



**SIGNATURE OF UNWANTED SIGNAL DUE TO
INDUCED VOLTAGE AT PV SOLAR PANEL BY
LIGHTNING STRIKE**

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**MASTER OF SCIENCE IN ELECTRICAL
ENGINEERING**

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Faculty of Electrical Engineering

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**A thesis submitted
in fulfilment of the requirements for the degree of Master of Science
in Electrical Engineering**

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled “**Signature of Unwanted Signal due to Induced Voltage at PV Solar Panel by Lightning Strike**” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Nur Hidayu Binti Abdul Rahim

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

Signature :.....
Supervisor Name: : Ir. Dr. Md Nazri Bin Othman
Date :.....

DEDICATION

To my beloved:

husband; Muhammad Aiman Bin Husin

mother; Hjh. Murni Binti Salim

father; Hj. Abdul Rahim Bin Abdullah

and family

Thanks for being my inspiration and the full support given

ABSTRACT

The recent advancement of renewable energy sources especially photovoltaic (PV) system has resulted in outdoor installations of large power stations. Therefore, the PV system may be exposed to risky conditions such as the lightning strike activities that are generated by induced overvoltage. The induced overvoltage of lightning has a high tendency to inject the unwanted signal to the solar panel as well as to the cable of the solar system. Improper protection scheme of PV system installation may affect the overall system performance will harm the electrical apparatus especially the sensitive devices. The above problematic issue leads to an investigation on the effect of induced voltage to the PV system. The experimental work is conducted to analyse the effects of different cable parameters on the induced voltage due to the simulated lightning strike. The secondary study is about the investigation of unwanted signal behaviour due to the induced voltage under different arrangement of solar panel through three different transmission line cables namely the normal transmission line (non-twisted cable), the twisted cable and the coaxial cable. The results of the study show the existence of unwanted signal propagating on the solar panel proportionally with the distance of the solar panel and the lightning impulse source. The conducted experiment has proven that the magnitude of the induced voltage could be reduced proportionally with the studied distance by selecting the suitable types of cable connection to the PV system. In the future, this thesis could guide the proper protection scheme for PV system installation such as the method of a proper cable shielding technique and coordination of surge protection device (SPD).

ABSTRAK

Pada era kemajuan masa kini, sistem solar merupakan sumber tenaga boleh diperbaharui dan telah melibatkan pemasangan di stesen kuasa besar. Oleh yang demikian, sistem photovoltaic boleh terdedah kepada keadaan berisiko seperti aktiviti kilat yang akan menghasilkan voltan teraruh. Voltan aruhan yang terhasil daripada pancaran kilat mempunyai kecenderungan yang tinggi untuk mengaruh isyarat yang tidak diingini kepada panel solar dan juga kabel sistem solar yang terdedah. Skim perlindungan yang salah dalam pemasangan sistem PV boleh menjejaskan prestasi keseluruhan sistem yang akan merosakkan peralatan elektrik terutama peranti sensitif. . Isu-isu yang permasalahan di atas membawa kepada penyiasatan ke atas kesan voltan teraruh kepada sistem PV. Kerja-kerja eksperimen yang telah dijalankan adalah untuk menganalisis kesan parameter dari kabel yang berbeza kepada voltan teraruh yang disimulasikan oleh pancaran kilat. Kajian kedua pula adalah tentang tindakbalas isyarat yang tidak dikehendaki di bawah perkiraan yang berbeza daripada panel solar melalui kabel talian penghantaran yang ada di antara talian penghantaran normal (kabel tidak berpintal), kabel berpintal dan kabel sepaksi. Keputusan kajian menunjukkan kewujudan isyarat yang tidak dikehendaki yang merambat pada panel solar berkadaran dengan jarak panel solar dan sumber kilat gerak hati. Eksperimen yang dijalankan telah membuktikan bahawa magnitud voltan teraruh dapat dikurangkan berkadaran dengan jarak apabila jenis kabel yang sesuai disambung ke sistem PV. Pada masa akan datang, tesis ini boleh menjadi rujukan bagi skim perlindungan yang betul untuk pemasangan sistem PV seperti kaedah pemilihan kabel perlindungan yang betul dan penyelarasan peranti perlindungan lonjakan (SPD).

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LIST OF ABBREVIATIONS

ABBREVIATION	TITLE	PAGE
PV	Photovoltaic	1
SPD	Surge Protective Devices	3
DMI	Digital Measuring Unit	8
FDTD	Finite Difference Time Domain	12
IC	Intra Cloud	13
CC	Cloud to another Cloud	13
CG	Cloud and the Ground	13
LPCR	Low Positive Charge Region	15
PVIs	Photovoltaic Installations	16
LEMP	lightning electromagnetic impulse	16
SEMP	switching electromagnetic impulse	16
CLVPDS	conventional low voltage power distribution system	16
LPS	lightning protection system	16
HV	High Voltage	16
LPMS	Lightning Protection Measure System	17
TA	Transistor Active	18
SC	Substrate Contact	18
RF	Radio-Frequency	18

MOV	Metal Oxide Varistor	19
CPE	Customer Premises Equipment	20
WT	Wavelet Transform	21
EM	Electromagnetic	22
NEC	National Electrical Code	34
CEC	Council Electrical Code	34
EMI	Electromagnetic Interference	37
STP	Screened Twisted Pair	37
DC	Direct Current	38
AC	Alternating Current	38
DPO	Digital Phosphor Oscilloscope	58
DMI	Digital Measuring instrument	59

LIST OF PUBLICATION

A. Journal

1. N.H. Ab Rahim, Z.A. Baharuddin, M.N. Othman. "Investigation of Wave Propagation to PV-Solar Panel Due to Induced Overvoltage Generated by Lightning Impulse Generator" TELEKOMNIKA Advanced Science and Technology Letters Vol.38(Energy 2013), pp.15-22
2. N.H. Ab Rahim, Z.A. Baharuddin, M.N. Othman, P.N.S. Ab Rahman, "The Comparative Study Between Twisted And Non-Twisted Distribution Line for Photovoltaic System Subjected to Induced Voltage Generated by Impulse Voltage" TELKOMNIKA Indonesian Journal of Electrical Engineering Vol. 12, No. 8, August 2014, pp. 5774 ~ 5778
3. P.N.S. Ab Rahman, Z.A Baharuddin, N.H Abdul Rahim, "Misidentification of Type of Lightning Flashes in Malaysia," TELKOMNIKA Indonesian Journal of Electrical Engineering Vol. 12, No. 8, August 2014, pp. 5938 ~ 5945

B. Exhibition

1. N.H. Ab Rahim, Z.A. Baharuddin, M.N. Othman, "The Investigation Of Coupling-Unwanted Signal To The Solar Panel Material Due To Induced Overvoltage Created By Short Spark Gap" 3rd International Conference and Exhibition on Sustainable Energy and Advanced Materials (ICE-SEAM 2013)

CHAPTER 1

INTRODUCTION

1.1 Introduction

A general process of generating electrical power by changing solar radiation into direct current electricity by using semiconductors is known as Photovoltaic (PV). Basically, it will exhibit the PV effects which are known as direct strike or indirect strike. Usually, PV power generation employs solar panels composed of a number of solar cells containing a PV material. The manufacture of solar panel and PV arrays has advanced significantly in recent years. This is due to the growing demand for renewable energy sources nowadays. According to (Ahmed et al, 2010), the world's PV capacity in the world has presented the total output power that had run over a calendar year is equal to some 80 billion kWh of electricity used. This is sufficient to cover the annual power supply needs of over 20 million households in the world. As reported in (Ahmed et al, 2010) and (Luque & Hegedus, 2003), solar PV is now, after hydro and wind power, the third most important renewable energy source in terms of globally installed capacity. There are more than 100 countries that use solar panels as a major electricity source. Generally, the research of PV system is highly demanding as well as useful and relevant for massive contribution for future application. However, large size of solar cells have tendencies of increased probability to be effected by lightning strike activities, either direct or indirect strike.

The phenomenon of lightning has been the subject of intensive study by researchers (Kamer, 1993), (Rakov et al., 2002) and (P.Hasse, Mcghee, & Grimble, 2000). Even though an accurate picture of the lightning phenomenon cannot be expected, but with the early signs, it is sometimes able to be predicted. In order to overcome this, protective measures will be the best alternative against lightning effects which are categorized into two types: a direct attack that happens to strike directly to a related energy sources, heating, flash and firing lightning current. The second type is the indirect and crashes, also known as lightning caused by overvoltage. For this kind of situation, it did not get a quick impression of the coupling between the lightning stroke, PV system conductors, and cables in electrical and electronic systems. The work of lightning and surge protection of PV installations by researcher (Hernández, Vidal, Jurado, & Member, 2008) have speculated about two installations of PV systems which were damaged during lightning thunderstorms, may be 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, leading to a firm conclusion when the evident is sufficient and also allowing conjectures when the evidence is less then conclusive. However, the evidence is insufficient to conclude that all observed damage was caused by direct lightning strike effect since it is not easy to predict the exact time frame of the lightning strike that happen to the specific point. Therefore further investigation of direct effect need to be done by considering the complexity, the cost, safety issues and other.

On the other hand, (S. Yokoyama, K. Miyake, 1983) stated that lightning-induced overvoltage are responsible for the majority of faults on overhead lines distribution, causing micro-interruption and mostly disturbances to sensitive electronic devices.

Moreover, the study of lightning-induced voltage can be done under controlled condition such as in the laboratory which is not costly and in a safer work environment compared to direct lightning strike. Furthermore, the result of this particular study can be a threshold or reference for estimating the effect of direct lightning strike.

Up to date, there is no experimental study in investigating and identifying the characteristics of lightning-induced overvoltage that is coupled to the PV system and electrical and electronic system. Recently, the lightning simulation for PV system concerning lightning-induced overvoltage appeared in (C. Zhang, Hu, Wang, Sun, & Li, 2013). Zang and co-workers (C. Zhang et al., 2013) calculated and analysed the induced overvoltage for PV panel arrays on the building rooftop. They concluded that the lightning-induced overvoltage is directly proportional to the peak value of lightning current. Indeed, they claimed that, more serious factors exposed to the overvoltage are the high-raised building, soil resistivity and the distance effect. Furthermore, their investigations concluded that the selection of Surge Protective Devices (SPD) should be considered for all the factors mentioned above. This problem greatly motivates our team to propose a novel study in examining and developing the proper lightning protection scheme for PV system.

Over the years in related studies, many researchers tried to discover ways to reduce production costs associated with PV technology and traditional solar panels. Now, as the industry continues to grow rapidly, its main priority has turn to improving the solar technology rather than creating it. The latest applications of solar panel in the world are the portable solar charger, solar garden, solar lamp and many other essentials that use solar energy. These PV cells are made of single crystal silicon (mono-crystalline), or a cut from a block of silicon that consists of many crystals (multi-crystalline) and called "first