PERFORMANCE ANALYSIS OF A PHOTOVOLTAIC CELL PLACED NEARBY POWER TRANSMISSION LINES

By

Mohamed Sayed Abdelkhalek Afifi

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
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In
Electrical Power and Machines Engineering

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Title of Thesis:

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Key Words:
Overhead Transmission Line; Electric Field; Photovoltaic; Performance; COMSOL

Summary:

The thesis studies the effect of the electric fields resulted from over-head transmission lines on the photovoltaic cells. The thesis research comprises modeling of Photovoltaic using finite element method on COMSOL Multiphysics software. The effect of light wave and electric field waves has been introduced to the model to study their effect on Photovoltaic model. The study is built on comparing the electrical performance parameters of the Photovoltaic module like voltage, current and power-voltage curve in the existences and absence of the transmission line fields. The study has been supported with practical measurements for photovoltaic module placed under the transmission line subjected to electric field of 2.1 kV/m, also laboratory verification carried out on higher values of electric field and using high voltage AC up to 25 kV to generate electric field up to 21.55 kV/m in the experimental case. The study shows that the performance of the photovoltaic module is not affected by the fields under the transmission lines which opens the door for further studies leading to better use of lands under their right of way.

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List of Abbreviations

CSM	Charge Simulation Method.
DNA	Deoxyribonucleic Acid.
ELF	Extremely Low Frequency Fields.
EMC	Electromagnetic Compatibility.
EMF	Electromagnetic Fields.
FDM	Finite Difference Method.
FEM	Finite Element Method.
OHTL	Overhead Transmission Line.
PV	Photovoltaic.

List of Symbols

∇	Mathematical Curl operator
A	Closed surface area in divergence equation
c	Speed of light in free spare and air 2.998 x 10_8 m/s
D	Electric flux density
E	East known potential point of point P in finite difference method
E_f	Electric Field
E_g	Bandgap energy needed to cross the band in semiconductor
E_{ph}	Energy of the photons
FF	the fill factor of the photovoltaic cell
h	Planks constant (6.625 x 10^{-34} joules.s)
h_E	distance between P and E in finite difference method
h_N	distance between P and N in finite difference method
h_S	distance between P and S in finite difference method
h_W	distance between P and W in finite difference method
I	the total current for photovoltaic cell
I_0	Diode current
I_L	light generated current of photovoltaic cell
I_{MP}	Maximum Current of the photovoltaic cell
I_{SC}	the short-circuit current of the Photovoltaic cell
j	complex number operator equals $= \sqrt{-1}$
k	Boltzmann's constant
n	Ideality factor of the diode
N	North known potential point of point P in finite difference method
P	Unknown potential point in finite difference method

P_{MP}	Maximum power of the photovoltaic cell
q	Electron charge constant
Q_1	Point charge 1
Q_2	Point charge 2
R_{CH}	Characteristic Resistance of photovoltaic cell
R_S	Series Resistance of photovoltaic cell
S	South known potential point of point P in finite difference method
T	Absolute Temperature
V	The total voltage for photovoltaic cell
V_{MP}	Maximum voltage of the photovoltaic cell
V_{OC}	the open circuit voltage of the Photovoltaic cell
W	West known potential point of point P in finite difference method
W_{FE}	Energy stored in the volume in finite element method
ε	The isotropic permittivity of the material
ε_x	The anisotropic permittivity of the material in x-direction
ε_y	The anisotropic permittivity of the material in y-direction
ε_z	The anisotropic permittivity of the material in z-direction
η	the efficiency of the Photovoltaic cell
σ	Electrical conductivity
λ	Wavelength of light wave
Φ	The potential symbol for numerical techniques
$\Phi(E)$	Potential value of point E in finite difference method
$\Phi(N)$	Potential value of point N in finite difference method
$\Phi(S)$	Potential value of point S in finite difference method
$\Phi(W)$	Potential value of point W in finite difference method

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Abstract

The Electromagnetic Fields and Electromagnetic Compatibility (EMC) are key sciences; they are used to ensure the proper performance of the electrical and electronic devices. These sciences should be utilized to study the effect of the equipment on each other and expect the performance when parameters change.

Many unplanned performances for electric equipment has been noticed, especially due to the effect of the electric fields surrounding the transmission line. There is a need to know about the performance of many devices when subjected to abnormal conditions especially electric fields.

The selected device to be tested is the photovoltaic module (PV). The analysis needed to be done is to study the change in performance that may result if the module is placed nearby a transmission line.

Many studies have been done to numerically calculate the electric fields nearby transmission lines, also many studies have been made to model the PV cells to calculate its performance parameters. The most common studies simulated the PV cells using finite element method.

This research uses a simulation using finite element package. A blending of two physics in COMSOL® Software has been done to simulate such environment, which are the “Electromagnetic Waves” and the “Semiconductors”.

The study has been supported with practical measurements for photovoltaic module placed under the transmission line subjected to electric field of 2.1 kV/m, also laboratory verification carried out on higher values of electric field and using high voltage AC up to 25 kV to generate electric field up to 21.55 kV/m in the experimental case.

The main results obtained shows that there is no change noticed in the performance of the PV cell, which opens the door for better utilizing the huge areas under the transmission lines in PV farming.