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The Comparative Study between Twisted and Non-Twisted Distribution Line for Photovoltaic System Subjected to Induced Voltage Generated by Impulse Voltage

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Abstract

The recent advancement of renewable energy sources and specifically photovoltaic system has resulted in outdoor installations of large power stations. A photovoltaic system is exposed to extreme ambient conditions due to the lightning strike activity that generated induced overvoltage which have a high tendency to affect the electrical apparatus especially renewable energy plant that directly exposed to this source. This study is performed through experimental work by comparing the effect of induced overvoltage propagation upon between the twisted and non-twisted distribution line for photovoltaic system. The induced voltage is performed by using lightning impulse generator. It is found that the maximum voltage of the unwanted signal is proportional with the distant of the specimen. The closer distant between solar panel material and spark discharge, the more serious effect would occur due to the induced overvoltage.

***Keywords**: photovoltaic systems, induce overvoltage, wave propagation*

1. Introduction

The costs of transmission and distribution systems are taking an increasingly larger portion of utility capital investment today. However, the construction of larger power generating stations was achieved follow by user demand [1]. The phenomenon of lightning has been the subject of intensive study by researchers [2-5] and its behaviour is fairly predictable in general terms, although the exact description of specific incidents is not predictable. Protection against lightning effects includes two categories: direct strike (direct effects) and indirect strike. Direct strike is concerned with the energy, heating, flash, ignition of the lightning current, and indirect strike or also known as lightning-induced overvoltage (indirect effect) which coupling between the lightning stroke and, either to the PV system or lines conductor in electrical and electronic systems.

The work of lightning and surge protection of photovoltaic installations by researcher [6] have speculated about two installations of PV systems which were damaged during lightning thunderstorms, may due to direct lightning strike. The two locations were located in Vulcano Island (Italy) and Kythnos Island (Greece). Following the description of these two case studies, a discussion is presented and leading to firm conclusion when the evident is sufficient and also allowing conjectures when the evident is less then conclusive. However, the evident is insufficient to conclude that all observed damage was caused by direct lightning strike effect since it is very difficult to predict when exactly lightning strike to the specific point. Therefore further investigation of direct effect need to be done by considering the complexity, the cost, and safety issues.

Recently, the lightning simulation for PV system concerning lightning-induced overvoltage was appeared in [7]. The work of [8] calculated and analysed the induced overvoltage for PV panel arrays on the rooftop of building. They concluded that the lightning-induced overvoltage is directly proportional to the peak value of lightning current. Indeed, they

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claimed that the high building, soil resistivity and the distance effect were more serious factor to be exposed to the overvoltage. Furthermore, their investigations concluded that the selection of Surge Protective Devices (SPD) should be considered for all the factors mentioned above. This problematic matter has greatly encouraged to further study in examining and developing the proper lightning protection scheme for PV system.

From the experiment of investigate the effect of the propagation of unwanted signal on solar panel with surge protection devices (SPD) and without SPD indicated in the results of some previous test in author journal [9]. From the work experiment results, the distance of solar panel and indirect lightning is significantly affecting the unwanted signal values and thus can cause damage to electronic equipment. On this basis, the key lightning protection techniques are offered and this problematic matter has greatly encouraged to further study in examining and developing the proper lightning protection scheme for Photovoltaic system.

2. Experimental Work

The experimental work is conducted to determine the breakdown probability of a spark gap under voltage impulse by generating 66 kV impulse voltages. The experiment is carried out at High Voltage Laboratory, Universiti Teknikal Malaysia Melaka. The instruments used are as below:

a) Diode (140kV, 20mA)
b) Smoothing and Energy Storage Capacitor (25nF)
c) Parallel Resistor (Tail Resistor)
d) Series Resistor (Wave front Resistor)
e) Solar panel array (21V, 80W)
f) Spark Gap
g) Measuring Capacitor
h) Impulse Voltage Configuration Circuit
i) Oscilloscope
j) Electrical copper cable 1.5mm^2 (15m)
k) Twisted electrical copper cable 1.5mm^2 (15m)

The experiment is set up to investigate the effect of indirect lightning strike on the output of solar panel. The experiment is conducted using impulse generator in high voltage laboratory to produce impulse voltage. The output from solar panel in the form of waveform is read using 2-input channels oscilloscope. Impulse voltage is generated by discharging high voltage capacitors through switching onto network of resistor and capacitors. To perform a testing for impulse voltage, double exponential impulse voltage has been utilised.

The experiment is conducted to investigate the effect of the propagation of unwanted signals on a solar panel with twisted and non-twisted cable. The solar panel with the rated of 21V and 80W is placed perpendicular apart from spark gap with the range distance of 1.0m to 2.0m. Furthermore, in order to see the relationship between voltage of unwanted signals and the distance of solar panel is increased by the factor of 0.5m. The 15m length of 1.5mm^2 electrical copper cable (twisted or non-twisted) is connected from the solar panel to the oscilloscope and the internal impedance is set to 1MΩ under full bandwidth operation. The lightning artificial voltage (1.2/50μs) is generated up to 66 kV and the trigger is set to be 30% of the input voltage. Trigger system is function to stabilise the repetitive waveforms and capture single-shot waveforms. The result is saved with ASCII format and analysed by using MATLAB.

3. Experimental Result and Discussion

Figure 1 and 2 below shows the input signal when lightning artificial voltage (1.2/50μs) is generated up to 66kV for both twisted and non-twisted distribution line with the distance between solar panel array and spark gap of 1.0m and 2.0m respectively.

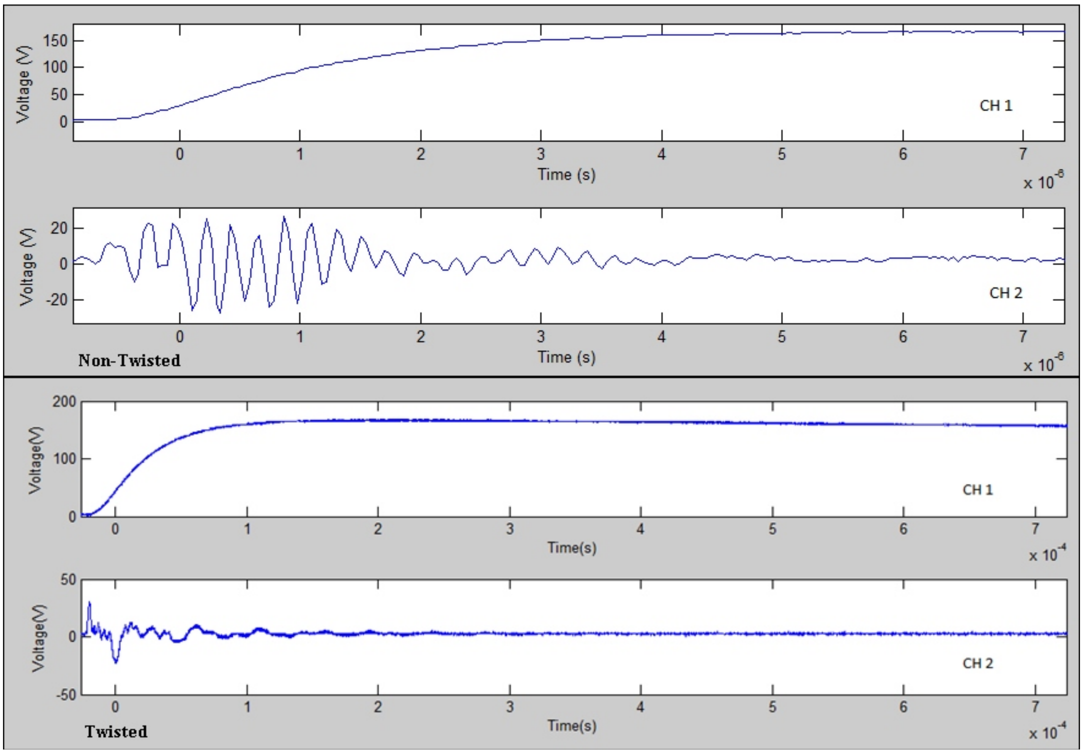

Figure 1. Profile of input signal (1.2/50 μs) of distribution line with the peak voltage of 66 kV and the unwanted signal of solar panel at distant of 1.0 m
* Actual voltage for input signal (CH 1) = 390 x voltage oscilloscope

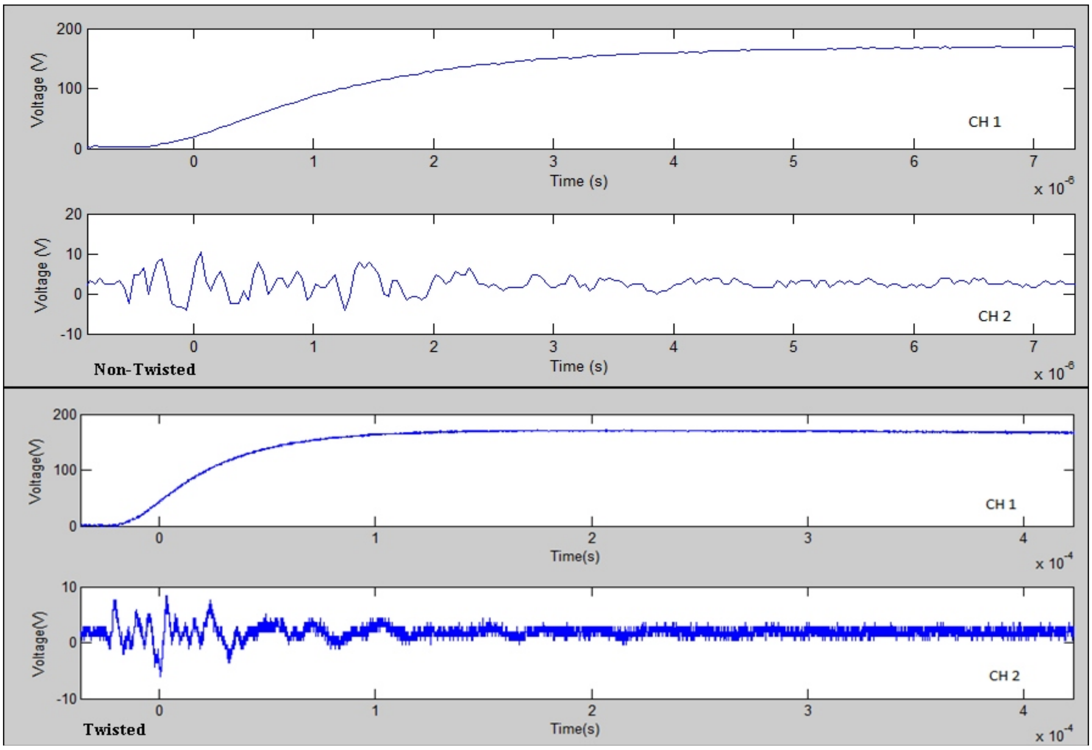

Figure 2. Profile of input signal (1.2/50 μs) of distribution line with the peak voltage of 66 kV and the unwanted signal of solar panel of 2.0 m
* Actual voltage for input signal (CH 1) = 390 x voltage oscilloscope

Figure 1 show the characteristic of unwanted signal due to induced overvoltage perform by artificial lightning generator at 1.0m distance. The induced overvoltage is labelled as input signal (CH 1) while the unwanted signal is labelled (CH 2). Figure 1 indicates that the unwanted signal (CH 2) is appeared as train pulses which are correlated with fast front. It is found that the first pulse of pulse train exhibits the highest voltage. For example, at the distance gap of 1.0m, unwanted signals are found to be 26.8V and 24.8V for twisted and non-twisted respectively.

Figure 2 below shows the results of the gap distance of 2.0m for both twisted and non-twisted distribution line with the maximum voltage of unwanted signal of 7.2V and 6.8V respectively. From this experiment, it is observed that the maximum voltage of unwanted signal (first pulse) decreases when the gap distance between spark gap and solar panel is increased (see Table 1).

Table 1. Maximum Voltage of Unwanted Signal Propagation in Solar Panel

Distance (m) and maximum voltage of unwanted signal (v)			
Distance	**1.0m**	**1.5m**	**2.0m**
Non-Twisted	26.8	15.2	7.2
Twisted	24.8	10.8	6.8
Mean	25.8	13	7
Factor (<2)	1.0806	1.4074	1.0588

Statistically, the result of unwanted signal from different distance of solar panel is decreasing proportionally as shown on Table 1 above. There is a significant distinction when comparing the results of unwanted signal signature between the distance of 1.0m and 2.0m. The different between twisted and non-twisted for 1.0m gap is about a factor of 1.0806. Furthermore, it has been found that for the gap of 1.5m and 2.0m, the factors are 1.4074 and 1.0588 respectively. At the distance between the solar panel and spark gap 1.0m and 2.0m, the average magnitudes of unwanted signals are 25.8V and 7V respectively as shown on Figure 3 below.

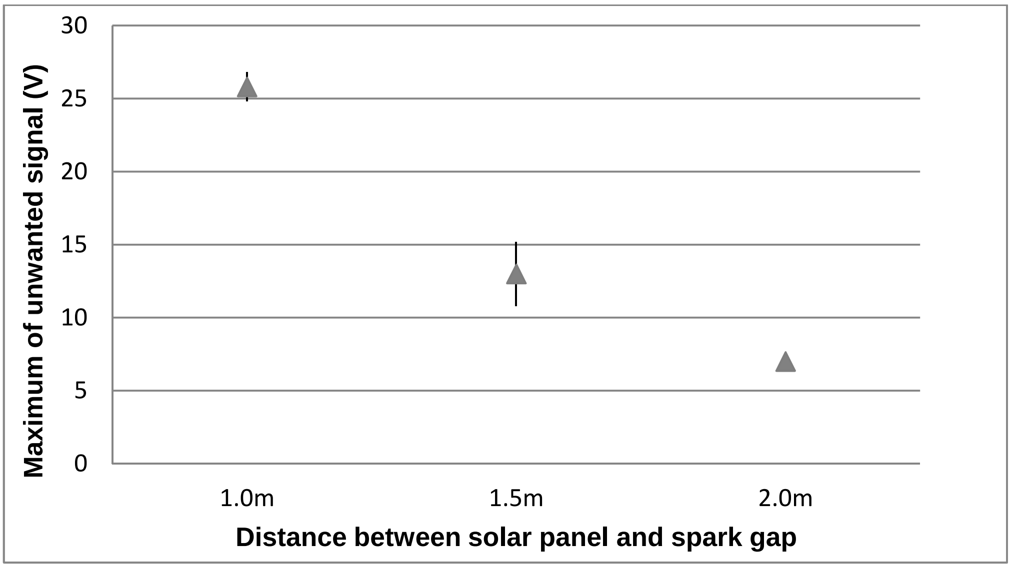

Figure 3. Gap Distance of Solar Panel and Spark Gap versus Maximum Voltage of Unwanted Signal

Based on the above result, it is found that there is no significant effect between twisted and non-twisted distribution line. It is expected that the small discrepancy may due to insufficient of induced voltage level capability in the lab setting.

4. Conclusion

A photovoltaic system is characterized by an extensively distribution of panels that needs a modeling criterion in order to increase the safety level, maintenance, operation and reliability. Based on the obtained experimental result, there is a bit significant different between twisted and non-twisted distribution line based on the existence of unwanted signal due to the induced voltage with the profile of maximum voltage, duration and pulse width of unwanted signal result. From the result obtained, twisted cable is not an effective way to reduce the induced voltage towards solar panel. Hence, through the same experiment work, it is expected that the new protection scheme for the solar panel such as the improvised Surge Protective Device (SPD) and shielded technique of twisted distribution line will be proposed for future work solution.

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