Solar Watch Simulation

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Abstract- *Solar energy is a clean source of renewable energy. The solar energy is in demand nowadays. There is large use of solar cells in appliances. The solar powered watch is popular these days. The watch is operated using a solar cell. The objective is to study the photo voltaic cell used for solar powered watch using MATLAB simulation software. The simulation results and graphs are given for validating the output. The watch is reliable and efficient to use.*

Keywords- renewable energy, solar energy, photo voltaic cell, simulation.

I. INTRODUCTION

Solar energy is essential source of renewable energy. It is in great demand because of the side effects the fossil fuels have on environment. Also, the fossil fuels are near to become exhausted in near future. The solar energy is also clean source of energy. Large amount of solar energy available makes it a highly appealing source of electricity. In 2011, the International Energy Agency said that the development of affordable, in exhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries energy security through reliance on an indigenous, in exhaustible, and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise.

Solar Power is conversion of sunlight in to electricity. The PV converts light into electric current using photo electric effect. In the last two decades, the Photovoltaic cell (PV) are marching towards becoming a mainstream electricity source. The reisan increase indemand for domestic use of renewable sources, such as wind and solar combination. Hence, there is need for simulation models of solar cell to efficiently design.

A solar-powered watch is a watch that is powered entirely or partly by a solar cell. Development in this regard is that some of the early solar watches of the 1970s had innovative and unique designs to accommodate the array of photovoltaic solar cells needed to power them. In the1990s, Citizen started to sell light-powered watches under the Eco-Drive series name. Since their introduction, photovoltaic devices have greatly improved their efficiency and there by their capacity. Watch makers have developed their technology such that solar-powered watches are now a major part of their range of watches. Several other watch manufacturers offer similar watches or are developing such technology.

There is an increasing trend for domestic use of hybrid renewable sources, preferably wind and solar combination. Hence there is need for simulation models of the wind turbine and PV modules to efficiently design and integrate these sources to power systems. Nowadays, smart grid researchers demand wind turbines and PV panel models to deploy in their power system simulations as distributed generators and explore impacts of distributed generation on power distribution. These models should also represent the transient responses of renewable energy sources for stability and reliability analyses.

Numerous amounts of experiments are carried out in terms of the solar cell or photovoltaic cell. Therefore, solar cell model needs to be developed for a better understanding. A Matlab Simulink is a solar cell circuit that acts under a variety of situations for the solar panel as discussed in the paper. Matlab software provides a visual simulation for the analysis of solar cell working. The software also provides the facility of plotting graphs necessary for the circuits as discussed.

In this paper, it is shown that the solar cell model could work with watches while taking sunlight as input energy and giving electrical energy (charging of watch). Moreover, the generation of a safe output voltage makes the watch suitable for general use. The simulation shows the process of charging and also the charging of lithium-ion batteries provided along in case of low sunlight orno sunlight for a longer period of time.

Typically, sunlight and artificial light are absorbed by a solar panel behind the crystal. The dial is either on a layer above or actually on the solar panel. This solar panel converts the light into electrical energy to power the watch. The watch will usually store energy in a rechargeable cell to power itself during the night or when covered such as a wearer's clothing. The watch uses lithium-ion batteries to store sufficient energy to power the watch for several months/years without light exposure.

II. METHODOLOGY

Fig. 1 shows the top-level block diagram of the proposed PV module. The first block, referred as to behavioural PV model, performs theoretical calculations based on physics of the PV cell and it yields nominal values of voltage and current generated by the panel. The second block electrically drives to the electrical load according to the limited power I-V characteristics. Depending on the load value, the voltage drop over load (**VL**) and the load current(**IL**) are adjusted according to maximum power provided by PV panel. The maximum power point (MPP), namely the peak power, is limited by approximately $Pm \cong Vm\ Im$.

A. **Behavioural PV Modelling**

The physics of the PV cell is very similar to that of the classical diode with a pn junction [6]. When the junction absorbs light, the energy of absorbed photons is transferred to the electron proton system of the material, creating charge carriers that are separated at the junction [7]. An ideal PV cell is assumed to have no series loss and no leakage to ground. However, due to its non-ideal structure in nature, there are some losses occurred in real PV cells. Therefore, these losses are expressed by using resistances in equivalent circuits. Fig. 2 shows an equivalent electrical circuit modelling the complex physics of the PV cells [8-10]. The behavioural model of the proposed PV model is based on this equivalent electrical circuit model. Current source, *Iph*, which is a current produced by the photons, is constant at a fixed value of radiation and temperature.

The shunt resistance, *Rsh*, is used to represent the shunt leakage current, *Ish*. The series resistance, Rs, is used to represent the voltage drop at the output. PV power conversion efficiency (PPCE) is sensitive to small changes at Rs, but the PPCE is not sensitive to changes at *Rsh*. The small increase in Rs significantly reduces the output of the PV module [8]. In the equivalent circuit, the current, *Icell*, delivered to the external load equals the current IL and voltage over the load equals the voltage of PV cell, *Vcell* [2,9]. Current and voltage of PV panel depends on load value and presents nonlinear, power limited electrical characteristics.

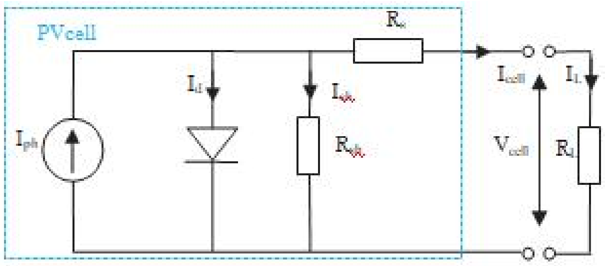

Figure1. Equivalent electrical circuit model of PV cells.

The Equation (1) describing output current of the non-ideal PV cell was derived using Kirchhoff's current law as follows[11]:

$$I_{cell}=I_{ph}-I_d-I_{sh} \tag{1}$$

The overall current, which the PV cell can provide, was formulated by Equation (2), where *G* and *Gr* are active and the reference radiation, *Tc* and *Tcr* are module temperature and reference temperature of the module, respectively [11].Producers usually provide electrical specifications of the PV module at standard conditions, namely solar radiation of 1000 W/m^2 and cell temperature of 25^{o}C. These values correspond to Grand *Tcr*, respectively [11].

$$I_{cell} = I_r + \left[\alpha\left(\frac{G}{G_r}\right)(T_c - T_{cr}) + \left(\frac{G}{G_r} - 1\right)I_{sc}\right] \tag{2}$$

The parameter *Isc* represents short circuit current of the [module and α is the temperature coefficient of short circuit current. The voltage of PV cell was formulated by Equation (3) and Equation (4) [11], where ß are temperature coefficient of open circuit voltage.

$$V_{cell} = -\beta(T_c - T_{cr}) - R_s\Delta I + V_r \tag{3}$$

$$\Delta I = \left[\alpha\left(\frac{G}{G_r}\right)(T_c - T_{cr}) + \left(\frac{G}{G_r} - 1\right)I_{sc}\right] \tag{4}$$

Herein, *Rs* is used to represent the voltage drop at the output of the PV cell. The parameters *Ir* and *Vr* are reference values taken from I-V curve [12, 13]. PV module is formed by connecting PV cell in series and parallel to each other. In this case, the output current and voltage of PV module is expressed in Equation (5) and Equation (6) , respectively.

$$V_m = N_{sc}V_{cell} \tag{5}$$

$$I_m = N_{pc}I_{cell} \tag{6}$$

Herein, *Vm* is the output voltage, and *Im* is the output current. *Nsc* and *Npc* are expressed numbers of series and parallel connected PV cells, respectively [11]. Simulink schema of behavioural PV model, using the Equation (2) and Equation (3), is demonstrated in Fig.3.

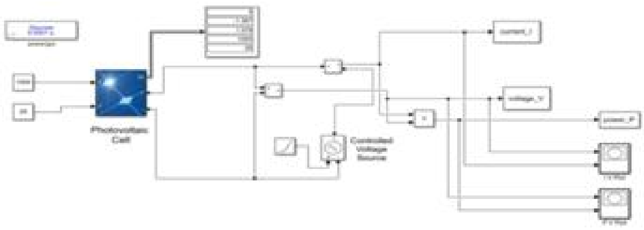

Figure2.Simulink model to plot IV and PV characteristics

TABLE I. Module Parameters Value

ModuleParameter	Values
Open circuitvoltage V_{oc}(V)	2
Voltageatmaximumpowerpoint V_{mp}(V)	1.5
Short-circuitcurrent I_{sc}(A)	0.22
Currentatmaximum powerpoint I_{mp}(A)	0.2
Temperaturecoefficientof V_{oc}(%/deg.C)	- 0.36099
Temperaturecoefficientof I_{sc}(%/deg.C)	0.102

This section illustrates PV module simulation examples. The module parameters were largely configured according to Solar ex MSX60 specifications for solar radiation of $1000W/m^2$ and cell temperature of 25^oC. Parameter settings are listed in Table 1.

(i) Module I-V characteristics

In PV cell, we are more interested in the total current and voltage that the PV module can generate, so we define the Module I-V curve, or the current-voltage curve,

(ii) Module P-V characteristics

Similar to an IV curve, the highest voltage occurs at the open-circuit condition and the current is zero and the short-circuit voltage is zero at the origin of the curve, but the current is maximum. Since the power is nothing but the voltage times the current (P=VxI), the power at both the short-circuit and open-circuit conditions is equal to zero since either voltage or current equals zero at each of these points. If we observe the power and voltage starting at the open-circuit condition (where the voltage is maximum and power is zero), and as we increase the load of the circuit, the power starts increasing and the voltage falls down until it reaches thevalue at MPP (where power is maximum). If we increase the load further, the voltage keeps falling down. However, the power will decrease as well until it reaches the value of zero at short circuit condition (where the both voltage and power are zero). It can be seen that it is as it is illustrated in Figure 3. The curve indicates the voltage and current at different operating conditions.

The highest current corresponds to the short circuit condition (when a PV module's positive and negative terminals are connected without load, causing very high current to pass), while the highest voltage occurs at open-circuit condition (when a PV module's positive and negative terminals are not connected to any load, causing no current to pass). If we observe the current and voltage starting at the open-circuit condition (where voltage is maximum and current is zero), and as we increase the load of the circuit, the current starts increasing and the voltage falls down until it reaches the value of zero at short-circuit condition (where the current is maximum). The knee of the curve indicates the operating condition in which current and voltage result in maximum power point (MPP). The voltage and current values at MPP are referred to as "*Vmpp*" and "*Impp,*" respectively.

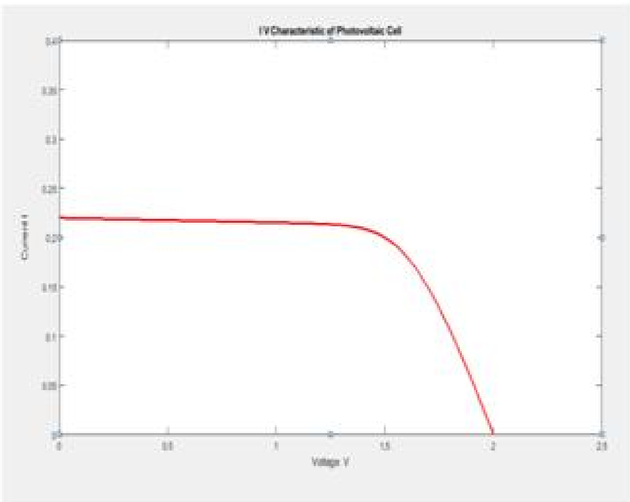

Figure 3. IV Characteristic of PV cell

much easier to find the peak power on the P-V curve in comparison to the I-V curve, as it resembles a hump. The power at MPP is referred to as *"Pmpp."*

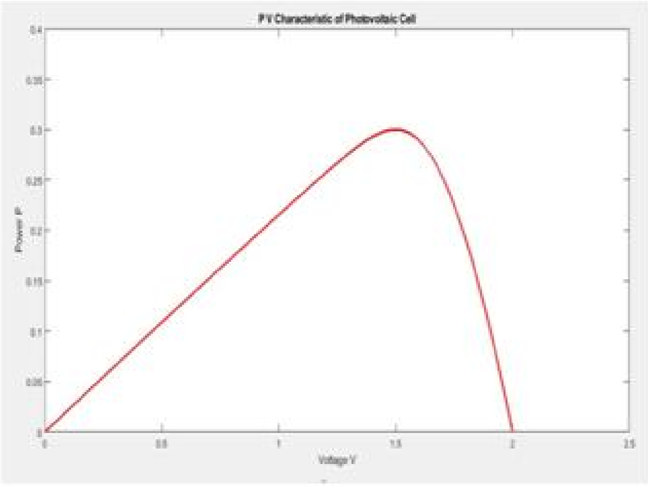

Figure4.PVCharacteristicofPVcell

A. Solar Watch Simulation

In the process, sunlight and artificial light are absorbed by a solar panel behind the crystal. This solar panel converts the light in to electrical energy to power the watch. The watch will usually store energy in a rechargeable cell to power itself during the night or when covered such as a wearer's clothing.

Case 1:

Simulink simulation of the proposed PV module connected to Li-ion battery. The load resistance (watch) is set to 5 Ohm for working near by MPP. A reference adiation (G) of 1000 W/m^2 and module temperature (Tc) of 25^{o}C were used in the simulation. Voltage and current of the load are settled to its steady state value after roughly 0.05 second transient regime. So at these ratings PV cell will carry total load of the circuit. The general constant voltage of 1.503 V is maintained across the watch with supply of current 0.3 A at which battery will perform work.

Case 2:

Now the reference radiation (G) which is much less than 1000W/m2 and module temperature (Tc) of 25^{o}C were used in the simulation. Voltage and Current of the load are settled to its steady state value after roughly 0.05 second transient regime. So at these ratings both PV cell and battery will work together which leads to the general constant voltage of 1.503 V and supply of current 0.3A across the watch.

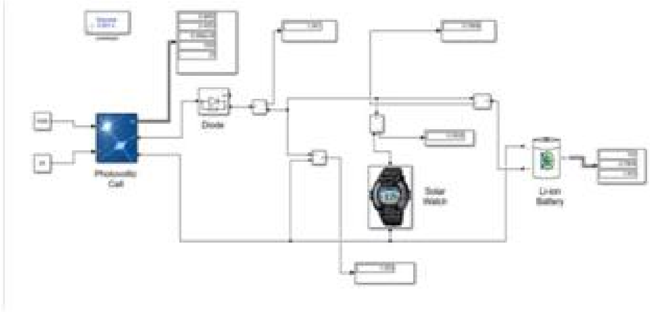

Figure 1.Solar watch circuit simulation

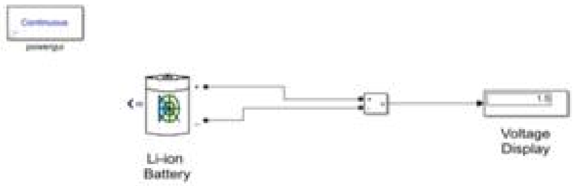

Figure2 : Li-ion battery simulation

III. CONCLUSION

This study presents a general purposes PV simulation module and its application, solar watch using MATLAB / Simulink simulation environment. The PV module has two main parts:

A) Behavioral model of PV cells.
B) Solar watch simulation with lithium-ion battery simulation.

The behavioural model estimates voltage and current of PV panel for a given solar radiation and temperature conditions.

The solar watch simulations hows that at low intensity on PV panel work load is divided between PV cell and Li-ion battery to run the watch. When desired intensity is achieved then the PV cell will carry complete load to run the watch as well a store charge the Li-ion battery.

The watch is capable to run even in the room light. Since the load is divided between PV cell and Li-ion battery, the watch has gained the huge life span of working. The issue of multiple replacement of common button cell for functioning of watch is eliminated.

Unlike a disposable battery such as dry battery and button battery, are chargeable battery is an ecofriendly battery.

It can be used for along period of time by recharging and discharging the energy repeatedly. Lithium-ion cells can be recharged hundreds, potentially thousands of times before a replacement battery is necessary.

Nowadays, solar energy integration in microgrids is becoming primary concern of power system industry. Modelling renewable energy sources for a large-scale power system integration simulation is more important these days because these simulation tools will be a part of optimal design and intelligent management process.

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