

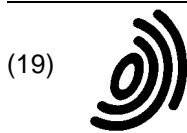
CETF and No CapX 2020

PUC Dockets 12-1053 & 12-1337

## Corona and Ultra Violet Exhibits

	<b>Class</b>	<b><u>Freq uency</u></b>	<b><u>Wave length</u></b>	<b><u>Energy</u></b>
<u>Visible</u>	$\gamma$ <u>Gamma rays</u>	300 <u>EHz</u>	1 <u>pm</u>	1.24 <u>MeV</u>
	HX <u>Hard X-rays</u>	30 EHz	10 pm	124 <u>keV</u>
		3 EHz	100 pm	12.4 keV
	SX <u>Soft X-rays</u>	300 <u>PHz</u>	1 <u>nm</u>	1.24 keV
	EUV <u>Extreme ultraviolet</u>	30 PHz	10 nm	124 <u>eV</u>
	NUV <u>Near ultraviolet</u>	3 PHz	100 nm	12.4 eV
	NIR <u>Near Infrared</u>	300 <u>THz</u>	1 <u><math>\mu</math>m</u>	1.24 eV
	MIR <u>Mid infrared</u>	30 THz	10 $\mu$ m	124 <u>meV</u>
	FIR <u>Far infrared</u>	3 THz	100 $\mu$ m	12.4 meV
	EHF <u>Extremely high frequency</u>	300 <u>GHz</u>	1 <u>mm</u>	1.24 meV
<u>Radio waves</u>	SHF <u>Super high frequency</u>	30 GHz	1 <u>cm</u>	124 $\mu$ eV
	UHF <u>Ultra high frequency</u>	3 GHz	1 <u>dm</u>	12.4 $\mu$ eV
	VHF <u>Very high frequency</u>	300 <u>MHz</u>	1 <u>m</u>	1.24 $\mu$ eV
	HF <u>High frequency</u>	30 MHz	10 m	124 <u>neV</u>
	MF <u>Medium frequency</u>	3 MHz	100 m	12.4 neV
	LF <u>Low frequency</u>	300 <u>kHz</u>	1 <u>km</u>	1.24 neV
	VLF <u>Very low frequency</u>	30 kHz	10 km	124 <u>peV</u>
	VF / ULF <u>Voice frequency</u>	3 kHz	100 km	12.4 peV
	SLF <u>Super low frequency</u>	300 <u>Hz</u>	1 <u>Mm</u>	1.24 peV
	ELF <u>Extremely low frequency</u>	30 Hz	10 Mm	124 <u>feV</u>
		3 Hz	100 Mm	12.4 feV

Sources: [File:Light spectrum.svg](#) <sup>[1]</sup> <sup>[2]</sup> <sup>[3]</sup>



(12)

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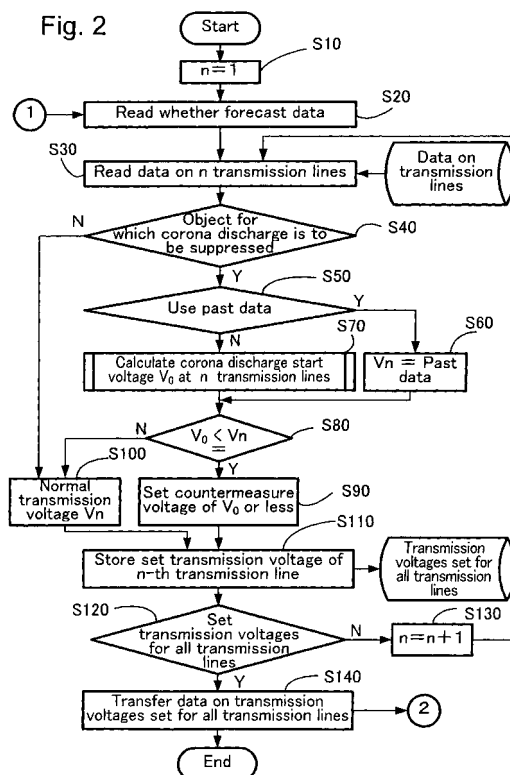
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(54) **ELECTRIC POWER SYSTEM SUPPRESSING CORONA DISCHARGE FROM VIEWPOINT OF ENVIRONMENT**

(57) Epidemiological surveys show that the risk of suffering from childhood leukemia in places near high-voltage power transmission lines is higher. Relevant data and material have been collected and analyzed. I found that the major factor in the high risk of childhood leukemia is ultraviolet radiation (particularly UV-B and UV-C) generated by corona discharge from high-voltage transmission lines.

The present invention provides an electric power system for stably supplying power while suppressing corona discharge generating ultraviolet radiation which may cause health problems in human beings. The corona discharge start voltage varies with the weather. Data on weather forecasts is inputted for each district at certain times so as to calculate the corona discharge estimated start voltage for each transmission line with a computer. If the calculation result predicts start of corona discharge at normal transmission voltage, the transmission voltage of the line is lowered or power transmission through the transmission line is stopped. Another method of solving the problem is to install corona discharge detecting means on transmission lines near places where people reside. If the detecting means detects corona discharge, the transmission voltage is lowered, or the transmission through the transmission line stopped.

Fig. 2



**Description**

## TECHNICAL FIELD

**[0001]** The present invention relates to an electric power system, and to an operating method therefor for stably supplying power while suppressing corona discharge which generates ultraviolet radiation which may cause health problems in humans. Objects are to provide an electric power system, a computer program product for the electric power system, a computer readable medium in which the computer program is recorded, a server in which the computer program is installed, and an operating method therefor.

## BACKGROUND ART

**[0002]** Fig. 8 shows a basic diagram of a large electric power system. As shown in Fig. 8, the large electric power system comprises basically electric power generation, transmission of the electric power, and distribution of the electric power. In other words, the electric power system comprises distribution electric power systems in which the main elements are power plants (generating stations), transmission lines, substations, distribution lines, etc., and corresponding control systems, that maintains normal operating conditions, in which the main elements are communication devices, protection devices, and control devices.

**[0003]** As shown in Fig. 8, an electric power system comprises power plants (generating stations) G1, G2 ... Gn, electric power transmission lines H1, H2 ... Hk, substations T1, T2 ... Tm, interconnected transmission lines C1, C2 ... Cj, distribution lines D1, D2 ... Dh, distribution substations U1, U2 ... Ua. The power plants (generating stations) G1, G2 ... Gn are nuclear power stations, hydropower plants, thermal power generation plants, etc. These plants are constructed far from large cities that use large amounts of electric power, due to difficulties in finding cost-effective sites near large cities.

**[0004]** The generated electric power is transformed to higher voltages (500KV, 275KV, 220KV, 187KV, etc.) to decrease transmission loss, and is transmitted to the outskirts of large cities by the electric power transmission lines H1, H2 ... Hk. The transmitted electric power is sent by the substations T1, T2 ... Tm and the interconnected transmission lines C1, C2 ... Cj. It is for the purpose of isolating imbalances in electric power consumption between districts, to integrate electric power generated by many kinds of electric power resources, to supply stable and economic electric power to the consumer.

**[0005]** The unified electric power is transformed to a lower voltage (154 KV to 22 KV), distributed to the distribution substations U1, U2 ... Ua by the distribution lines D1, D2 ... Dh and supplied to customers.

**[0006]** Electric power systems have been researched for a long time, and stable electric power can therefore be supplied to customers. Electric power is now a crucial base for industrial societies.

**[0007]** The corona discharge that appears when electric power is transmitted at high voltage has been researched, and it was found that the corona discharge may not appear, under common weather conditions, around the transmission and distribution lines.

**[0008]** However, research on the corona discharge on the fields of electric power systems are mainly directed to corona loss, corona noise, and apparatus damage from corona discharge. There is rarely research about corona discharge influences on the human body.

**[0009]** In 1979, Wertheimer and Leeper reported an association between childhood leukemia and certain features of the wiring connecting their homes to the electrical distribution lines. Since then, a large number of studies have been conducted to follow up this important result. Analysis of these papers by the US National Academy of Sciences in 1996 suggested that residence near power lines was associated with an elevated risk of childhood leukemia.

**[0010]** The opinion that the cause of the phenomenon was exposure to electric and magnetic fields at extremely low frequencies (less than 300 HZ, EML) became mainstream without notice. Therefore, the discussion about the phenomenon was limited to only whether the cause elevated risk of childhood leukemia was EML (like in witch-hunts in the Middle Ages in Europe).

**[0011]** In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields (EMF) Project to address health issues regarding exposure to EMF. The EMF Project is currently reviewing research results and conducting risk assessment of exposure to static and extremely low frequency (ELF) electric and magnetic fields.

**[0012]** The International Agency for Research on Cancer (IARC), a specialized cancer research agency of the WHO, concluded the first step in the WHO health risk assessment process by classifying ELF fields with respect to the strength-of-the-evidence that they could cause cancer in humans on June 2001. WHO Fact sheet No. 263 reported "Two recent pooled analyses of epidemiological studies provide insight into the epidemiological evidence that played a pivotal role in the IARC evaluation. These studies suggest that, in a population exposed to average magnetic fields in excess of 0.3 to 0.4  $\mu$ T, twice as many children might develop leukemia compared to a population with lower exposures." They also reported that "In spite of the large number of data base, some uncertainty remains as to whether magnetic field exposure

or some other factor(s) might have accounted for the increased leukemia incidence."

**[0013]** The first and largest epidemiological research was conducted to investigate the possible risk factors for child leukemia and brain tumors, the major childhood cancers, in Japan.

**[0014]** The research was conducted by the National Institute for Environmental Studies (NIES) supported by the Japanese Ministry of Education, Culture, Sports, Science and Technology. The final report of the research was published in July 2003.

**[0015]** According to the report, the first cases of acute lymphoid leukemia (ALL) and acute myeloid leukemia (AML), which are major cases of childhood leukemia, were investigated.

**[0016]** The report states as follows:

(1) The risk of childhood leukemia (ALL+AML) caused by magnetic field strength in a childhood bedroom does not rise until about 0.4  $\mu$ T. The risk begins to rise over 0.4  $\mu$ T. The adjustment odds ratio is 2.63 (95% confidence interval: 0.77-8.96). In the individual analysis case of childhood leukemia (ALL+AML), only the risk of ALL exhibited large increases above 0.4  $\mu$ T. The adjustment odds ratio is 4.73 (95% confidence interval: 1.14-19.7) and is significant.

(2) The risk of childhood leukemia (ALL+AML) at less than 50 m from a high voltage transmission line is significantly higher than that more than 100 m distant from a high voltage transmission line. Specially, the adjustment odds ratio of childhood leukemia (ALL+AML) based on the reference category, that the distance from a residence to the nearest high voltage transmission line is over than 100 m, are 1.56 (95% confidence interval: 0.87-2.91) at 50 to 100 m distance and 3.29 (95% confidence interval: 1.39-7.54) under 50 m distance.

**[0017]** In only the ALL case, the adjustment odds ratio of childhood leukemia (only ALL) is 1.36 (95% confidence interval: 0.70-2.65) 50 to 100 m distance and 3.69 (95% confidence interval: 1.47-9.21) under 50 m distance. These data suggests that the risk increases near high voltage transmission lines.

**[0018]** There is no consistent evidence that exposure to ELF fields experienced in the daily living environment causes direct damage to biological molecules, including DNA. Since it seems unlikely that ELF fields could initiate cancers, a large number of studies have been conducted to determine if ELF exposure can influence cancer promotion or co-promotion. Results from animal studies conducted so far suggest that ELF fields do not initiate or promote cancer. In 1998, a working group examining the issue for the US National Institute of Environmental Health Sciences (NIEHS) concluded that the scientific evidence of the risk to health humans by ELF magnetic fields is weak. In animal studies in Japan, the phenomenon of childhood leukemia due to ELF magnetic field exposure has not been observed. It is therefore believed that other factors will turn out to be the cause of the childhood leukemia.

**[0019]** The inventor's tests calculated the influence by the electromotive forces of 0.4  $\mu$ T ELF magnetic fields using electromagnetic theory. The inventor founded that the electromotive forces of 0.4  $\mu$ T are too weak to break DNA chains that were discovered by molecular biology. The inventor also founded that the joule heat generated by 0.4  $\mu$ T ELF magnetic fields is too small to influence the living body. Furthermore, there are many electrical home apparatus that generate ELF magnetic fields of more than 0.4  $\mu$ T.

**[0020]** When these facts were discussed at a symposium, a medical doctor stated incredulously:

"The magnetic field produced by a high voltage transmission line is different to the magnetic field produced by an electrical home appliance. Don't you know that?"

**[0021]** The theory stated by the medical doctor is not explained by present-day physics (electromagnetic theory, quantum mechanics, and elementary particle theory) and physical chemistry. So, the inventor decided to investigate the reference field. After the investigation, the inventor discovered the following.

(1) The corona discharge occurring around transmission lines causes the emission of ultraviolet light. The corona discharge changes from glow corona to brush corona to streaming corona as the voltage in the transmission line is increased. When the glow corona occurred, the emission of ultraviolet light was observed. However during the day, this is not observable due to the brightness of sunlight.

The collision of an electron and a nitrogen molecule causes a band of the nitrogen molecule to be excited at a wavelength of 202.3 nm excitation potential, or the nitrogen molecule becomes an ionized nitrogen molecule of ionization of wavelength of 80 nm ionization potential. Therefore, by the Frank-Condon principle, slightly longer wavelengths of ultraviolet light are emitted from the ionized or excited nitrogen molecules. If the kinetic energy of an accelerated electron is larger, the nitrogen molecule is excited to higher energy levels. Therefore, shorter wavelengths of ultraviolet light are emitted.

(2) According to the document 11, the wavelengths of 315 nm, 337 nm, 357 nm, 391 nm, and 427 nm in the ultraviolet are emitted in glow corona discharge, and wavelengths of 315 nm, 337 nm, and 357 nm ultraviolet are emitted in

stream corona discharge. In the document 12, wavelengths of 82.6 nm to 124.2 nm ultraviolet are reported.

(3) Ozone, NO gas, and NO<sub>2</sub> gas are generated during corona discharge. According to the document 13, wavelengths of 230 nm and 240 nm ultraviolet are emitted by NO gas. Nitrogen molecules and oxygen molecules are excited or ionized during corona discharge. If these ionized molecules collide with a transmission line, radio noise is generated. The voltage of beginning of corona discharge is much influenced by the weather, the scratches on the transmission lines of transmission lines and dew condensation of transmission lines.

(4) In the past, the radio or television noise generated by corona discharge and the acoustic noise generated by corona discharge were studied. The corona loss that is generated higher voltage than that of glow corona discharge is also studied well. However, the fact that ultraviolet light is emitted at the level of glow corona discharge has not been studied.

(5) Corona discharge continued for a long time because the maxim voltage of an electric field decreases when the corona discharge begins. Therefore, a human near the corona discharge has a high probability to be exposed for a long time to the ultraviolet light generated by the corona discharge.

**[0022]** In the Fact Sheet No. 205 of the WHO, there is a description about noise, ozone and corona. However, I suppose that the discussion of noise, ozone and corona was completed without the knowledge that corona discharge generates ultraviolet light. In the document, "Both the noise levels and ozone concentrations around power lines have no health consequence" is only reported. The ultraviolet light generated by the corona discharge was not mentioned. If there was no discussion of this matter, discussion should be resumed about the ultraviolet light generated by the corona discharge.

**[0023]** The high voltage transmission lines generate extremely low frequency electric and magnetic fields and also generate harmful ultraviolet light when corona discharge begins.

**[0024]** There was a rumor that ultraviolet light was regarded good for health for a period, and was not subject to much notice. Lately the effects on human health by ultraviolet light have been examined more seriously. The effect on the skin, eyes and the immune system has been noted.

**[0025]** Children are at especially high risk of suffering damage from exposure to ultraviolet radiation. Fact Sheet N-261 was published on July 2001 by the WHO. However, the exposure limit to ultraviolet radiation was not indicated by the WHO.

**[0026]** According to the theory of quantum mechanics, an electromagnetic wave of wavelength  $\lambda$  has energy of  $hc/\lambda$  where  $h$  is Planck's constant and  $c$  is the speed of light. According to document No. 17, since the wavelength of ultraviolet light is very short, ultraviolet light has very high energies and can damage the DNA in living things.

**[0027]** Ultraviolet light is divided into UV-A (400 nm to 315 nm), UV-B (315 nm to 280 nm), and UV-C (280 nm to 100 nm) in the order from the longest wavelength.

**[0028]** The ultraviolet light of solar radiation is progressively filtered as sunlight passes through the atmosphere, in particular by ozone and oxygen molecules. Therefore, on the Earth's surface we can only observe UV-A and weakened UV-B. Consequently, the report about the influence of ultraviolet light to human health is in ordinary discussed about UV-A and UV-B that reach the Earth's surface. It is reported that UV-B is harmful and damages DNA and weakens immune equation. UV-C is used for sterilization. It is extremely dangerous to expose the human body to UV-C radiation. As mentioned above, the ultraviolet light generated from corona discharge contains UV-B and UV-C. The UV-B is absorbed by ozone and the UV-C is absorbed by ozone and oxygen molecules. The UV-B extends far from the corona discharge generating area, because ozone density is low outside of the corona discharge generated area. The UV-C is greatly absorbed by oxygen molecules that are common at the Earth's surface. However, the UV-C extends up to 200 m to 300 m from the corona discharge generated area.

**[0029]** Therefore, the residences nearer to the corona discharge generated from transmission lines seriously suffered from exposure to ultraviolet light (particularly UV-B and UV-C) generated from corona discharge, because corona discharge sometimes continues for a long time.

**[0030]** From the molecular biology perspective, the DNA of the human body is damaged by UV-B and UV-C. However, the damaged DNA is normally repaired by several repair systems in the human body.

**[0031]** The repair systems in children are sometimes not effective. If children are exposed on UV-B and UV-C for a long time, it may be beyond the repair limit.

**[0032]** In addition, ultraviolet light influences the immune system of the human body. The mechanism by which ultraviolet light decreases the immune system is considered to be as follows.

**[0033]** In the epidermis of the skin, there are many Langerhans cells having the shape of a spread palm. The Langerhans cell obtains the information that a foreign object has entered the human body, then moves to a lymph node and transmits the information to lymphocytes for the lymph node dealing with the foreign object.

**[0034]** If the Langerhans cells are destroyed by ultraviolet light, it is difficult to obtain the foreign object invasion information. The lymphocytes can not receive the information, and the immune system cannot equate.

**[0035]** According to the above research, the corona discharge generates ultraviolet light even at the glow corona level.

The ultraviolet light contains UV-B and UV-C that are harmful to the human body. If humans are living near high voltage transmission lines, the same symptoms as exposure to harmful ultraviolet light are expected. UV radiation is classified as probably carcinogenic to humans (usually based on strong evidence of carcinogenicity in animals) in WHO Fact Sheet NO. 263.

**[0036]** According to the above facts, I believe that the risk of childhood leukemia near high voltage transmission lines, which is admitted by the epidemiologic research, is mainly caused by harmful ultraviolet light generated by corona discharge.

**[0037]** Therefore, it is necessary to stop corona discharge, even at the glow corona level, by decreasing the transmission voltage rapidly. It is also important to maintain the trust that electric power is safe and convenient. The trust is established by long term efforts by electrical engineers.

**[0038]** I cannot find documents regarding suppressing corona discharge for stopping ultraviolet light generation. There are several documents about suppressing corona discharge for the prevention of damaging power apparatuses, prevention of broadcasting noise, and reducing corona power loss.

Patent document 1: Japanese Unexamined Patent Application Publication No. H11-038078

Patent document 2: Japanese Unexamined Patent Application Publication No. H10-038957

Non-Patent Document 1: Japan Electrical Engineering Handbook Sixth Edition, pages 485 to 486, 1005 to 1023, and 1225 to 1226

Non-Patent Document 2: Japan Electrical Engineering, Ionized Gas Discussion, pages 28 to 51, and 103 to 114

Non-Patent Document 3: World Health Organization (WHO) Fact Sheet No. 263, Electromagnetic fields and public health: extremely low frequency fields and cancer

Non-Patent Document 4: World Health Organization (WHO) Fact sheet No. 205, Electromagnetic fields and public health: extremely low frequency (ELF)

Non-Patent Document 5: World Health Organization (WHO) Fact sheet No. 261, Protecting Children from Ultraviolet Radiation.

Non-Patent Document 6: The National Institute for Environmental Studies (NIES), Epidemiologic study on childhood cancers in Japan (1999 - 2002), by Dr. Michinori Kabuto

Non-Patent Document 7: Central Research Institute of Electric Power Industry, CRIEPI Review, No. 47 page 56

Non-Patent Document 8: Central Research Institute of Electric Power Industry, A Study on Audible Noise from AC and DC Transmission Lines, by M. Fukushima

Non-Patent Document 9: Central Research Institute of Electric Power Industry, Corona Effects of UHV AC Overhead Transmission Lines, by T. Sasano, S. Tomita, K. Tanabe, Y. Deguchi, and H. Harada

Non-Patent Document 10: Maruzen Ltd., Molecular Biology, by Seiichi Tanuma, page 81

Non-Patent Document 11: Muroran Institute of Technology, Decomposition Characteristics of Benzene in Flue Gas by Corona Discharge Plasma, by Kohki Satoh, Nobuyuki Yoshizawa, Hidenori Itoh, Hiroaki Tagashima, and Mitsue Shimosuma.

Non-Patent Document 12: Tables of Vacuum Ultraviolet Emission Bands of Molecular Nitrogen from 82.6 to 124.2 nm, by J-Y. Roncin and F. Launay, A&A Supplement series, Vol. 128, March 1, 1998, pages 361 to 362

Non-Patent Document 13: Texas Instruments, Use of Spectrograph-based OES for SiN Etch Selectivity and Endpoint Optimization, by F.G. Celii and C. Huffman, et al.

Non-Patent Document 14: Health Guidance Manual against Ultraviolet Light, Japan Ministry of The Environment home page

Non-Patent Document 15: DHC Shuttpan, Children, Skin and Sun, by Ichihashi Masamitsu

Non-Patent Document 16: <http://www.intl-light.com> Light Measurement Handbook, by Alex Ryer

Non-Patent Document 17: Oxford University Press, PHYSICAL CHEMISTRY Sixth Edition, by P.W. Atkins

## DISCLOSURE OF THE INVENTION

### Objects of the Invention

**[0039]** An object of the invention is to provide the electric power system stably supplying electric power while suppressing corona discharge that generates ultraviolet light which is harmful to the human body (for example, the cause of childhood leukemia). The corona discharge start voltage varies with the weather, the level of scratches when the transmission lines were wired, and the level of weathering of wires. Therefore, it is not economical to set a low transmission voltage for the whole system to stop the corona discharge, because the transmission capacity is extremely limited.

**[0040]** It is also not practical to detect corona discharge over the entirety of the power transmission lines that is wired over extremely long distances. It is desirable to suppress corona discharge practically, economically, and effectively.

## SUMMARY OF THE INVENTION

**[0041]** In this invention, the data which are related to the beginning of corona discharge on each transmission line are recorded in a memory means in advance. Data on weather forecasts is inputted for each district at predetermined time intervals so as to calculate the estimated corona discharge start voltage for each transmission line with a computer. If the calculated corona discharge beginning voltage of a transmission line is lower than the normal transmission voltage of the line, the countermeasures of the transmission voltage that are recorded in the memory means in advance are selected to set transmission voltage of the transmission line. The calculation of the estimated corona discharge start voltage and selecting of set transmission voltage are executed on all transmission lines in the electric power system. The set transmission voltage data are inputted to a power system analysis means. The power system analysis means analyze the load of the apparatuses of the power system. According to the analysis result, specific countermeasures are adopted by the apparatuses of the power system. Therefore, an electric power system for stably supplying power while suppressing corona discharge is achieved.

**[0042]** Another method of this invention for solving the problem is to install a corona discharge detecting means and a sending means which sends the detected data, on transmission lines near places where people reside. If the means detects corona discharge, the sending means sends the detected data to a power system analysis means. The power system analysis means analyze the load of the apparatuses of the power system under the conditions that the transmission voltage of the detected line is lowered, or the transmission through the detected transmission line stopped. According to the analysis result, the specific countermeasures are adopted to the apparatuses of the power system. Therefore, an electric power system for stably supplying power while stopping the generation of ultraviolet radiation, which is harmful to humans, on short time is achieved.

**[0043]** By this invention, the corona discharge that continues for a long time and generates harmful ultraviolet light is suppressed for power transmission lines.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0044]**

- Fig. 1 is a block diagram of a preferred mode for carrying out this invention.
- Fig. 2 is a process flow chart of a digital processing unit in this invention.
- Fig. 3 is an example of weather forecast data.
- Fig. 4 is an example of data on transmission lines.
- Fig. 5 is an example of data of transmission voltage set for transmission lines.
- Fig. 6 is a block diagram of example 3 for carrying out this invention.
- Fig. 7 is a block diagram of another example for carrying out this invention.
- Fig. 8 is a basic diagram of a large electric power system.

## PREFERRED MODE FOR CARRYING OUT THE INVENTION

**[0045]** An electric power system comprises a weather data input means which inputs weather data, for example temperature, atmospheric pressure and weather, etc., at the district of each operating transmission line, memory means which stores each transmission line data and processed data by digital processing unit, digital processing unit which calculates corona discharge start voltage of each transmission lines and decides set transmission voltage of the transmission line, adjust apparatuses which adjusts each line transmission voltage to the set transmission voltage, and a power system analysis means.

**[0046]** Data on weather forecasts is inputted for each district at predetermined time intervals. The digital processing unit calculates the estimated corona discharge start voltage for each transmission line by the data in weather forecasts. If the calculated corona discharge start voltage of a transmission line is lower than the normal transmission voltage of the line, the countermeasures transmission voltage that is recorded in memory means in advance is selected to set transmission voltage of the transmission line. If the calculated corona discharge start voltage of a transmission line is above the normal transmission voltage of the line, the normal transmission voltage is selected to set the transmission voltage of the transmission line.

**[0047]** The power system analysis means analyze the load of the apparatuses of the power system. According to the analysis result, specific countermeasures are adopted to the apparatuses of the power system. Therefore, the electric power system can stably supply electric power economically and effectively while suppressing corona discharge.

**[0048]** An electronic computer comprises weather data input means which inputs weather data, for example temperature, atmospheric pressure and weather, etc., at the district of each operating transmission lines, memory means which stores each transmission line data, digital processing unit which calculates corona discharge start voltage of each



transmission line, deciding means which sets transmission voltage of the transmission line, and output means which outputs each line's set transmission voltage.

[0049] In the computer, the computer program product comprises data on weather forecasts being inputted step, calculating the estimated corona discharge start voltage for each transmission line by the data on weather forecasts step, if the calculated corona discharge start voltage of a transmission line is lower than the normal transmission voltage of the line, the countermeasures transmission voltage that is recorded in memory means in advance being selected to set transmission voltage of the transmission line step, if the calculated corona discharge start voltage of a transmission line is above the normal transmission voltage of the line, the normal transmission voltage being selected to set transmission voltage of the transmission line step, outputting or sending the set transmission voltage of all transmission lines step.

[0050] By adopting the set transmission voltage of all transmission lines that do not generate corona discharge, the total automated operating system of electric power can stably supply electric power economically and effectively while suppressing corona discharge.

[0051] In an electric power system, a corona discharge detecting means are installed on transmission lines near places where people reside, and a sending means sends the detected data to a power system analysis means. If the detecting means detects corona discharge, the transmission voltage is lowered, or the transmission through the transmission line is stopped.

[0052] In the electric power system, recalculation of transmission route is performed for stably supplying power.

[0053] The corona discharge detecting means comprises a device that detects ultraviolet level electromagnetic waves. The corona discharge detecting means is set so as to receive the ultraviolet light that is generated by corona discharge on the target transmission line. In this case, the corona discharge detecting means has to perform detection during the day. Therefore, the ultraviolet light that is generated by corona discharge has to be distinguished from that from the Sun. A Solar-Bind Vacuum Photodiode is desirable as the device.

## First Embodiment

[0054] Fig. 1 is block diagram of a preferred mode for carrying out this invention. Fig. 2 is the process flow chart of digital processing unit in this invention. Fig. 3 is an example of weather forecast data. Fig. 4 shows an example of data on transmission lines. Fig. 5 is an example of data of transmission voltage set for transmission lines.

[0055] In the embodiment of Fig. 1, weather data input means 7, digital processing unit 8 and memory means 9 are added to the basic structure of large electric power system shown in Fig. 8. Moreover, power system analysis means 10 and transmission voltage regulating means 11 are need to be changed as much as to operate by the set transmission voltage that is after described below.

[0056] The weather data input means 7 is the means that inputs weather forecast data to digital processing unit 8, and it is possible to realize this by connecting a commercial modem (for example, NEC Aterm IT21L) to a personal computer as shown in Fig. 3.

[0057] The digital processing unit 8 is the device that processes the Fig. 2 flow chart process, and it is possible to realize this by personal computer which has more than an 8 bit central processing unit. The digital processing unit 8 may also realize this by a digital signal processor.

[0058] The memory means 9 is a means that stores each transmission line data and processed data by digital processing unit 8. The memory means may be realized by a hard disk drive, semiconductor memory, etc. The memory means may use personal a computer internal memory.

[0059] According to Fig. 8, the processing details of the digital processing unit 8 are explained. When the software of the digital processing unit 8 starts, the digital processing unit 8 sets n to 1 at first (S10). Next, the digital processing unit 8 inputs weather forecast data by the weather data input means. The weather forecast data are temperature, atmospheric pressure and weather of the set district of each transmission lines are desirably input every 2 hours. Thereafter, the data of first recorded transmission line 21 is read from the memory means 9 (S30). The example data of each transmission line are shown in Fig. 4. The contents of the data of each transmission line are Object for which corona discharge is to be suppressed or not, Use past data, Normal transmission voltage, area where set up, Surface coefficient of wire m0 and coefficient k that is decided by the design of transmission line, and Countermeasures voltage. These data are pre-recorded in memory means 9. The reason for setting the data of the object for which corona discharge is to be suppressed or not is that some transmission lines are laid in nonresidential areas and is not a problem to human health. The reason for setting the data of Using past data or not is that in the case of actual corona discharge observation executed, the actual data and that conditions should be recorded. Some transmission lines are so long that the area where set up, are more than two areas.

[0060] It is decided that the transmission line is the object for which corona discharge is to be suppressed or not (S40). If the transmission line is not the object, the normal transmission voltage that has been recorded is set for transmission voltage (S100). If the transmission line is the object, it is decided by the digital processing unit 8 using read data whether

the past data should be used or not. If the past data should be used, the past data recorded in memory means is used for corona discharge start voltage (S60).

**[0061]** If the past data cannot be used, the corona discharge start voltage  $V_0$  of the transmission line is calculated by substituting the weather forecasts data and the transmission data for an equation. The equation is desirably the following equation 1 and equation 2. Here,  $m_1$  is a weather coefficient that is now 1.0 on a fine day and is 0.8 on a rain, snowy day, or a foggy day. It is desirable to decide more accurately one according to actual data collection,  $m_0$ : surface coefficient of wire,  $k$ : the coefficient decided by structure,  $r$ : radius of the element wire of transmission wire (cm),  $b$ : atmospheric pressure (hPa),  $t$ : temperature (C).

[Equation 1]

$$V_0 = 1.178 m_0 k m_1 \delta^{2/3} (1 + 0.301 / \sqrt{r \delta})$$

[Equation 2]

$$\delta = 0.290 b / (273 + t)$$

**[0062]** The corona discharge start voltage  $V_0$  is compared with the normal transmission voltage  $V_n$  (S80). If the normal transmission voltage  $V_n$  is equivalent or lower than the corona discharge start voltage  $V_0$ , pre-stored countermeasures voltage is set for set transmission voltage (S90). On other cases, the normal transmission voltage  $V_n$  is set for set transmission voltage (S100). Then, the set transmission voltage of the first transmission line is recorded to memory means 9 (S110). Then, it is checked if all transmission lines have been set or not (S120). If all transmission lines have not been set, 1 is added to  $n$  (S130), and next transmission line data is read (S30). In this way, one after another transmission voltages of the transmission lines are set. If the set transmission voltage of all transmission lines (object are the transmission lines that the phase voltage is more than 22kV, is anticipated to generate corona discharge) have been set, these data are sent to the power system analysis means 10.

**[0063]** The power system analysis means 10 decides the load of the apparatuses of the power system in the condition of the set transmission voltage of all transmission lines. According to the analysis result, the load of each apparatuses of the power system is ordered to these apparatuses. The voltage of the transmission lines are adjusted by the transmission voltage regulating means 11. Therefore, the corona discharge generation on the transmission lines is suppressed in advance. Another advantage is that the electric power system can stably supply because analysis of stable power supply is made in advance. Second Embodiment

**[0064]** Another embodiment of this invention is computer program which comprises weather data input means, memory means, digital processing unit and output means and has the same function of Fig. 2. In this embodiment, the all transmission line's set transmission voltages which are calculated using the computer program are entered to an electric power system. Then, it is possible to get same effect as first embodiment. The computer readable memory device which stores the computer program or the server in which the computer program is stored is possible to electric power supply company for embodiment. Third Embodiment

**[0065]** Fig. 6 is a block diagram of example 3 for carrying out this invention. In this embodiment, corona discharge detect means 12, digital processing unit 13 and transmitter 14 are added to the basic structure of large electric power system shown in Fig. 8. In addition, power system analysis means 10-2 and transmission voltage regulating means 11-2 in the basic structure are need to change a little as described later.

**[0066]** The corona discharge detect means 12 is the means for detecting the occurrence of corona discharge at a transmission line. The corona discharge detect means 12 is most desirable in that the ultraviolet light detecting device which is installed near places where people reside has minimal effect conventional electric power systems.

**[0067]** A Solar-Blind Vacuum Photodiode is most desirable as the ultraviolet light detecting device at the present time. However a semiconductor photo-diode, a phototube, a photoconductive sensor, a photovoltaic sensor, etc. may be used as the ultraviolet light detecting device. A special filter to distinguish the ultraviolet light from the sun may be used to intercept the ultraviolet light from the sun, so as to detect only the ultraviolet light generated by corona discharge.

**[0068]** The corona discharge detect means 12 more detects effectively whether or not corona discharge occurring that is harmful to humans, by detecting wavelengths of 100 nm to 320 nm (UV-C, UV-B) which are especially harmful to humans. The corona discharge detect means 12 may also be realized by a device for detecting corona noise or a device for detecting a corona sounds.

**[0069]** Digital processing unit 13 converts information detected by the corona discharge detect means 12 into information which is needed by a superior power system analysis means 10-2. The digital processing unit 13 may be realized by a circuit that uses a generally available micro-computer and associated software. The transmitter 14 transmits information converted by the digital processing unit 13 to the power system analysis means 10-2. The transmitter 14 may be realized by wired or wireless means, or by other equivalent means.

**[0070]** When the occurrence of corona discharge at a transmission line that is being surveyed is detected by the corona discharge detect means 12, the fact that the corona discharge has occurred is converted into information needed by the power system analysis means 10-2. The converted information is transmitted to the power system analysis means 10-2 by the transmitter 14.

**[0071]** The power system analysis means 10-2 analyzes other conditions necessary for the power system based on the transmitted information, determines the load on each device, and issues orders to each device. The transmission voltage regulating means 11-2 also receives orders as part of this issuing of orders ordering. The transmission voltage regulating means 11-2 lowers the transmission voltage of the corona discharge detected transmission line according to the orders. Another method is to stop transmission in the transmission line in which the corona discharge is detected. As a result transmission voltage of the transmission line decreases, and the corona discharge stops. If the corona discharge does not stop, the information from corona discharge detection means 12 and the information which has been stored in memory means 15 are again transmitted to the power system analysis means 10-2.

**[0072]** The power system analysis means 10-2 analyzes based on re-transmitted information the power system and determines the load on each apparatuses, and issues order to apparatuses.

**[0073]** The transmission voltage regulating means 11-2 further decreases the transmission voltage of the corona discharge detected transmission line according to the orders.

**[0074]** As a result the transmission voltage of the corona discharge detected transmission line further decreases, and the corona discharge stops.

**[0075]** Therefore, the corona discharge on the detected transmission line is stopped in a short time. Another advantage is that the electric power system can stably provide power supply because the analysis of the power system is made before decreasing the transmission voltages.

**[0076]** However, it is uneconomical to adopt lowered transmission voltages even if the condition has changed so that corona discharge is not generated. An easy method for solving of this problem consists of returning to the previous transmission voltages at the predetermined time (roughly when weather changes) after decreasing the transmission voltages. If the corona discharge is not generated with the previous transmission voltages, the previous transmission voltages are maintained. If the corona discharge is generated with the previous transmission voltages, the same step as in the corona discharge generation mentioned above is adopted.

**[0077]** Fig. 7 is a block diagram of another example for carrying out this invention.

**[0078]** A weather detecting means 16 is added to the construction of Fig. 6. The weather detecting means 16 is a means for detecting the weather conditions that affect the corona discharge generation voltages, for example temperature, pressure, humidity, etc. The means to send the information which the weather detecting means 16 gets to the digital processing unit 13 is also contained in the weather detecting means 16. The detection of temperature, pressure, humidity, etc., are realized by selecting for each a proper device from the prior art.

**[0079]** When the corona discharge detecting means 12 detects the corona discharge, the weather detecting means 16 detects the weather conditions. The information detected by the weather detecting means 16 is converted by the digital processing unit 13. The converted information is then stored in memory means 15.

**[0080]** After the corona discharge is stopped by the step mentioned above, the transmission voltage is changed to the previous one, the weather conditions which are newly detected by the weather detecting means 16 are different from the stored weather conditions and are assumed not to generate corona discharges.

**[0081]** In addition, the conditions data which the corona discharge generates for each transmission line are stored in memory means 15. The stored data may be used as past data in the first embodiment of this invention.

**[0082]** While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention.

**[0083]** For example, the electric power system is described as being large scale. This invention is adaptable to smaller scale electric power systems. In a system, partly human operations are possible for this invention.

**[0084]** In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed for carrying out this invention, but that the invention will include all embodiments

falling within the scope of the appended claims.

## Claims

1. An electric power system comprising:

a weather data input means for inputting weather data, temperature, atmospheric pressure and weather, in the district of an operating transmission line;  
a memory means for storing said transmission line data and processed data by a digital processing unit;  
a digital processing unit for calculating corona discharge start voltage of said transmission lines and deciding set transmission voltage of the transmission line; and  
a power system analysis means;

characterized in that:

data on weather forecasts is inputted for the district at predetermined time intervals,  
the digital processing unit calculates the estimated corona discharge start voltage for said transmission line by the data on weather forecasts,  
if the calculated corona discharge start voltage of the transmission line is lower than a normal transmission voltage of the line, countermeasure transmission voltage that is recorded in memory means in advance is selected to set transmission voltage of the transmission line or stop the transmitting electric power on the transmission line,  
if the calculated corona discharge start voltage of the transmission line is above the normal transmission voltage of the line, the normal transmission voltage is selected as the set transmission voltage of the transmission line, the power system analysis means analyzes the load of apparatuses of the power system, and according to an analysis result, the electric power system operates the apparatuses and transmits electric power.

2. An electronic computer comprising:

a weather data input means for inputting weather data, temperature, atmospheric pressure and weather, in the district of an operating transmission line;  
a memory means for storing said transmission line data and processed data by digital processing unit;  
a digital processing unit for calculating corona discharge start voltage of said transmission line and deciding set transmission voltage of the transmission line; and  
an output means for outputting and transmitting the set transmission voltage of the transmission line; including;  
a step of inputting weather data,  
a step wherein the digital processing unit calculates a estimated corona discharge start voltage for said transmission line, by the weather data,  
a step wherein if the calculated corona discharge start voltage of the transmission line is lower than a normal transmission voltage of the line, countermeasure transmission voltage is selected as the set transmission voltage of the transmission line,  
a step wherein if the calculated corona discharge start voltage of the transmission line is above the normal transmission voltage of the line, the normal transmission voltage is selected as the set the transmission voltage of the transmission line, and  
a step of outputting and sending the set transmission voltage of all the transmission lines.

3. A computer readable storage medium, for storing the program of claim 2.

4. A server for storing the program of claim 2.

5. An electric power system comprising:

a corona discharge detection means;  
a weather detecting means;  
a transmitter;  
a digital processing unit; and

a power system analysis means;

including;

5        stopping corona discharge in a short time by lowering the transmission voltages of a transmission line that generates corona discharge, or stopping transmitting electric power in the transmission line;  
adjusting loads of apparatuses in the electric power system; and  
operating the apparatuses under an adjusted condition for supplying electric power.

10      **6.** The electric power system according to claim 5,  
Further comprising:

15        storing weather conditions before and after occurrence of corona discharge, and  
changing the transmission voltage to a previous one, when the weather conditions are assumed not to generate  
corona discharge.

**7.** The electric power system according to claim 5, wherein said corona discharge detection means is an ultraviolet light detecting device.

20      **8.** The electric power system according to claim 5, wherein said corona discharge detection means is the ultraviolet light detecting device that detects wavelength 100 nm to 320nm ultraviolet light.

**9.** The electric power system according to claim 5, wherein:

25        the previous transmission voltage is restored a predetermined time after lowering the transmission voltages.

**10.** An electric power system operating method comprising:

30        a weather data input means for inputting weather data, temperature, atmospheric pressure and weather;  
a memory means for storing said transmission line data and processed data, by a digital processing unit;  
a digital processing unit for calculating corona discharge start voltage of said transmission line and deciding set transmission voltage of the transmission line; and  
a power system analysis means;

35      **characterized in that:**

40        data on weather forecasts is inputted at predetermined time intervals,  
the digital processing unit calculates the estimated corona discharge start voltage, by the data on weather forecasts,  
if the calculated corona discharge start voltage of the transmission line is lower than the normal transmission voltage of the line, a decision is made to make countermeasure transmission voltage that is recorded in memory means in advance a set transmission voltage of the transmission line or to stop transmitting electric power on the transmission line,  
45        if the calculated corona discharge start voltage of the transmission line is above the normal transmission voltage of the line, the normal transmission voltage is selected as to set the transmission voltage of the transmission line,  
said power system analysis means analyzes the load of the apparatuses of the power system, and  
according to an analysis result, the electric power system operates the apparatuses and transmits electric power.

50      **11.** An electric power system operating method comprising:

55        a corona discharge detection means;  
a weather detecting means;  
a transmitter;  
a digital processing unit; and  
a power system analysis means;

including the step of;

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stopping corona discharge in a short time by lowering the transmission voltages of a transmission line that generates corona discharge, or stopping transmitting electric power in the transmission line, adjusting loads of apparatuses in the electric power system, and operating the apparatuses under an adjusted condition for supplying electric power.

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Fig. 1

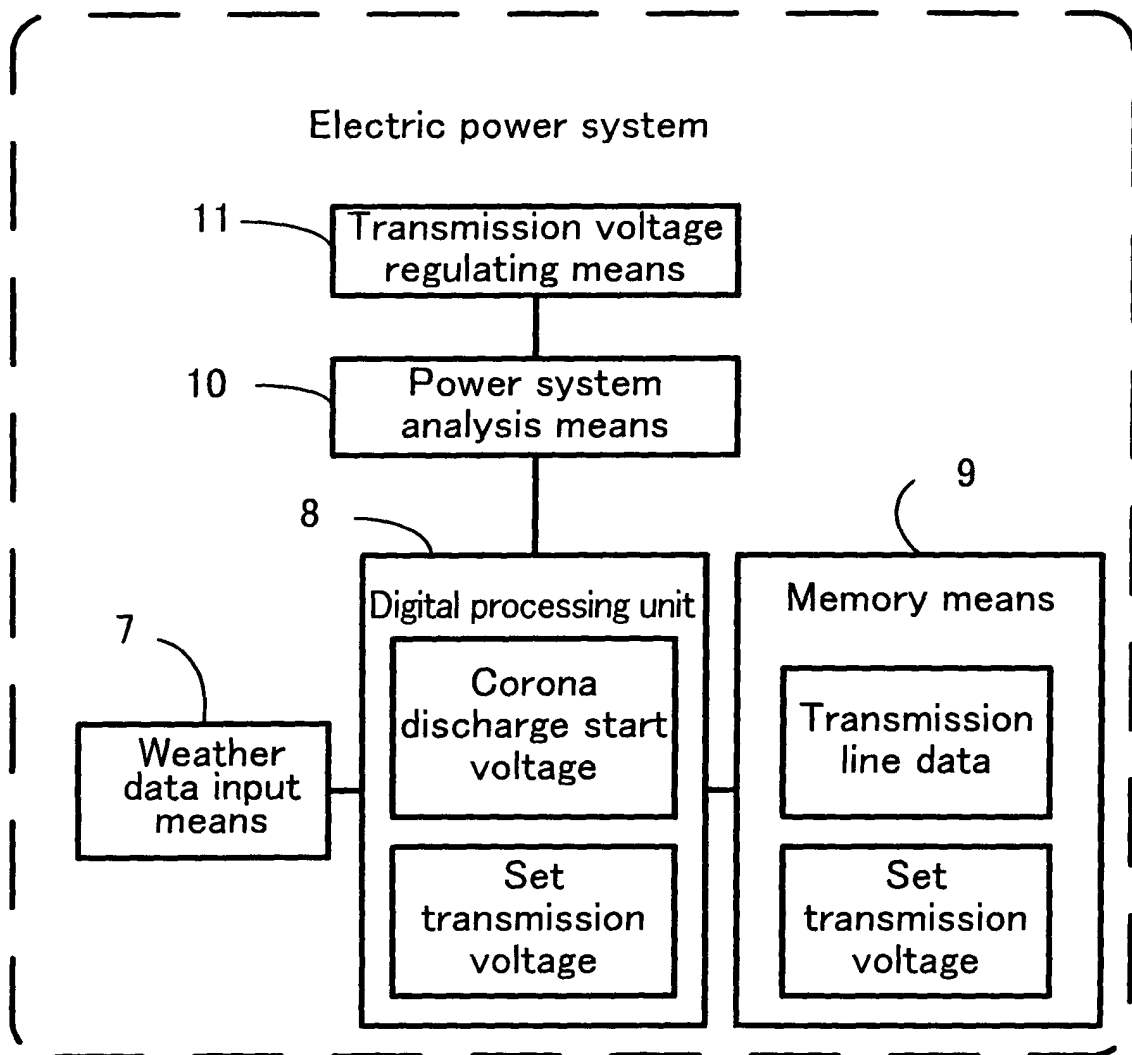


Fig. 2

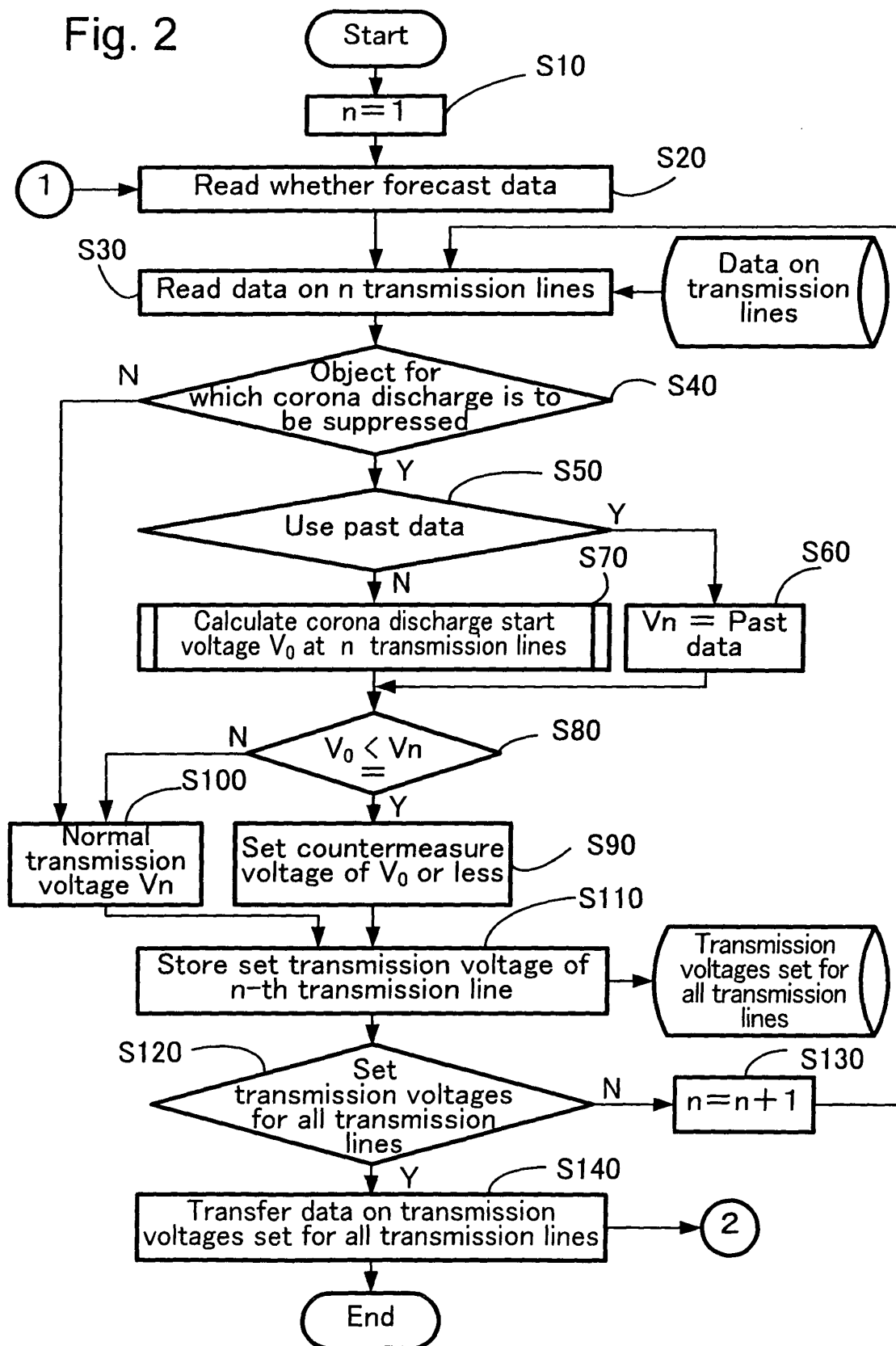




Fig.3

area	a	b	c	...
Temperature (C)	17	21	20	...
Pressure (hP)	1006	1020	1002	...
Weather	Rain	Fine	Drizzle	...

Fig. 4

Transmission Line	H1	...	Hk	C1	...	Cj	D1	...	Dh
Object for which corona discharge is to be suppressed	Y	...	N	Y	...	Y	Y	...	N
Use past data	N	...	—	N	...	Y	N	...	—
Past data (KV)	—	...	—	—	...	Rain 185	—	...	—
Normal transmission Voltage (KV)	500	...	275	220	...	220	154	...	22
Area where set up	ab	...	i	h	...	k	l	...	n
$m_0 * k$	0.96	...	—	0.80	...	—	0.68	...	—
Measures voltage 1 (KV)	480	...	—	190	...	180	100	...	—
Measures voltage 2 (KV)	450	...	—	170	...	170	90	...	—

Fig. 5

Transmission Line	H1	...	Hk	C1	...	Cj	D1	...	Dh
Set transmission voltage (KV)	480	...	275	190	...	180	100	...	22

Fig. 6

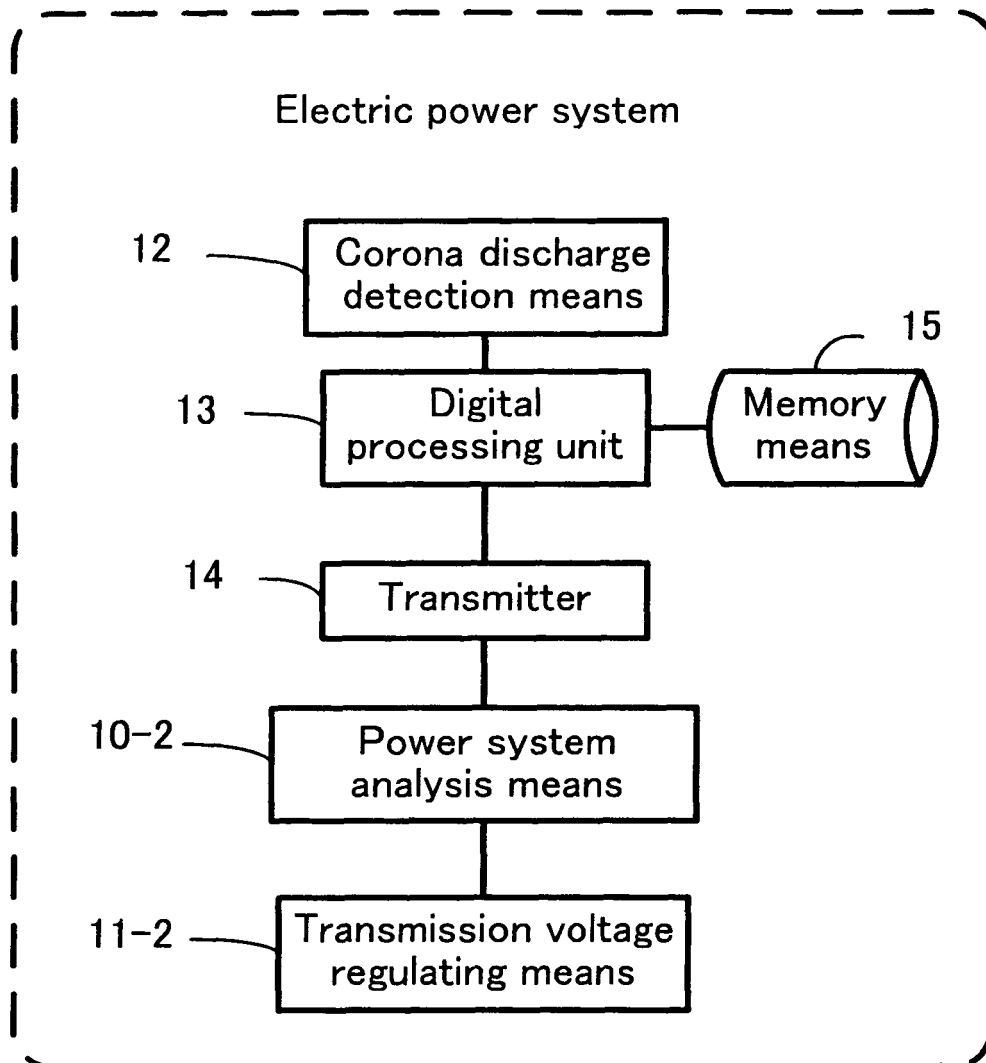


Fig. 7

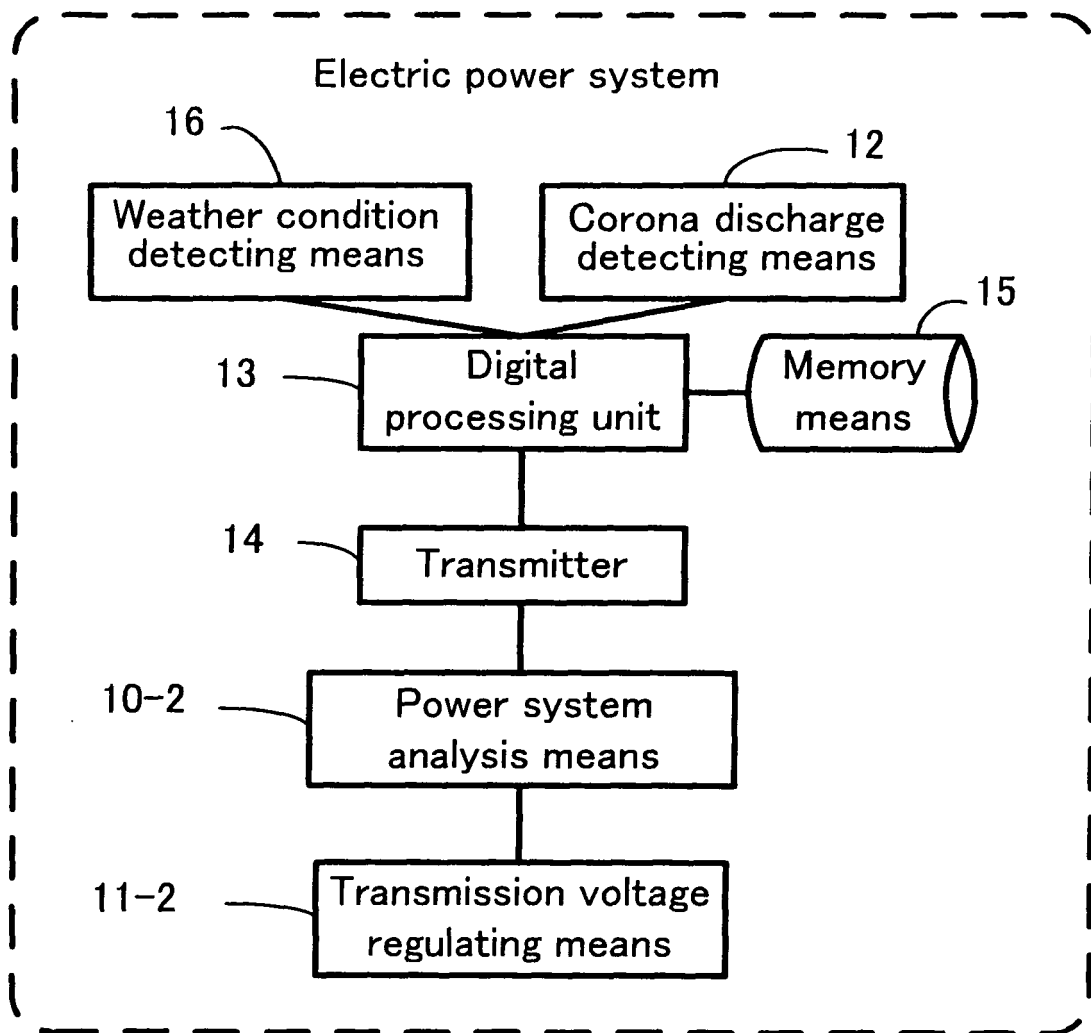
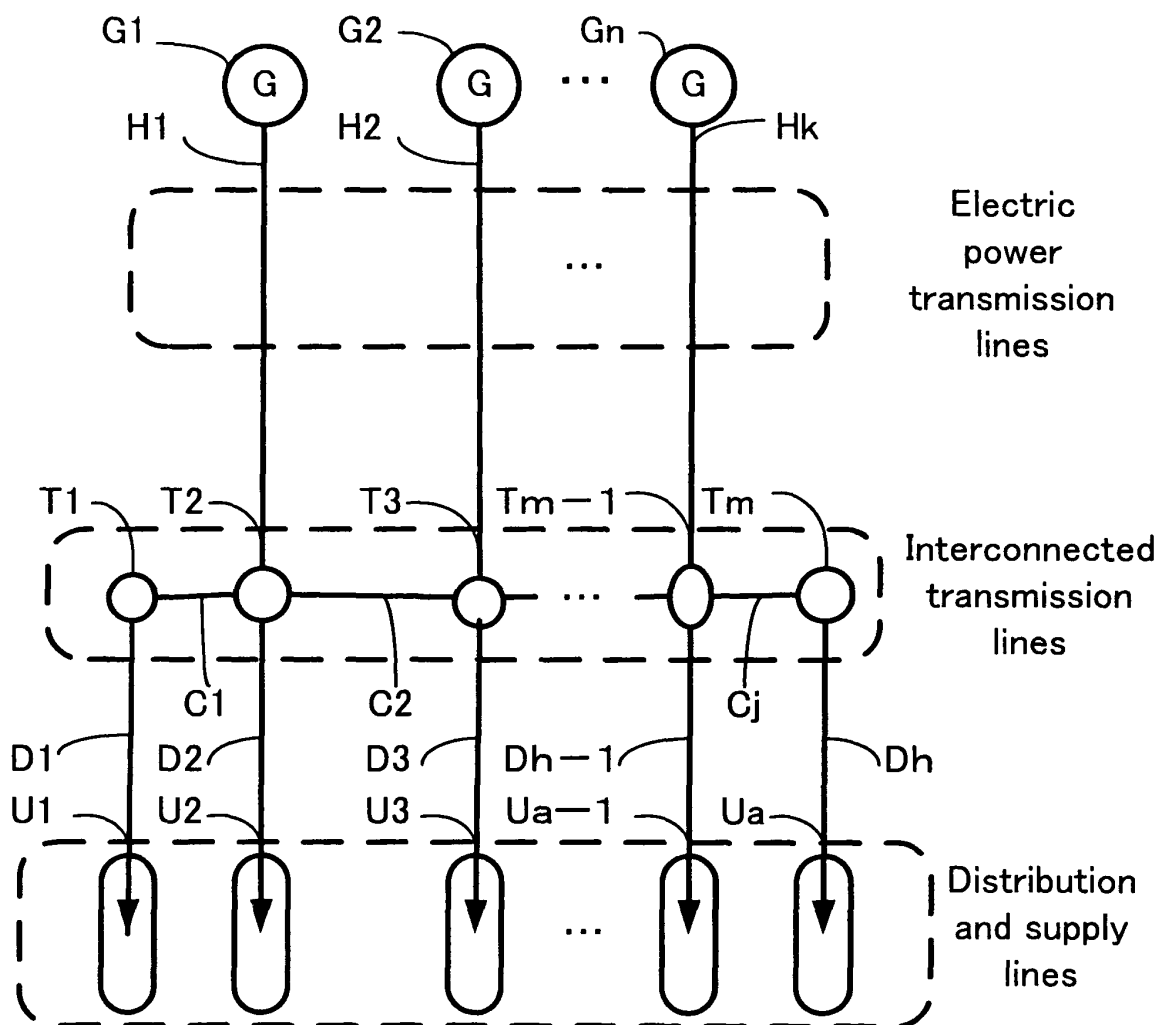


Fig. 8



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/016153

A. CLASSIFICATION OF SUBJECT MATTER  
Int.Cl.<sup>7</sup> H02J3/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl.<sup>7</sup> H02J3/00-5/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005

Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E, A	JP 2004-127857 A (Sankusu Kabushiki Kaisha), 22 April, 2004 (22.04.04), Full text; Fig. 1 (Family: none)	1-11

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

## \* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&amp;" document member of the same patent family

Date of the actual completion of the international search  
25 January, 2005 (25.01.05)Date of mailing of the international search report  
08 February, 2005 (08.02.05)Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

# The Ultraviolet Detection of Corona Discharge in Power Transmission Lines

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## ABSTRACT

Corona discharge is a common phenomenon in power transmission lines external insulation, and it may cause serious defect if without effective detection. The ultraviolet (UV) imagery technology has been widely used to detect the corona discharge in industry in recent years, but some influence factors' functions are not definite. In this paper, the fracture aluminum strands which is common in power transmission lines were used as the electrode model while a SuperB ultraviolet imager were utilized to detect, the photon count rate was detected with different detect distance, electric field, aluminum strands length and UV gain were applied. Then the multivariate regression analysis (MRA) was taken to calculate the function between the photon count and the factors.

**Keywords:** Corona Discharge; Transmission Lines; Defect Detection; UV Imager; Multivariate Regression Analysis

## 1. Introduction

With the development of Extra High Voltage (EHV) and Ultra High Voltage (UHV), the electromagnetic environment problem caused by corona discharge of conductor was paid attention increased [1-3]. The corona discharge could generate the negative phenomenon such as radio interference, audible noise, ozone-forming, electrochemical reaction [4-6]. The detection of the defect of the corona discharge has been added to the daily inspect in transmission lines in recently years [7].

The corona discharge in the transmission lines often occurred at the high voltage terminal of amour clamp, split clamp, conductor surface and the end of fractured aluminum strands caused by lightning stroke or conductor galloping. And the influence of fractured aluminum strands is extra clear, it not only generate corona discharge by distort the electric field at the end of the strands, but also make a bad influence on the mechanical behavior of the conductor, the defect would make serious harm to transmission security if without fix timely [8]. So it is important to find and fix fractured aluminum strands at the early stage in transmission lines patrol.

The traditional ovular estimate and infrared thermography technology don't have well effect on the fractured aluminum strands detection. For the ovular estimate, people may have different vision disparity and the corona discharge could be find nearly only in intensity at night [9]. While the infrared thermograph technology is able to detect the defect with consecutive electrothermal effect,

but the corona discharge must be serious, so it is not promptly for detection of little heat at the early corona stage [10, 11]. So the infrared thermograph technology is not widely used in the outdoor corona detection in transmission lines.

The ultraviolet imaging technology is able to catch the specific wavelengths photon of UV signal, and then combine with the visible light to decide the corona discharge point. And the strength of discharge is judge by the photon counting rate.

The UV imager was researched and developed to detect the discharge phenomenon by occidant at the earliest. It can find the discharge point with small temperature rise at the early discharge stage, is currently one of main methods of discharge detection in the world [12]. From 1980s, the EPRI attempted to utilize the UV imager to test the discharge in the transmission lines [13-15], and have got good achievements. In china it is also have convinced performance in actual use.

The ref [16, 17] take the research of corona discharge performance of insulator at different applied voltage, the UV imager was used to measure the discharge. In ref [18], several influence factor of UV imager was studied, such as photon counting rate, detect distance, discharge capacity. Refs [19, 20] have discussed the principle of UV imager, and then the UV imager of SuperB was used to detect the corona of electrical equipment in the transmission lines. In ref [21], the UV imager was used to decide the corona inception voltage of the conductor un-



der dry or rainy conditions.

In this paper, the UV imager type of SuperB, which designed by Ofil company, was used to detect the corona discharge at the top of fractured aluminum strands. And the electric field, length of the strand, detection distance and gain level were researched. Then the MRA was taken to calculate the function between the photon count and the factors.

## 2. Introduce of Experiment

### 2.1. Test System

The experiment was carried out in a shielding hall with a size of  $66\text{ m} \times 30\text{ m} \times 18\text{ m}$ , and the test model was  $4 \times \text{LGJ300/40}$ , bundle space was 45 cm, height was 6.8 m, the model picture was showed in **Figure 1**. And the temperature was  $8.4^\circ\text{C} \sim 10.8^\circ\text{C}$ , relative humidity was 35%~43%.

The UV imager with type of DayCor SuperB was showed in **Figure 2**. And the 50 Hz source with maximum of 1000 kV and 1000 kVA was showed in **Figure 3**.

And the measurement system schematic diagram was showed in **Figure 4**.

### 2.2. Fractured Aluminum Strands Information

The fractured aluminum strands (see **Figure 5**), was set at one of the LGJ300/40 conductor, with different length (see **Figure 6**).



Figure 1. Picture of test model.



Figure 2. UV imager of SuperB.

And the different strand length, detection distance, applied voltage, UV gain level were show in **Table 1**. The electric field of the conductor surface (not the top of strand) was calculated by ANSOFT for applied voltage as 10.7 kV/cm, 13.6 kV/cm, 16.4 kV/cm, 19.3 kV/cm, and respectively.



Figure 3. 1000kV transformer.

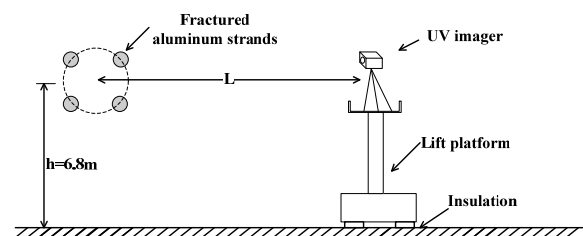


Figure 4. Measurement system schematic diagram.

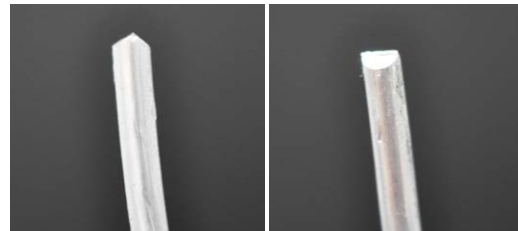


Figure 5. The top of the fractured aluminum strands.

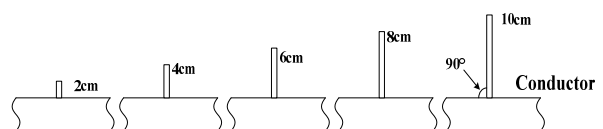


Figure 6. Schematic diagram of fractured aluminum strands.

Table 1. Information of the factor.

Influence factor	content				
Length of strand (cm)	2	4	6	8	10
Applied voltage (kV)	150	190	230	270	
Detection distance (m)	7	9	11	13	
UV gain	60	80	100	120	

### 3. Results and Analysis

With the different influence factor applied on the strands, the corona phenomenon was detected by the UV imager. Limited by the paper length, one of them was showed in Figure 7.

We noticed in Figure 7 that the photon counting rate would increase with the rise of the applied voltage, such as applied voltage was 150 kV (with conductor surface electric field is 10.7 kV/cm) while the photon counting was 7620, with the voltage increased to 270 kV (with field 19.3 kV/cm) the photon counting rise at 22660.

#### 3.1. Influence of Voltage (Electric Field)

With the applied voltage of 150kV, 190kV, 230kV, 270kV, the electric field was 10.7kV/cm, 13.6kV/cm, 16.4kV/cm, 19.3kV/cm, respectively, one part of result of experiment was show in Figure 8.

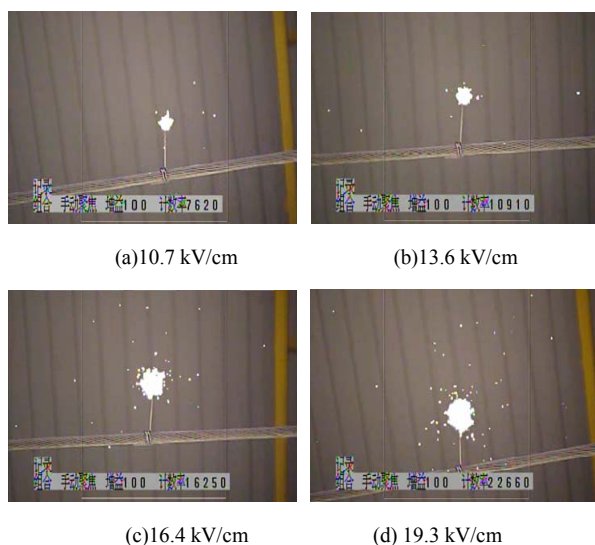


Figure 7. Corona discharge at the top of fractured strand with different voltage applied (length of strand is 10cm, detection distance is 9 m, UV gain is 100).

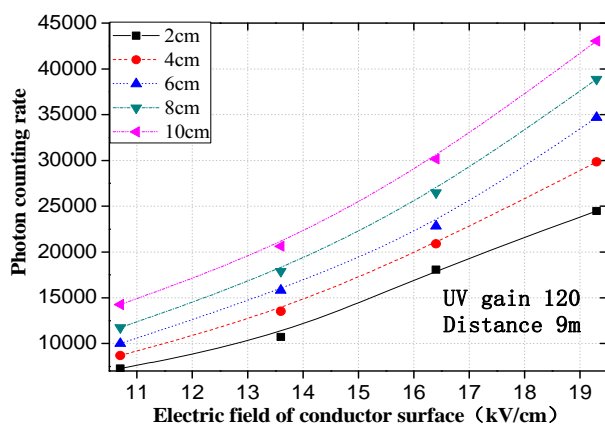


Figure 8. Influence of electric field.

#### 3.2. Influence of Detection Distance

With the different detection distance of 7 m, 9 m, 11 m, 13 m, the results were partly showed in Figure 9.

#### 3.3. Influence of UV Gain

With the different UV gain was set in the experiment, the results were partly showed in Figure 10. However, the UV gain character is most related to the signal processing module of the UV imager designer, so it may different from other UV imager.

#### 3.4. Influence of Length of the Strand

With the different length of strand applied on the conductor, the results were partly showed in Figure 11.

### 4. Multivariate Regression Analysis

MRA was developed from one dimension regression analysis and used to investigate the connection between dependent variable and several independent variables. MRA is considered as an effective mathematical method to solve practical engineering problem.

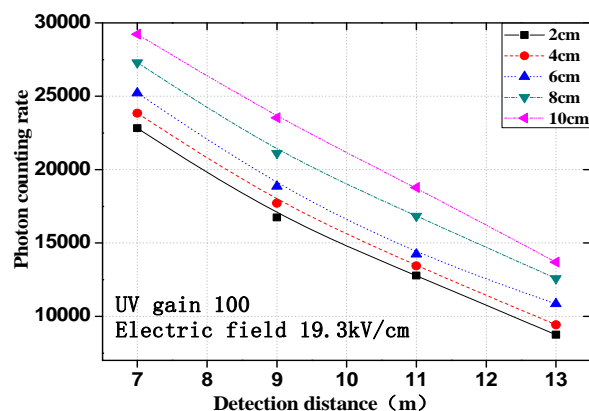


Figure 9. Influence of detection distance.

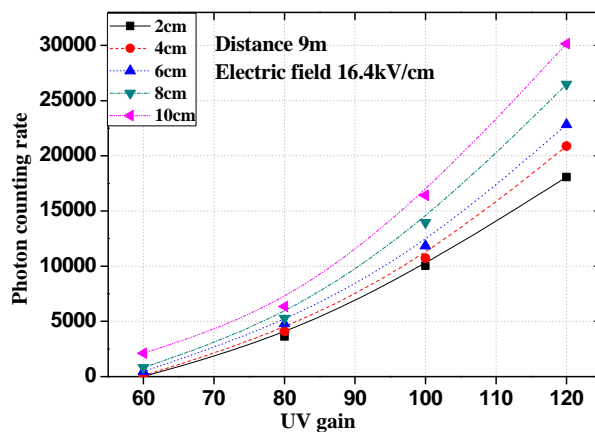


Figure 10. Influence of UV gain.

The multiple regression prediction equation about the photon counting rate was:

$$P = \beta_0 + \beta_1 \cdot E^2 + \beta_2 / L + \beta_3 \cdot K + \beta_4 \cdot s \quad (1)$$

In the equation, electric field was set as E, kV/cm; detection distance was set as L, m; UV gain was set as K; length of strand was set as s, cm.

And the significance test was taken, including R, F and T test, showed in Equation (2), (3) and (4).

$$R = \sqrt{\frac{\sum_{i=1}^n (\hat{y}_i - \bar{y})^2}{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (2)$$

$$F = \frac{\sum_{i=1}^n (\hat{y}_i - \bar{y})^2 / m}{\sum_{i=1}^n (\hat{y}_i - y_i)^2 / (n - m - 1)} \sim F(m, n - m - 1) \quad (3)$$

$$T_j = \frac{(b_j - \beta_j) / \sqrt{c_{jj}}}{\sqrt{\sum_{i=1}^n (\hat{y}_i - y_i)^2 / (n - m - 1)}} \sim t(n - m - 1) \quad (4)$$

The results of MRA and significance test were display in Table 2.

The result of significance test is well, so the regression equation about photon counting rate is:

$$P = -57980 + 49.29E^2 + 101230 / L + 347.7K + 754.4s \quad (5)$$

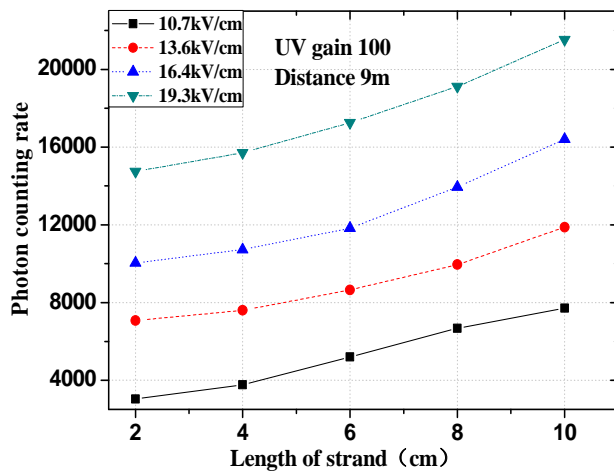


Figure 11. Influence of strand length.

Table 2. Mra about photon counting rate and significance test.

	R		F		T		
	R	F	$\beta_0$	$\beta_1$	$\beta_2$	$\beta_3$	$\beta_4$
Value	0.934	1080	-57980	49.29	101230	347.7	754.4
$\alpha$	---	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

## 5. Conclusions

In this work, the fractured aluminum strands was taken for the test model to research the corona discharge detection of UV imager. The influence detect distance, electric field, strands length and UV gain were investigated while the MRA was utilized to summarize the regression equation about the photon counting rate. These conclusions have good contribute to expand UV imaging technology in practical transmission lines patrol of corona discharge.

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**United States Patent** [19]  
**Labriola, II**

[11] **Patent Number:** **5,986,276**  
[45] **Date of Patent:** **Nov. 16, 1999**

[54] **APPARATUS AND METHOD FOR ELIMINATING X-RAY HAZARDS FROM ELECTRICAL POWER DISTRIBUTION FIELDS**

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[21] Appl. No.: **08/697,820**

[22] Filed: **Aug. 30, 1996**

**Related U.S. Application Data**

[63] Continuation-in-part of application No. 08/264,470, Jun. 23, 1994, abandoned.

[51] **Int. Cl.<sup>6</sup>** ..... **G21F 1/12**

[52] **U.S. Cl.** ..... **250/515.1**

[58] **Field of Search** ..... 250/515.1, 505.1, 250/517.1, 519.1

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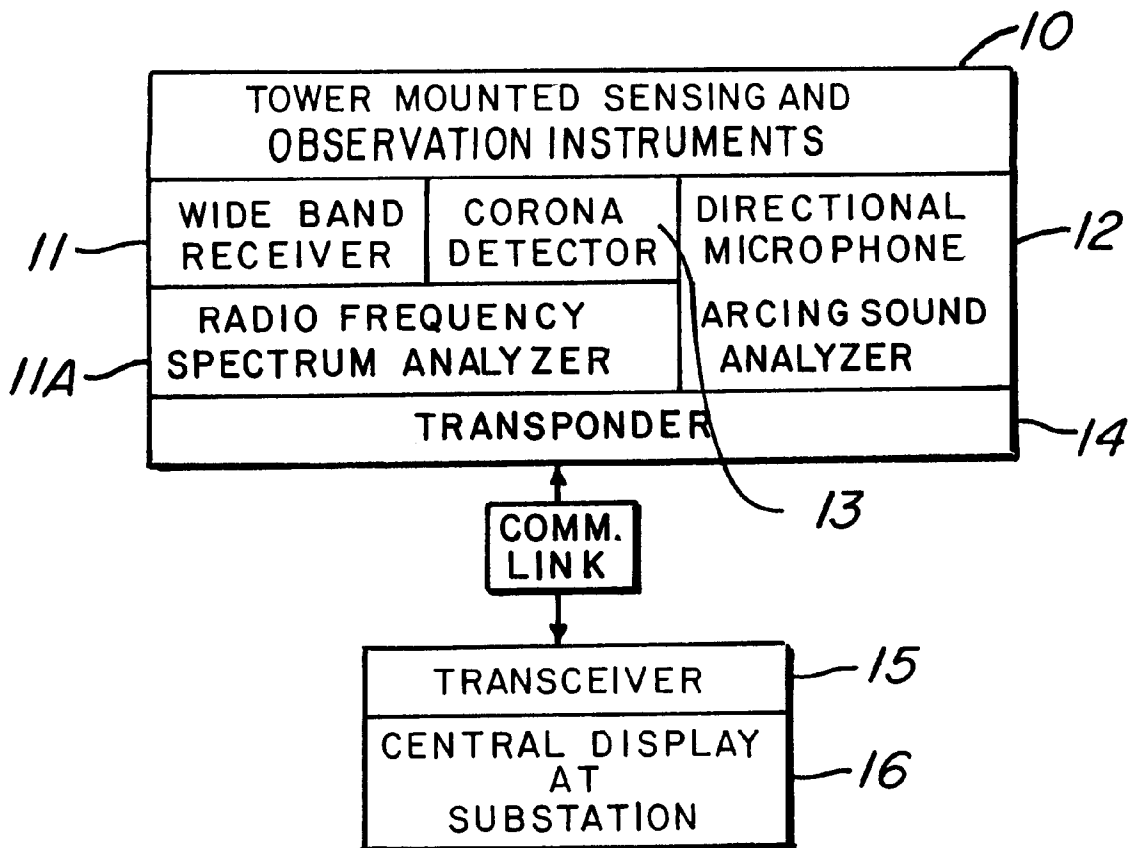
*Primary Examiner*—Kiet T. Nguyen

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[57] **ABSTRACT**

Health hazards to persons from prolonged exposure to high power fields, and specifically to X-ray radiation in such fields in the etiology of leukemia and other forms of cancer, are eliminated by preventive monitoring to detect corona indicating existence of ionization fields, and by coating cable and support structures with a material comprising low molecular number (Z) elements in carriers such as polymers in amorphous or molded forms to absorb energy and prevent X-ray formation. Shields of relatively high Z elements in polymer bases are provided to confine potential X-ray sources due to arcing at switch contacts.

**18 Claims, 2 Drawing Sheets**



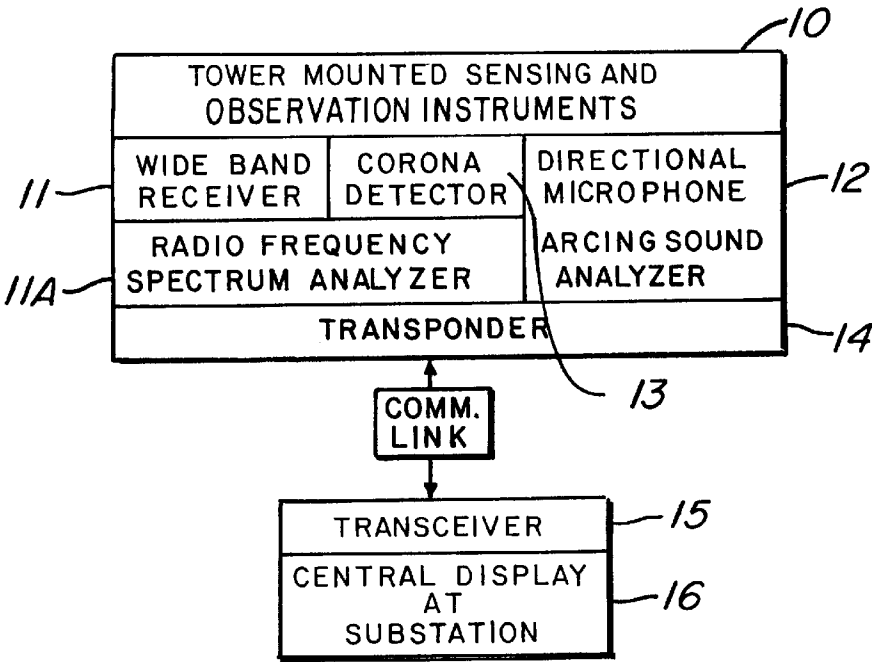


FIG.—1

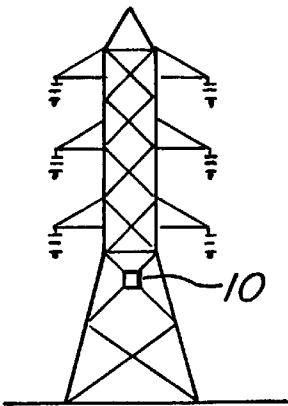


FIG.—1A

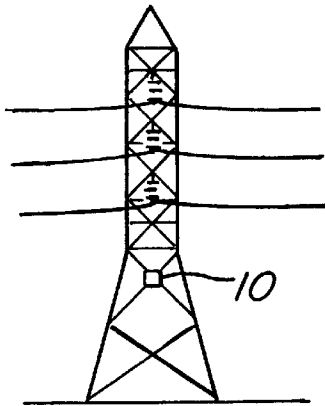


FIG.—1B

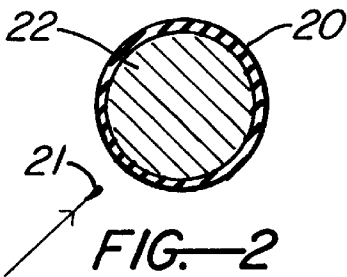


FIG.—2

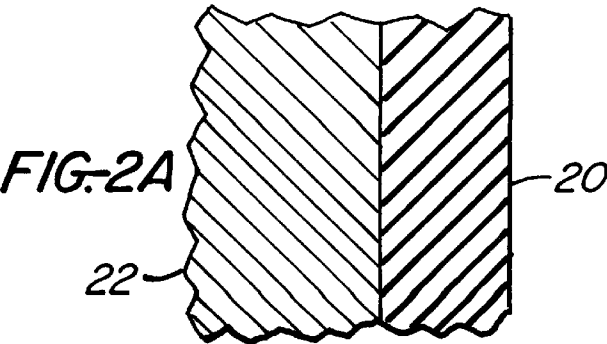
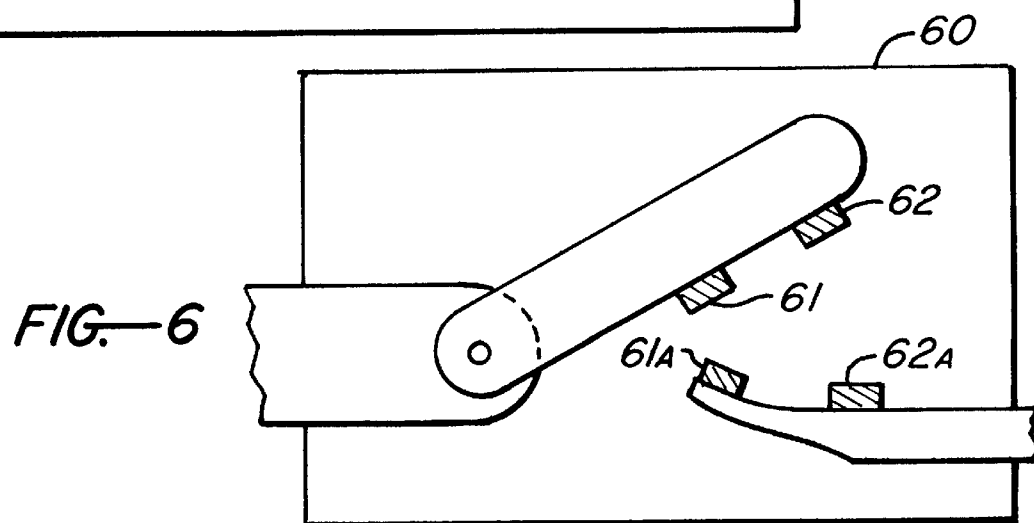
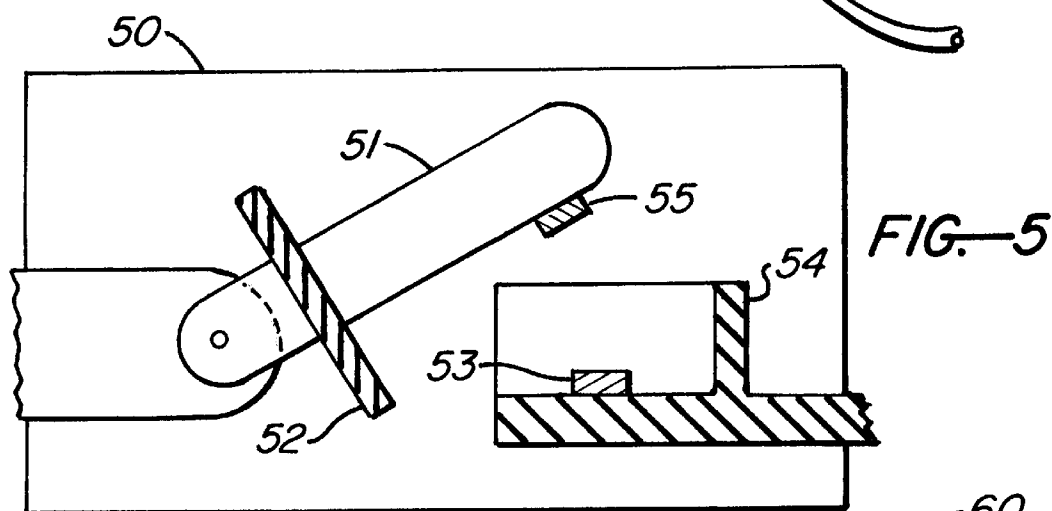
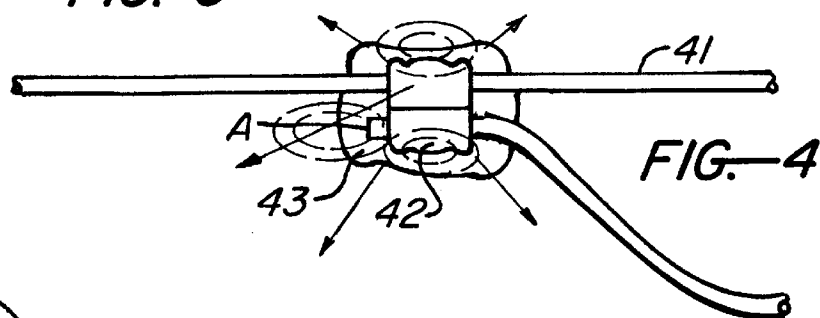
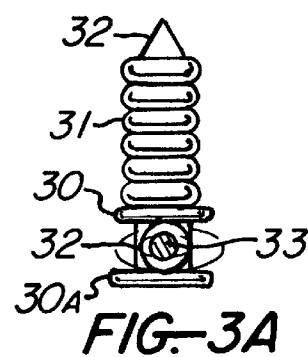
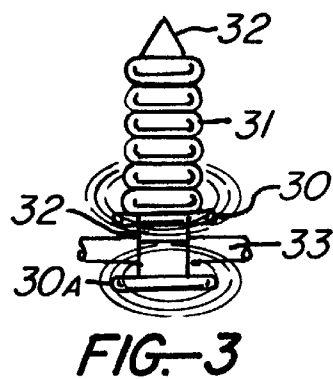


FIG.—2A



# APPARATUS AND METHOD FOR ELIMINATING X-RAY HAZARDS FROM ELECTRICAL POWER DISTRIBUTION FIELDS

## RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 08/264,470, filed Jun. 23, 1994, now abandoned.

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates generally to electric power systems and electrostatic and electromagnetic fields associated with high voltage fields; more particularly the invention relates to X-ray radiation in such fields, which is suspect in the etiology of leukemia and other forms of cancer. Health hazards to persons from prolonged exposure to such fields are eliminated by preventive systems and equipment shielding according to the invention.

For several years studies have indicated a strong statistical relation between various childhood cancers and proximity of persons to high tension power lines. A Johns Hopkins University study by S. J. London et al. showed an especially high correlation of cancers to extremely high voltage lines. This study was done by comparing the utility power configurations associated with childhood leukemia with a random sampling of people in the Los Angeles area. It showed two to three times higher occurrence of high power lines in the vicinity of the leukemia patients than for the general public. Other studies have shown an occurrence of breast cancer in male power line workers approximately four times that of the general public.

Because of such studies, power companies have been attempting to ascertain a causal relation between the presence of power lines and the health effects. When the locations studied in the Johns Hopkins University study were checked for electric field strength—i.e., electric and magnetic fields, no correlation was found. Despite the lack of correlation to electric field strength or magnetic field strength, reduction of these fields has been the primary focus of the power companies, for lack of more definitive approaches.

Certain relevant technical aspects are well known in the art. The electric field surrounding a low frequency conductor is approximately perpendicular to the surface of the conductor, as with power lines with corona discharge, and field strength increases near small radii. The equipotential lines are parallel to the conductor and the gradient is perpendicular to the surface in the vicinity of the surface. The wavelength at 60 Hz is sufficiently long with respect to the ionization zone around the conductor to ignore the component in the direction of the conductor. The high electric field provides the energy to accelerate the free electrons to sufficient energy levels to generate X-rays. Soft X-ray levels are only 2–10 times the energy of hard ultra-violet UV, and continue up from there.

Extraneous electric and magnetic fields, which were thought to be a health risk associated with electric power transmission, were avoided in the prior art by using various cable and wiring arrangements, particularly coaxial transmission lines configured so that return current flows in the outer conductors in a bi-polar field-cancelling mode particularly suited to reducing electromagnetic fields. See U.S. Pat. No. 5,218,507 to Ashley, June 1993. However, little attention has been given to X-rays caused by high voltage fields

accelerating electrons in coronas. It has been believed that X-rays produced thereby are too soft to be of concern. Recently, there have been statistical studies of correlations of cancer cases with the possibility of X-ray generation in power plants in the vicinity of patients' normal activity. See IEEE Transactions on Broadcasting, Vol. 36, No. 1, March 1990.

## BRIEF SUMMARY OF THE INVENTION

Recent research indicates a plausible cause and effect relationship between ionizing radiation and cancer effects.

The electrical and magnetic fields emanating from 60 Hz power lines are nowhere near the energy bands that should produce ionizing radiation. Therefore, high voltage discharge corona effects appear to be a possible cause of X-ray generation.

X-rays for common medical imaging are in the 20 keV (20 kilovolt electron) energy band. The energy released when an electron drifts in vacuum, through a 20,000 volt field, gaining kinetic energy, and impinging on an appropriate target, converts kinetic energy to energetic photons, producing X-rays.

An electron drifting through the same field in air would normally encounter a significant number of air molecules which, because of impacts, would slow the electrons down and prevent sufficient kinetic energy to produce X-rays. As the electric field strength increases, however, the distance necessary to travel to gain the same kinetic energy decreases. This increases the chance that an electron will gain the energy necessary to produce an X-ray when it impacts a target. The target material also affects the generation of X-rays, the efficiency increasing rapidly with increasing atomic number (Z) of the target.

High tension power lines produce extremely high local fields. In places, these are higher than the 20 kilovolts/inch necessary to ionize the air. The corona thus produced is visible as a slight glowing, under proper conditions, or may be heard as crackling on a radio when passing near high tension power lines. A strong discharge may even be audible in the proximity of high tension lines, but not all of this is corona, because some arcing also occurs due to surface contamination of the insulators and faulty insulators.

In accordance with the invention, the electric field strength may be reduced by several means and the target material may be changed. Providing such means and modifications are objects of the instant invention.

A primary object of the invention is to reduce quantity and energy of X-rays generated by high voltage apparatus, by use of low atomic number materials as corona discharge targets. The materials being conductive, insulating, or semiconductive, are used to coat, cover, or sheath high voltage transmission lines and components.

An object of the invention is to use such materials to coat or form the discharge points of high voltage devices, including lightning rods, high voltage contacts, switches and relays, and to use these materials (semiconductive or conductive) to form a coating material capable of covering rough/pointed areas including junctions and hardware to further reduce X-ray generation by reducing arcing. This increases the effective radius of the conductor to reduce the electric field strength and reduce target efficiency. Additionally, shielding may be employed against X-rays emitted from high voltage switches, relays, and interconnects.

Another object of the invention is to provide a method and means for remote sensing of ionizing radiation, including



instrumentation to detect and measure, combined with a transponder to report arcing in power equipment, including poles and tower installations. The detection methods include ultrasonics, X-ray, and radio frequency emissions monitoring.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing flow of monitoring information in a power station to assure that ionizing radiation does not become hazardous;

FIG. 1A shows a typical monitoring installation;

FIG. 1B is a side view of the installation of FIG. 1A;

FIG. 2 illustrates a low Z coating on an electrical conductor to prevent the generation of ionizing energy;

FIG. 2A is an enlarged sectional view of the electrical conductor of FIG. 2;

FIG. 3 is an elevational view showing use of low Z target shields on an insulator in a power distribution tower;

FIG. 3A is a side view of the insulator of FIG. 3;

FIG. 4 is an enlarged fragmentary view illustrating the use of low atomic number (Z) conductive putty to reduce corona from sharp points in transmission system wiring to provide a safe arcing target;

FIG. 5 is an elevational view of a high voltage switch shielded to reduce X-ray emission; and

FIG. 6 is an elevational view of a switch having low Z contacts to carry the initial arc upon opening or closing to reduce X-ray generation due to low target efficiency at the are site.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

X-rays represent the energy produced by the rapid deceleration of high speed electrons. Electron streams which have been accelerated by strong electric fields surrounding wires and hardware are intensified by sharp points. Sufficiently high fields cause air to break down or ionize, thus causing coronas.

High speed electrons, when slowed by collision with the nuclei of some materials, produce X-rays. High atomic weight nuclei more effectively slow the high speed electrons, and thus produce both more X-rays and higher energy X-rays. Light atomic weight nuclei are less effective in slowing the high speed electrons, requiring multiple collisions, each of which collisions only releases a portion of the total kinetic energy, resulting in lower energy photons, such as light. The percentage of electrons which are able to so interact so as to produce photons is dependent upon the target material. The energy spectrum (if visible light, this would correspond to its color) of the resulting photons is also dependent upon the target material.

Both the quantity of high energy photons and their energy (destructive power) are related to the square of the atomic number of the atoms in the target material into which the electrons are impacting. When the target material is composed of more than one element, the effective atomic number (Z) of the composite is determined by summing up the molar percentage of each element present, multiplied by the atomic number of that element:

$$Z_{\text{effective}} = \sum Z_i \times \text{Fraction}_i$$

-continued

summed for each element present in the target material.

The target does not have to contain metals; it is preferable that it contain only the lighter elements such as hydrogen, carbon, nitrogen, and oxygen. Substituting carbon (Z=6) for steel (Z=26) as the impact target would reduce the X-rays generated by almost a factor of 19. Replacing it by polyisobutylene ( $Z_{\text{effective}}=2.67$ ) would reduce the generation by a factor of approximately 95 to 1. The effects would be even greater if the original target were copper (Z=29) or Zinc (Z=30).

X-ray "shielding", however, depends roughly on the mass of the shield encountered. Thus lead, being quite dense, requires only a thin layer to effectively shield an X-ray source, as compared with a lower density material such as iron.

Thus, the "safe" target sheathing material must be low-Z, while any shielding material must be high-Z. Care must be taken that the shielding material does not accidentally become a target, lest it become a producer of X-rays stronger than would exist if no changes had been implemented. The hydrocarbon target material intercepts the majority of the energetic electrons because of the very short mean path length of an electron in a solid.

Referring to FIG. 1, a block diagram showing the flow of monitoring information in a power station, to assure that ionizing radiation does not become hazardous, the sensing instrumentation preferably includes an energy field detector wide band receiver 11, spectrum analyzer 11A and an audiometer 12 for detecting arcing sounds using directed microphones aimed at critical points on a tower.

These instruments are continuously monitored by a transponder 14, which stores the data in memory for recall when interrogated by a transceiver 15; the data is transmitted to, and accumulated and displayed at, a distribution substation 16. The communications link between the tower monitors and the substation may be RF or fiber optic. Ideally, the monitoring instrumentation would be installed in every distribution tower in an area where there is human or animal life within 100 feet of the distribution lines. The preferred mounting position of monitor-transponder 10 relative to a distribution lines tower is shown in FIG. 1A and FIG. 1B.

Monitor transponder 10 at the tower (FIG. 1B) detects time/amplitude noise spectra and/or discharges due to ionization in the vicinity of the tower, these resulting in electrical arcing when the electrical tension between ions of different charge potential becomes sufficiently high to cause corona in a humid atmosphere. Corona discharges which precede and indicate potential X-rays, are detectable by this method and apparatus. The direction and origin of corona in the area of the tower is detectable by aiming a corona detector (an optical instrument) at the source of the corona.

Monitor-transponder 10 is positioned at the center of the tower, between the high voltage conductors and ground, and at the center of any potential X-ray fields which may develop between the high voltage lines and ground, which fields are harmful to biological life.

The hazards to biologic life associated with the X-rays produced due to tower electrical equipment faults, such as arcing or dirty insulators, are reduced by shortening the exposure time, as by prompt notification of the problem to repair personnel. Generally downward directed radiation patterns are of most interest. Corona is the phenomenon of air breaking down when the electric stress at the surface of

a conductor exceeds a certain elevated potential value. At higher values, the stress results in a luminous discharge with an arcing sound detectable by a directional microphone and amplifier. Common corona sources are the wires themselves, faulty insulators, and mounting hardware with sharp points.

As is known in the art, strong electric fields may develop between electrically conducting metal elements, such as between a switch or terminal board and any metal at or near ground potential, such as an electrical tower. The potential difference directs the field between the two closest exposed metal elements, so that high tension electrostatic flux fields develop between the two elements, so that high tension electrostatic flux fields develop between the two elements. The direction of such field is between the two exposed elements or points. The electric field charged particles cause X-ray photons to be created when the particles are accelerated between two high and two low potential metallic elements when the field becomes sufficiently strong.

The towers are therefore appropriate places to locate the detectors. The EMI detectors take advantage of the generally isotropic radiation patterns from very small antennae, the individual ionization points. Corona will produce a detectable signal anywhere nearby, as demonstrated by automobile radios near arcing towers.

The corona detection capability of the observation instrument **10** warns of an electrical stress build-up at some component at the tower that could produce X-rays if allowed to become too intense. Notification is thus given as an early warning to the substation to send a crew to correct the problem by the conventional methods of cleaning and/or replacing dirty or defective components.

The X-rays are not in the form of a single beam, but arise from many corona points either at sharp discontinuities, such as wire ends and point-shaped hardware, or along the body of the conductor when the dielectric strength of the air drops below the field strength. A typical design rule is to pick the conductor diameter, or effective diameter when multiple conductors are used, to produce 15 kV/inch. Dry air has a break down voltage of 20 KV/inch, and very damp air has significantly less. High tension power lines may produce coronas in foggy weather as may be viewed on a dark night.

Referring to FIG. 1, the tower-mounted sensing and observation instruments **10** are typically mounted on a platform, which is preferably rotatable for manipulation and aiming of the corona detector for optical observation of the area between the high voltage conductors and the ground about the tower. The directional microphone may also be aimed, in a manner similar to the use of the corona-detector, to detect pre-corona conditions identified by arcing sounds in the audio range. A radio frequency receiver and a spectrum analyzer, locates a source of pre-corona electrical field disturbance and identifies, by the nature of amplitude and noise burst spectra, whether a potential disturbance field is developing. Automatic means may be utilized for spraying low Z material on electrical distribution components where a disturbance field is developing, and operation thereof may be initiated by command via a communications link with a substation.

Repair personnel may be required in some instances to analyze and solve the problem. In either case, the possibility of development of a dangerous X-ray field is being prevented. Audio, visual and radio frequency, as well as remote digital instrument control of observation instruments in the tower, and low Z material spray nozzles, can be controlled from a substation via a communications link to prevent formation of X-ray fields.

FIGS. 2 and 2A illustrate the use of low atomic number (Z) coating **20** on an electrical conductor **22** to prevent the generation of high energy photons by the impact of highly accelerated electrons **21** into the conductor. The low Z material **20** produces fewer and lower energy electrons when inserted.

The formulation of a polymer or combination of several isomer molecules, comprising low atomic number (Z) atoms in a plastic product to form a sheath or outer covering on a conductor or cable, substantially eliminates the generation of X-rays in the area about the conductor. A polymer having an amorphous putty-like consistency is another material to be applied, according to the invention, to points where arcing might occur, thus to reduce corona generation about an electrical conductor and provide a soft target for any X-Radiation that might develop from the remaining corona.

Application may be by any appropriate means or method such as spraying, dipping, extruding, chemical grafting and wrapping, as examples. The low Z material application in accordance with the invention is typically of significantly less thickness, weight, thermal resistance, and windage factors than would be needed to provide a full wire-insulator for high tension wires.

The low Z target materials are applied about the outside of any of the elevated potential members, including the wires and connector hardware. The electrons accelerated by the high voltage potentials have a high probability of interacting with the low Z material, rather than penetrating to the contained high Z material. The process of the high speed electron being slowed by interaction with the low Z material produces much less X-ray energy and lower energy X-rays than would be produced by the interaction of the same electrons with high Z material.

More rigid molded elastomeric forms for other applications are shown in FIGS. 3, 3A and 4. The presence of the low Z discharge target provides an inefficient X-ray target rendering the high speed electrons harmless. FIG. 3 shows the use of a low Z shield on an insulator **31** such as is used in power stations. The supporting insulator device **32**, through which the high voltage conductor **33** passes, has low Z shield disks **30**, **30A** on either side of the conductor to provide a safe target for high speed electrons generated by corona. The insulator device **32** is mounted on the distribution tower structure by means well known in the art. FIG. 3A shows the conductor **33** retained in the insulator by well known means, and the low Z shield disks **30**, **30A** placed on either side of the conductor to dissipate high velocity electrons that could produce X-rays. The disks also reduce the electric field strength to reduce corona generation.

FIG. 4 illustrates the use of low atomic number (Z) polymer putty to reduce corona at points in high tension transmission system wiring, where residual corona and arcing has occurred, to provide an X-ray inhibitor for the residual problem. A conductor **41** for high voltage power, coupled by means of a crimp connector **42** having a tendency to develop an ionizing field at point A, can be electrostatically shielded when the connector **42** is covered with low Z putty coating or low-Z snap covers **43** to reduce the acceleration of electrons necessary to produce X-rays, while also acting as a soft target to further prevent X-ray generation.

The electrostatic field shaping means in accordance with the invention, is the surrounding of sharp points of higher Z material with low Z conductive material. Examples are the wire end A in FIG. 4 surrounded with the conductive putty **43**, and the conductive low Z disks **30** and **30A** surrounding

the mounting hardware **32** in FIGS. **3** and **3A**. In both cases, the use of large smooth conductive surfaces reduces the electric field that would otherwise arise proximate to a charged pointed object. This is opposite to the effect of using a sharpened pointed conductor to "draw lightning" by maximizing the field strength at the end of a lightning rod.

The source of free electrons is the discharge plasma from the ionization of air molecules placed in sufficiently strong electrostatic fields. These electrons gain speed as they accelerate through the same electrostatic fields. Sufficiently strong fields allow a percentage of these electrons to reach the required velocities, finally impinging on the conductor. This percentage is a function of the electric field strength and configuration, the dielectric breakdown strength of the surrounding gas which is a function of humidity and pressure, and the gas pressure. All of these factors affect the mean-free-path length before the average electron of the electron field loses much of its energy by impinging on a gas molecule, losing heat and producing low energy photons. Ionizing energy levels are considered by various sources as between 5–10 eV to 100 eV.

FIG. **5** shows a high voltage switch protected by high Z sheet or cast material to absorb ionizing radiation in specific directions, such as toward the ground, for the protection of persons on the ground in a power plant environment. For example, the contact bar **51** on a high power switch **50** in a power station environment can be fitted with a high Z shield **52**, which may be a solid high Z material or powered high Z material in a polymeric base, and the fixed contact **53** surrounded by a high Z ring **54**, such that any X-rays formed as the switch opens or closes will not reach personnel.

The source of the X-rays at the switch is this same accelerated electron from the ionization of air by a sufficiently strong electrostatic field. The highly energetic electrons ionizing the air (blue spark) may also generate soft X-rays if they gain enough energy and impinge on a high Z target, such as switch contacts. These arcs are commonly generated, with technicians in close proximity, when the switches are manually operated. The high Z material forms a "shield" that attenuates/absorbs a significant portion of the X-rays generated in the directions that the personnel are located.

The low Z material is used for targets that the high speed electrons are expected to impinge upon, namely the high voltage conductors and attached conductive hardware. As stated earlier high Z material is used as a "shield", such as a lead apron used to protect human body parts not being X-rayed, between the X-ray producing arc at the high Z switch contacts, and the technician operating the switch from below.

As indicated in FIG. **5**, high Z shielding is provided at locations of high-power switch contacts for switching induc-

tive loads into and out of high current lines. X-rays are developed when the inductive load is interrupted—i.e., when switched out by opening of a switch, a very high voltage arc can automatically produce X-rays. As a further safety measure, a set of low-Z contacts in parallel with the high-power switch contacts, are utilized to short out the inductive voltage rise upon opening of the switch. Some benefit is derived by the low Z contacts connecting before the switch contacts, and "breaking" after the switch contacts, thus to eliminate formation of X-rays. Low Z material is applied where high speed electron generation is expected—i.e., on the arcing points of the switch. The low Z material serves as an impact target for high speed electrons to reduce conversion efficiency between kinetic energy and X-rays. Low Z coatings can be sprayed on existing high Z shields to reduce the initial formation of X-rays on existing power switches in a power distribution system.

FIG. **6** illustrates an electrical switch **60** having low Z contacts pair **61**, **61A** for providing the initial contacting and final breaking points for the circuit. Such contacts prevent arcing at the normal electrical contacts **62**, **62A**, which would be more prone to X-ray generation, particularly when inductive loads are switched out, with their inductive voltage rise and corona at the switch gap. The second set of contacts, **61**, **61A** is to provide an initial striking contact and a final breaking contact with a material that generates less X-rays when arcing than does the conventional contact.

The shaping of the field is done by elements **52** and **54** (FIG. **5**). Similar techniques are the use of spheres in switching stations and Van de Graf generators to minimize ionization; the same effect is used for the opposite purpose in lightning rods and etched microwire cold emitters for solid state tubes.

The composition of materials depends on specific applications, and includes the amorphous putty-like polymer material composed of low Z material, possibly filled with carbon or other low Z materials. Other forms, such as plate or cast forms having low Z X-ray inhibitor therein, are useful for electrical componets.

An advantageous low Z polymer material is polyarylene ether benzimidazole, known as PAEBI, which is quite erosion resistant and resistant to atomic oxygen. It can be extruded into fibers or threads, and woven for certain applications.

A list of such polymers is set forth hereinafter in Table I, and a listing of the Periodic System, Group III or IV atoms possible for use with these polymers, is set forth in Table II.

TABLE I

EXAMPLE OF POLYMERS USABLE AS SAFE TARGET MATERIALS	
Vinyl Acetate	Polyvinyl acetate
$  \begin{array}{c}  \text{H} & & \text{H} \\  & \backslash & / \\  & \text{C} = \text{C} \\  & / & \backslash \\  \text{H} & & \text{O} \\  & &   \\  & & \text{C} = \text{O} \\  & &   \\  & & \text{CH}_3  \end{array}  $	$  \begin{array}{cccccccc}  \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\    &   &   &   &   &   &   &   \\  -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\    &   &   &   &   &   &   &   \\  \text{H} & \text{O} & \text{H} & \text{O} & \text{H} & \text{O} & \text{H} & \text{O} \\  &   & &   & &   & &   \\  & \text{C} = \text{O} & & \text{C} = \text{O} & & \text{C} = \text{O} & & \text{C} = \text{O} \\  &   & &   & &   & &   \\  & \text{CH}_3 & & \text{CH}_3 & & \text{CH}_3 & & \text{CH}_3  \end{array}  $

TABLE I-continued

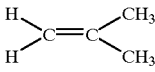
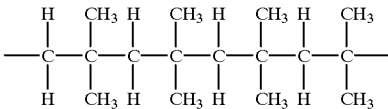
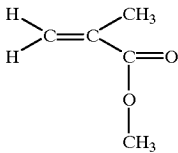
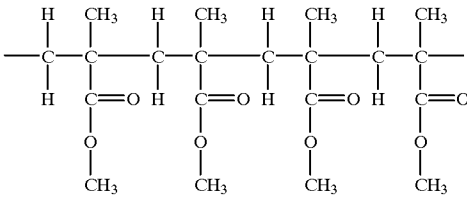
EXAMPLE OF POLYMERS USABLE AS SAFE TARGET MATERIALS	
Isobutylene	Polyisobutylene
	
Methyl methacrylate	Polymethyl methacrylate
	

TABLE II

LOW ATOMIC NUMBER ELEMENTS OF THE PERIODIC SYSTEM																										
Period	Z	Elements	Atomic Number		Shells		Subshells		1		2		3		4		5		6		7					
			K	L	M	N	O	P	Q	s	s	p	s	p	d	s	p	d	f	s	p	d	f	s	f	s
I	1	H	1																							
	2	He	2																							
II	3	Li	2	1																						
	4	Be	2	2																						
	5	B	2	2	1																					
	6	C	2	2	2																					
	7	N	2	2	3																					
	8	O	2	2	4																					
	9	F	2	2	5																					
	10	Ne	2	2	6																					
III	11	Na	2	2	6	1																				
	12	Mg	2	2	8	2																				
	13	Al	2	2	8	2	1																			
	14	Si	2	2	6	2	2																			
	15	P	2	2	6	2	3																			
	16	S	2	2	8	2	4																			
	17	Cl	2	2	6	2	5																			
	18	Ar	2	2	6	2	8																			
IV	19	K	2	2	6	2	6								1											
	20	Ca	2	2	6	2	6								2											
	21	Sc	2	2	6	2	6	1							2											
	22	Ti	2	2	6	2	8	2							2											
	23	V	2	2	6	2	6	3							2											
	24	Cr	2	2	8	2	8	5	1																	
	25	Mn	2	2	6	2	8	5	2																	
	26	Fe	2	2	8	2	8	8	2																	
	27	Co	2	2	8	2	8	7	2																	
	28	Ni	2	2	8	2	8	8	2																	
	29	Cu	2	2	6	2	6	10	1																	
	30	Zn	2	2	6	2	6	10	2																	
	31	Ga	2	2	8	2	8	10	2	1																
	32	Ge	2	2	6	2	8	10	2	2																
	33	As	2	2	6	2	6	10	2	3																
	34	Se	2	2	6	2	6	10	2	4																
	35	Br	2	2	8	2	8	10	2	5																
	36	Kr	2	2	6	2	8	10	2	6																

Thus there has been shown and described a novel apparatus and method for eliminating X-ray hazards from electrical power distribution fields which fulfills all the objects and advantages sought therefor. Many changes, modifications, variations and other uses and applications of the subject invention will, however, become apparent to those skilled in the art after considering this specification together with the accompanying drawings and claims. All

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such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

The inventor claim:

1. A system for eliminating X-ray radiation from power distribution tower equipment to ground, said system comprising:

means for monitoring power distribution equipment-generated corona,

said monitoring means comprising sensing instrumentation comprising an X-ray energy detector,

means for transmitting the status data to a control center for accumulation and analysis, and

means for correcting faults that are indicated by the analysis of the data,

whereby X-rays produced by tower equipment faults are eliminated by prompt monitoring, reporting and correction of the fault, thus to prevent any damaging X-ray development.

2. A system according to claim 1, wherein:

said sensing instrumentation further comprises an RF spectrum analyzer.

3. A system according to claim 2, wherein:

said sensing instrumentation further comprises a corona detector including a wideband receiver and spectrum analyzer for detecting corona spectra.

4. A system according to claim 1, wherein:

said sensing instrumentation further comprises an audio meter for detecting arcing sounds.

5. A method for eliminating radiation of X-rays from power distribution tower equipment to ground, comprising the steps of:

monitoring the presence of corona generated in the distribution equipment from a control center, and

applying low atomic number target materials to elevated-potential equipment for isolating potential X-ray targets to form safe discharge points for corona,

whereby electrons accelerated by high voltage potentials have a high probability of interacting with the low Z material rather than penetrating to high Z material.

6. The method according to claim 5, wherein:

said step for applying low atomic number target materials for isolating the potential X-ray generating target is a low Z hydrocarbon based plastic applied by at least one of the steps from the group comprising coating, spraying, dipping, extruding, chemical grafting, and wrapping.

7. A method according to claim 5, wherein:

the applying of low atomic number target materials comprises the applying of a low Z material covering potential electrical discharge points by at least one of the group comprising extrusion, spraying, flame spraying, dipping, plating, sheathing as with woven graphite fibers, chemical grafting, and wrapping.

8. The method according to claim 5, wherein:

said step for isolating potential X-ray targets by X-ray formation-inhibiting material comprises a low-X material covering applied to potential electrical discharge points by at least one step of the group of steps comprising extrusion, spraying, flame spraying, dipping, plating, sheathing as with woven graphite fibers, chemical grafting, and wrapping.

9. A method for eliminating radiation of X-rays by high speed electrons in high voltage fields from electrical equipment, comprising the steps of:

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shaping an electrostatic field of electrical potential by rearrangement of the electrical equipment to reduce peak field strength at potential X-ray targets, and

applying an X-ray inhibiting material comprising low atomic number atoms onto said potential X-ray targets in the electrical equipment, whereby kinetic energy of the high speed electrons is converted into heat and low energy photons.

10. A method according to claim 9, wherein:

the X-ray inhibiting material comprises polyarylene ether benzimidazole.

11. Apparatus for eliminating radiation of X-rays by high speed electrons in high voltage fields from electrical equipment, said apparatus comprising:

means for shaping a field of the electrical potential of the electrical equipment to reduce peak field strength of potential X-ray targets, and

means for isolating the potential X-ray targets by X-ray formation-inhibiting material comprising low atomic number atoms in a material placed between a source of the high speed electrons and the potential X-ray targets in the electrical equipment.

12. Apparatus according to claim 11, wherein:

said X-ray formation-inhibiting material comprises polyarylene ether benzimidazole.

13. Apparatus according to claim 11, wherein:

said means for isolating the potential X-ray target is a substrate configured to enclose a volume radiating the X-rays, and

at least one low atomic number element suspended in said substrate.

14. Apparatus according to claim 11, wherein:

said means for isolating the potential X-ray target is an X-ray-safe target material for preventing X-ray radiation from electrical equipment, said target material comprising a substrate such as polymer polyvinyl acetate plastic gum adhesive for conforming and adhering to electrical equipment.

15. Apparatus according to claim 11, wherein:

said means for isolating the potential X-ray target is a low Z putty coating to prevent acceleration of high speed electrons to produce x-rays, while providing a soft target, said low Z putty comprising a polymer such as polyvinyl acetate mixed with powdered carbon.

16. Apparatus according to claim 11, wherein:

said means for isolating the potential X-ray target is a hydrocarbon based plastic material covering for electrical conductors.

17. Apparatus according to claim 11, wherein:

said means for isolating the potential X-ray target comprises low Z material contacts in switches forming the initial and breaking contacts of a switch to reduce X-ray generation present upon opening or closing a switch.

18. Apparatus according to claim 17, wherein:

said contacts are in parallel with conventional contacts to reduce contact arcing, and the low Z material contacts provide an initial striking contact and a final breaking contact with material that generates less X-rays when arcing than the high Z material switch contacts.