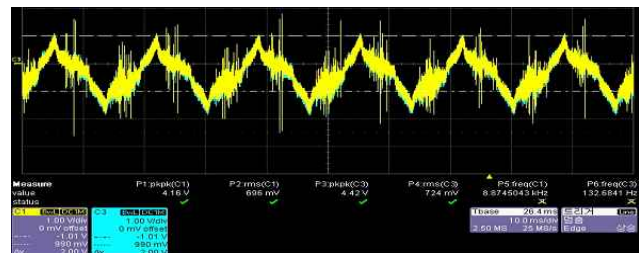Fig. 4. Waveform at d=0 in 5 kV(500 mV/div, and 10.0 ms/div).

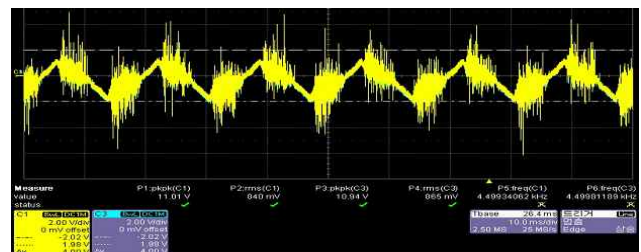Fig. 5. Waveform at d=0 in 10 kV(500 mV/div, and 10.0 ms/div).

Fig. 6. Waveform at d=0 in 15 kV(500 mV/div, and 10.0 ms/div).

points on the ground. This is due to the potential difference between those points which can exist by the current flowing in the ground.

3-2-2 0.3 m Separation Distance(d=0.3 m)

The measured voltages induced onto communication cable are shown in Table 2. CRO displays the waveform

Table 2. Measured voltage at d=0.3 m.

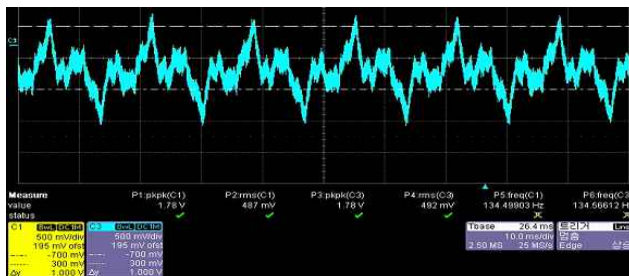| Source voltage (rms)	CRO-CH 1		CRO-CH 2	
	$V_{p\text{-}p}$(V)	V_{rms}(mV)	$V_{p\text{-}p}$(V)	V_{rms}(mV)
0 kV	1.65	474	1.66	479
5 kV	1.78	487	1.78	492
10 kV	3.42	496	3.36	514
15 kV	5.12	500	5.18	518

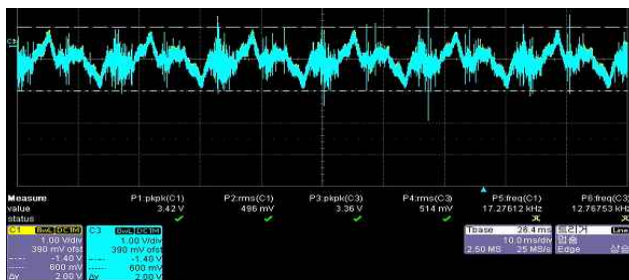Fig. 7. Waveform at d=0.3 m in 5 kV(500 mV/div, and 10.0 ms/div).

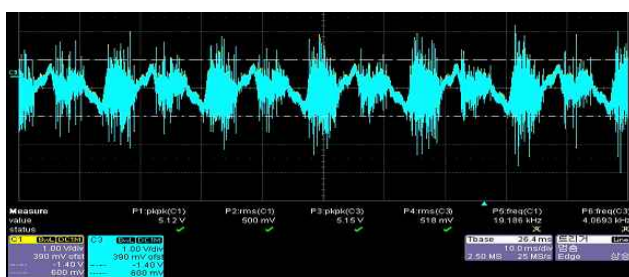Fig. 8. Waveform at d=0.3 m in 10 kV(1.0 V/div, and 10.0 ms/div).

Fig. 9. Waveform at d=0.3 m in 15 kV(1.0 V/div, and 10.0 ms/div).

shown in Fig. 7 when the voltage source level is 5 kV, Fig. 8/ 10 kV, Fig. 9/ 15 kV. The voltages of CH1 and CH2 are again not exactly the same, but slightly different. Also, by increasing the source voltage level, the induced voltage increases, but the degree of increase is smaller than the case of 0 distance.

3-2-3 0.6 m Separation Distance(d=0.6 m)

The measured voltages induced onto communication cable are shown in Table 3. CRO displays the waveform shown in Fig. 10 when the voltage source level is off(0 kV), Fig. 11 /5 kV, Fig. 12/ 10 kV, Fig. 13/ 15 kV.

CH1 and CH2 voltages are not the same exactly. At this time, the induced voltage rather decreased at 5 kV, and from the 10 kV level, there has been a small voltage increase.

3-2-4 Anaysis of Graph

Fig. 14 is for CH1; Fig.15 is for CH2. Although the

Table 3. Measured voltage at d=0.6 m.

Source voltage (rms)	CRO-CH 1		CRO-CH 2	
	$V_{p\text{-}p}$(V)	V_{rms}(mV)	$V_{p\text{-}p}$(V)	V_{rms}(mV)
0 kV	2.13	478	2.11	483
5 kV	2.06	463	2.05	468
10 kV	2.13	466	2.08	471
15 kV	4.58	486	4.45	493

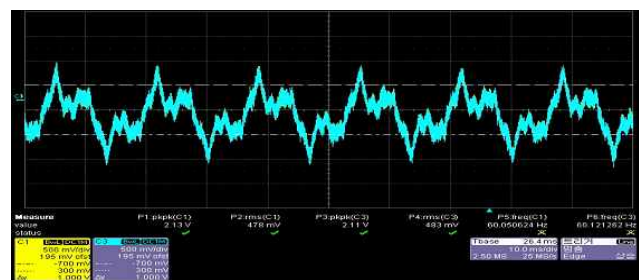

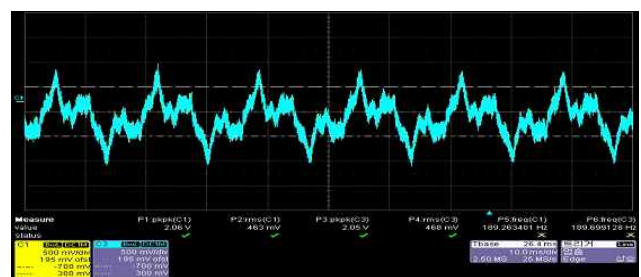Fig. 10. Waveform at d=0.6 m in 0 kV(500 mV/div, and 10.0 ms/div).

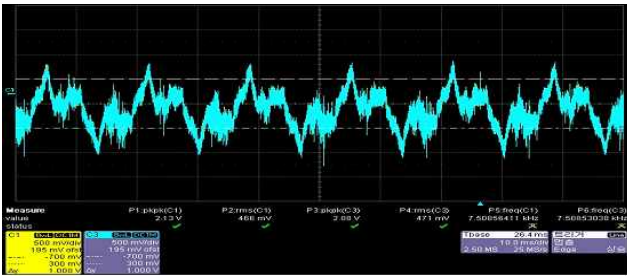Fig. 11. Waveform at d=0.6 m in 5 kV(500 mV/div, and 10.0 ms/div).

Fig. 12. Waveform at d=0.6 m in 10 kV(500 mV/div, and 10.0 ms/div).
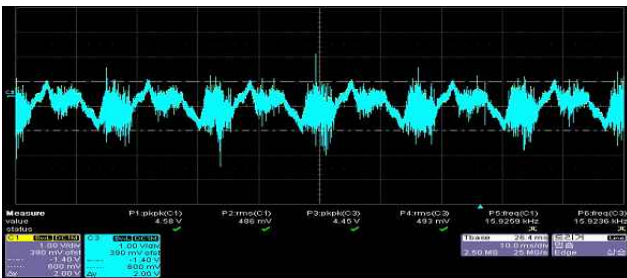

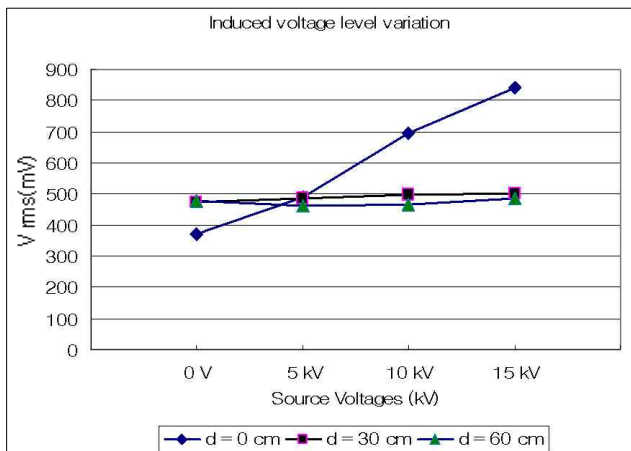Fig. 13. Waveform at d=0.6 m in 15 kV(1.00 V/div, and 10.0 ms/div).
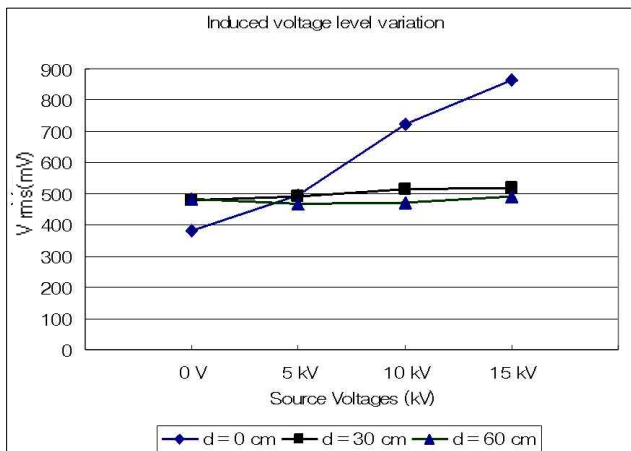

Fig. 14. Graphic analysis of induction(CH1).

Fig. 15. Graphic analysis of induction(CH2).

Table 4. Voltages induced by current source(d=0).

Source current (rms)	CRO-CH 1		CRO-CH 2	
	$V_{p\text{-}p}$(V)	V_{rms}(mV)	$V_{p\text{-}p}$(V)	V_{rms}(mV)
0 A	1.15	336	1.14	346
30 A	1.49	492	1.49	499
60 A	2.31	744	2.31	744
90 A	3.16	1,022	3.12	1,021

values of CH1 and CH2 are not exactly the same, the changing trend is almost the same. From the graph, it is clear that only in the case of the separate distance d= 0 is the induced voltage increasing proportionally. And in other d's, slight voltage is increased only at a high-voltage level above 10 kV.

3-3 Characteristics of High-Current Source

3-3-1 0 m Separation Distance(d=0)

The measured induced voltage is shown in the Table 4. The values of CH1 and CH2 are not exactly the same. And the induced voltage is increased by growing the current source level. Default voltage at a 0 source level exists. The CRO waveforms are shown in Fig.16 for the current source: 0 A; Fig. 17 for 30 A; Fig. 18 for 60 A; Fig. 19 for 90 A.
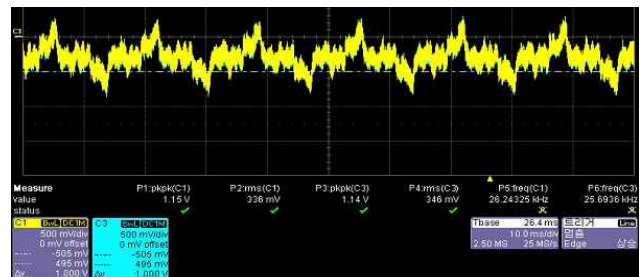

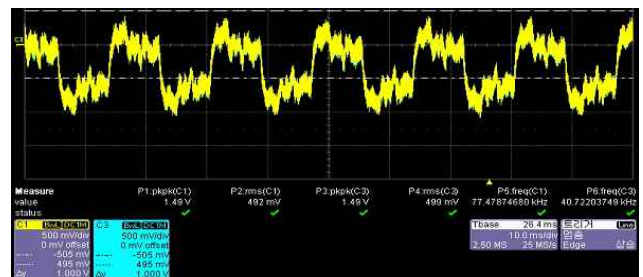Fig. 16. Waveform for 0 A current source(500 mV/div, and 10.0 ms/div).

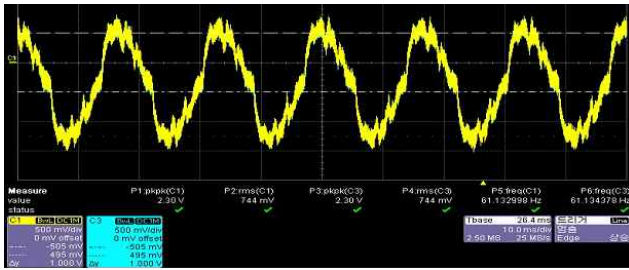Fig. 17. Waveform for 30A current source(500 mV/div, and 10.0 ms/div).

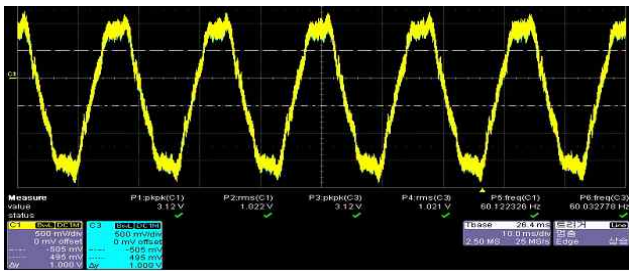Fig. 18. Waveform for 60 A current source(500 mV/div, and 10.0 ms/div).

Fig. 19. Waveform for 90 A current source(500 mV/div, and 10.0 ms/div).

3-3-2 0.3 m Separation Distance(*d*=0.3 m)

The measured voltages at *d*=0.3m are shown in Table 5. The RMS value is slightly increasing, except the case of 0A, which is caused by an unknown exterior source while the peak-to-peak value tends to slightly decrease. The measured waveform for each case is shown in Fig. 20～23.

3-3-3 0.6 m Separation Distance(*d*=0.6 m)

Interestingly, at this point, the induced voltage is rather decreased slightly. Each CRO waveform is shown in Fig. 24～27.

3-3-4 Analysis of Graph

With respect to the high-current source, at the point of *d*=0, the induced voltage is proportionally increasing by the growing source levels. At the point of *d*=0.3 m,

Table 5. Voltages induced at *d*=0.3 by current.

Source current (rms)	CRO-CH 1		CRO-CH 2	
	V_{p-p}(V)	V_{rms}(mV)	V_{p-p}(V)	V_{rms}(mV)
0 A	1.81	494	1.81	499
30 A	1.57	474	1.57	478
60 A	1.33	486	1.34	490
90 A	1.52	515	1.55	519

Table 6. Measured voltage at *d*=0.6 m.

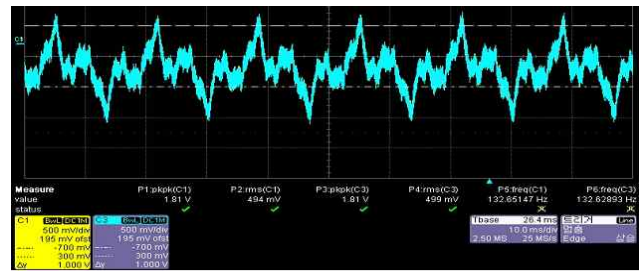| Source current (rms)	CRO-CH 1		CRO-CH 2	
	V_{p-p}(V)	V_{rms}(mV)	V_{p-p}(V)	V_{rms}(mV)
0 A	2.13	478	2.11	483
30 A	1.84	455	1.84	462
60 A	1.66	431	1.66	439
90 A	1.44	422	1.46	430

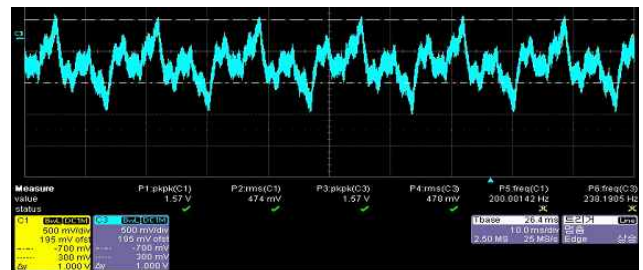Fig. 20. The CRO waveform in 0 A(500 mV/div, and 10.0 ms/div).

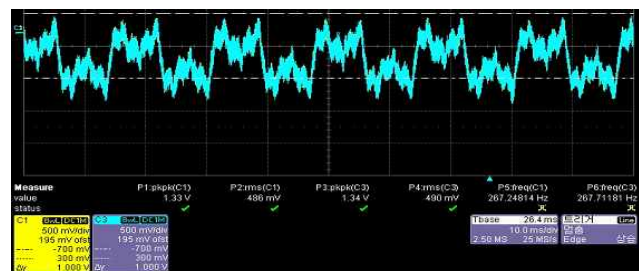Fig. 21. The CRO waveform in 30 A(500 mV/div, and 10.0 ms/div).

Fig. 22. The CRO waveform in 60 A(500 mV/div, and 10.0 ms/div).
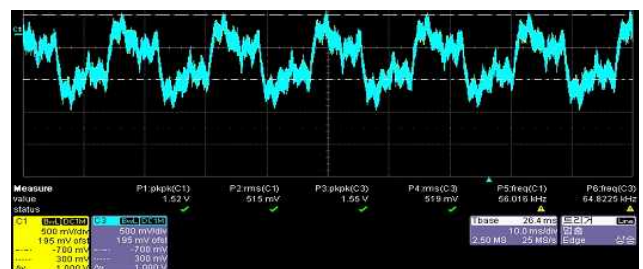

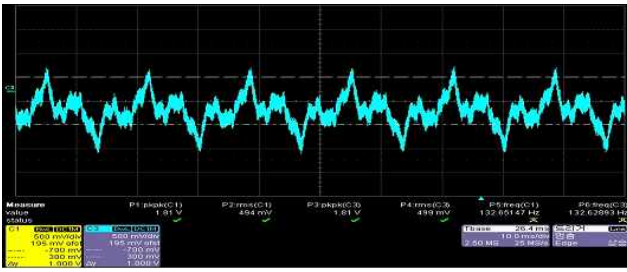Fig. 23. The CRO waveform in 90 A(500 mV/div, and 10.0 ms/div).

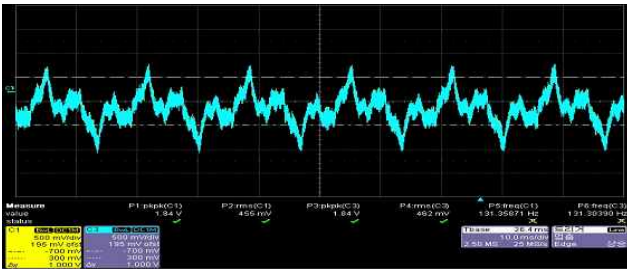Fig. 24. Current source: 0 A(500 mV/div, and 10.0 ms/div).

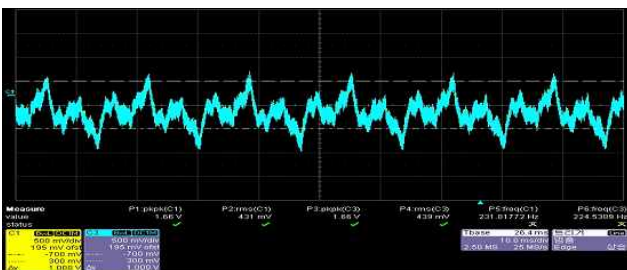Fig. 25. Current source: 30 A(500 mV/div, and 10.0 ms/div).

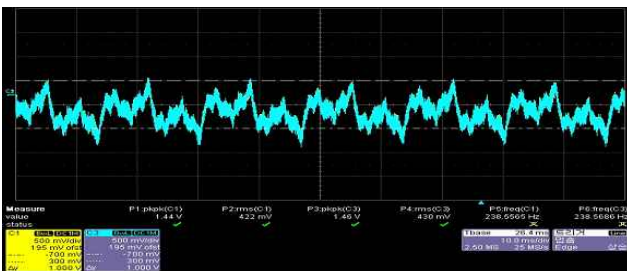Fig. 26. Current source: 60 A(500 mV/div, and 10.0 ms/div).

Fig. 27. Current source: 90 A(500 mV/div, and 10.0 ms/div).

induced voltage is slightly increasing with the step currents. At the point 0f 0.6 m, the induced voltage is rather slightly decreasing. For the CH1 and CH2 cases, the data values have little difference, but almost the same trend. Each channel curve is shown in Fig. 28 and Fig. 29.

Ⅳ. Conclusion

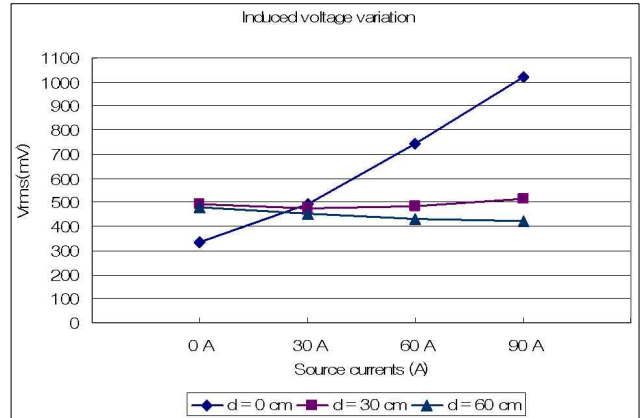That the voltage arising on telecommunication lines
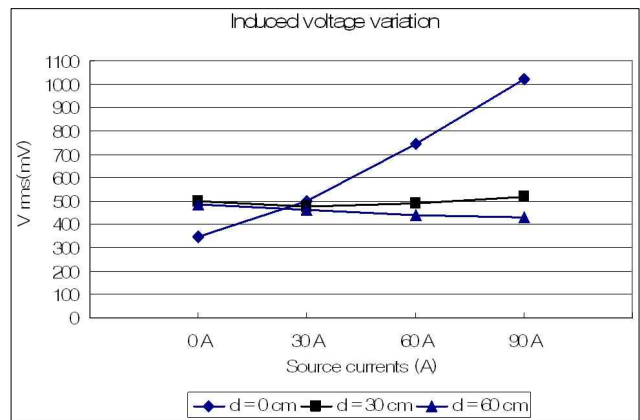

Fig. 28. Current source trend(CH1).

Fig. 29. Current source trend(CH2).

from power lines is by induction phenomenon has been confirmed by experiment in which an artificially made source generator was utilized. The induced voltage is generated by both an electric field from a high-voltage line and a magnetic field from a high-current source. It appears that the voltage induced by the magnetic source is 1.02 V_{rms}(average of CH1&2, at d=0, each maximum source level) which is greater than the voltage caused by the electric field.

References

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