A Review of Short Circuit Analysis in a Solar Systems

Engr. Seraj Alshakhoori[1] and Dr. lbrahim Omar Habiballah[2]

[1]King Fahd University of Petroleum and Minerals, Electrical Engineering Department
E-mail: Eg.Alshakhooris@gmail.com
[2]King Fahd University of Petroleum and Minerals Electrical Engineering Department
E-mail: IbrahimH@kfupm.edu.sa

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Abstract:
This paper presents the Short Circuit Analysis of a Solar Energy by analyzing the different type of faults. As a matter of fact, this paper also represents review of a research work, which had been done in field of Short Circuit Analysis.

Key words: Short Circuit Analysis, Solar Energy, Power System, and PV.

1. Introduction:

Solar energy is the cleanest, most sustainable and most abundant form of renewable energy source discovered till now. The United States of America currently owns some of the richest solar energy resources on the planet. Solar technologies can harness the energy for a variety of purposes, including generating energy, providing lighting or a comfortable internal environment, heating food and producing heat energy for domestic and industrial use. Solar energy is growing into an increasingly big business, and its contribution of energy industry is rising rapidly. Nearly everyone has realized the solar window or the solar work, but there are some less common solar technologies that are emerging.

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To meet the continuously growing demands of energy with primary focus on eco-friendly and clean energy solar energy system are being deployed at a previously unprecedented rate. Since the number of solar energy systems have seen a rapid increase the issues concerning them have also increased rapidly.

However, despite the overwhelming advantages, solar energy generation has its own pitfalls and production faults. The study conducted, reviews research and highlights different faults found in photovoltaic system, solar inverters, distribution system, microcontrollers in solar system and power supply mechanism. The study aims to increase efficiency and reliability of solar system, resultantly increasing their safety and making them more dependable. If these faults go undetected, they can not only diminish the overall reliability and availability of solar systems by significant factors but can also make systems age significantly faster and can greatly reduce the power output making them inefficient and expensive for deployment on industrial scale.

In photovoltaic systems the faults are broadly classified as visual, thermal and electrical. Faults that can be visually detected include discoloration of physical components of solar systems, surface soling of components, removal of lamination and browning of components installed. Similarly, thermal cues include the excessive heating of solar system that can cause various components to burn or fail. Whereas electrical signatures include current voltage curve measurement and fluctuations in power diagnosed by FR measurements.

However, the use of electrical signatures is well established practice in industrial settings for solar system monitoring and performing diagnostics. These techniques not only provide the promising and reliable prospects of detailed analysis, but techniques such as current voltage curves analyses are fundamental in understanding and diagnosing faults in solar systems. Diagnosis using electrical signatures provide the fundamental data that aid in establishing photovoltaic cell's health. Furthermore, the impacts of fault occurrences on wider system can studied using the output parameters V_{OC}, V_{MPP}, I_{SC}, I_{MPP}, obtained through techniques such as current voltage curves and P-V curves.

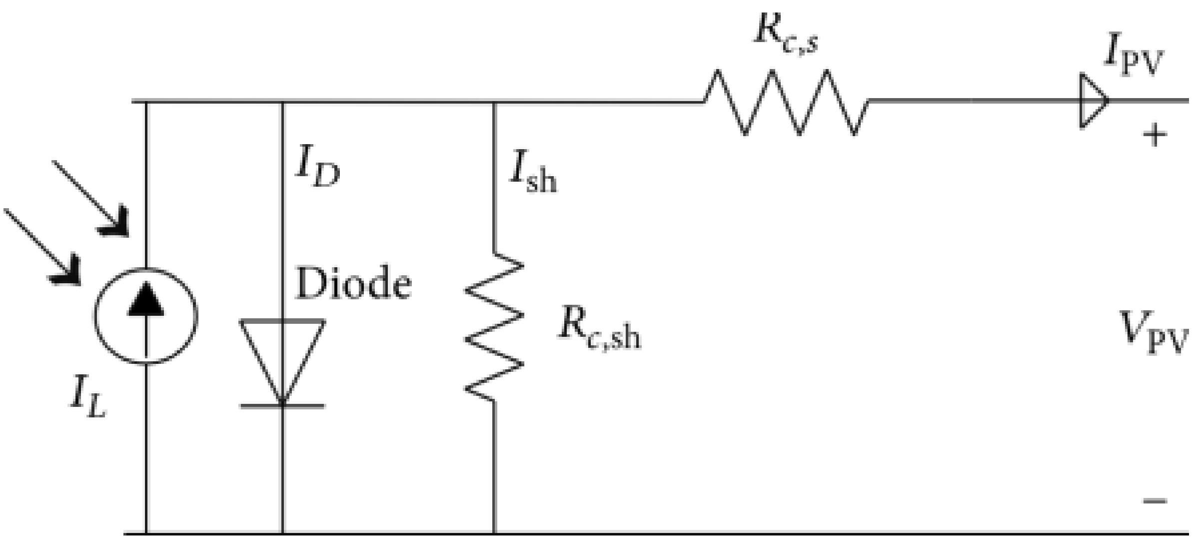

Figure 1: The one-diode model equivalent

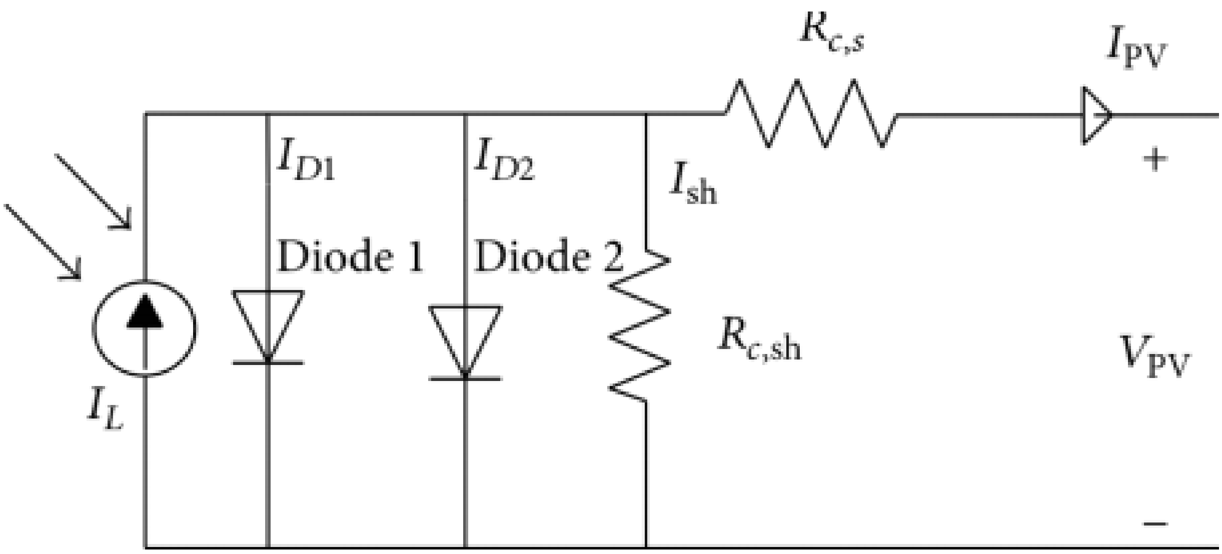

Figure 2: The two-diode model equivalent

Above illustrated figures are models for photovoltaic cells. Two models are presented namely the one-diode model and double-diode model. Two models were created as the current source and voltage source cannot be modelled as constant. Because of the current voltage properties of solar cell being non-linear, therefore single and double diode approach were taken.

Nomenclature:

VOC: open circuit voltage
VMPP: maximum power point voltage
ISC: short circuit current
IMPP: maximum power point current
MPPT: maximum power point tracer
STC: standard test condition
MPPT: maximum power point tracer
STC: standard test condition
I: solar cell current (A)
V: solar cell voltage (V)
IL: light-generated current (A)
ID: diode current (A)
*I*sh: shunt resistance current (A)
IS: saturation current of the diode (A)
Rc,*s*: solar cell series resistance (ohms)
Rc,sh: solar cell shunt resistance (ohms)
A: diode ideal factor ($1 \leq A \leq 2$)
G: solar irradiance (W/m2)
*G*0: reference solar irradiance (W/m2) = 1000
Tr: reference temperature (K) = 25 + 273
Ns: number of series solar cells per module
CT: temperature coefficient of the light-generated current (A/K)
*IS*0: reference saturation current (A)
Eg: band gap energy of the material (eV).

2. Literature Review:

2.1 Solar PV System:

Solar Photovoltaic systems receive the radiation coming from sun and convert it into electricity that fulfills energy needs in diverse applications. Photovoltaic (PV) solar panels differ from solar thermal systems in that they do not use the sun's heat to generate thermal power, instead they use sunlight through the 'Photovoltaic effect' to generate direct electric current (DC) (Nwaigwe, Mutabilwa, & Dintwa, 2019).

The common faults that occur in Solar Photovoltaic systems are Partial shading which occur due to environmental condition blocking the system, Open-circuit fault which can be caused due to numbers of reasons including loose or improper cabling, improper connections at junction boxes and panel breakdowns. Soling is caused by operating system in unclean environmental conditions and due maintenance. Lower Ground Fault occurs because of the flow of current to surface with zero fault impedance and is associated with current backed. Series arc fault occurs due to cell corrosion, damage and abrasion. Line-to-line faults occur as result of short circuit in between different potential points. Bypass diode faults result in short circuits due to improper configuration. Degradation faults are yellowing and browning, delamination, bubbles in the solar module, cracks in cells, defects in antireflective coating and delamination over cells and interconnections lead to degradation and increasing of the internal series resistance (Arani & Hejazi, 2016). Similarly, MPPT faults in Solar Photovoltaic systems occur due to inconsistencies in MPPT controllers. Uniform irradiance distribution is also commonly occurring fault and occur due to irregular irradiance intensity during daytime.

2.2 Inverter:

In accordance with above discussion the output of solar systems is in form of direct current (DC). However, most day to day appliances use alternating current and are generally constrained to fixed voltages. In order to make them interoperable output of solar system is converted using power inverters commonly called as photovoltaic inverters. These inverters can be configured to solar panels using various topologies.
The most common configuration is connecting all modules in series and attaching an inverter at the end. This approach is, however, constrained due to individual modules having an un proportional influence on the total power yield of the string (Nilsson, 2019). Common Inverter faults also include failure of each component of inverter such as IGBTs, capacitors, and drive circuitry. (Sabbaghpur Arani, and Hejazi, 2016)

Figure 3: Illustration of photovoltaic inverter with DC input and AC output.

2.3 Microcontroller:

Adoption of microcontrollers, in energy consumption and distribution systems, has seen a huge increase in past decade. They are mainly incorporated to reduce the power consumption making system more efficient and less expensive to operate. The continuous monitoring of solar system components and parameters will lead towards efficient usage of solar energy. The microcontrollers have also been employed to acquire various signals for monitoring purposes or to control activities such a battery charging and solar tracking. Microcontrollers are also used for interfacing photovoltaic-derived energy with the grid supply as a way of providing a reference point for synchronization.

2.4 Power Supply

Power supply plays crucial role in solar systems by maintaining voltage levels. The commonly occurring faults pertaining to power supply include excessive discharging and overcharging of power storage source. In solar photovoltaic system there are two kinds of charge regulators that are mainly utilized, namely series charge regulator and shunt charge regulator. Power Loss Analysis (PLA) is employed to diagnose power supply-oriented faults.

2.5 Behavior of the PV system during fault

Photovoltaic system's behavior depends upon the type and severity of fault occurred. Inverter faults generally leads towards components and circuitry failure, that may lead towards complete shutdown of overall system. Degradation faults tend to increase the ageing of system. Irrespective of the location of fault, photovoltaic system supplies almost same fault current, due to its maximum inverter current limit (Vijayakumar, 2012). Blocking and controller faults can cause short-circuit. Normally short circuit currents are varying between 1.5 to two times of rated current (Bejmert, 2012). Partial shading, blocking have no direct impact upon system hardware but reduce the output of solar energy systems resultantly making the systems inefficient to operate.

2.6 Distribution systems

Distribution systems automate the process for automatically adding residential and commercial buildings in feeders with end-use equipment and providing enough diversity in equipment characteristics such that realistic transmission level load profiles are generated (Jain et al.). The faults concerning distribution systems include time variations and fluctuations that result in destabilizing overall distribution network. Unfavorable climatic conditions and sever weather make the distribution systems prone to resilience issues. PV and fault analysis in distribution network include measuring and analyzing the profile of time-varying fault current. Additionally, it also includes estimating the amount of time that will be required for a relay to interrupt the fault current. The goal of PV and fault analysis in distribution networks is to maximize the active power transfer from PV.

3. Conclusions:

This study provides overview of solar energy and solar systems. It discusses and categorizes wide array of faults that can occur in solar photovoltaic systems. The faults were categorized into thermal, electrical and visual. The paper also highlights some of the most commonly used and well-established industrial practices for detection and diagnosis of faults in solar energy systems. The paper aims to provide comprehensive guide for practicing engineers and researchers to understand and diagnose the commonly occurring faults in solar energy systems.

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