Solar Energy 145 (2017) 90–98

Contents lists available at ScienceDirect

Solar Energy

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A novel simulation model for PV panels based on datasheet parameter tuning

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ARTICLE INFO

Article history:
Received 17 December 2015
Received in revised form 6 November 2016
Accepted 4 December 2016
Available online 16 December 2016

Keywords:
Photovoltaic panel
Optimization method
Parameter tuning
PV simulator

ABSTRACT

Circuit simulation model for photovoltaic array is very useful in simulating and evaluating the performance of power conditioning system. Among various programs, PSIM is widely used in power simulation and its physical model can handle changing output according to temperature and irradiance. However, accuracy of the model heavily depends on user-defined information. Specifically, construction of the conventional PSIM model involves calculation of tangential slope at open circuit voltage point in the I-V curve and estimation of ideality factor, both of which are obtained by trial and error and thus strongly influence the model accuracy.

In this paper, a new PSIM simulation model for PV panels using online parameter tuning is presented. The proposed model utilizes only datasheet values measured under STC and excludes the necessity of the error-prone processes. Furthermore, all of the five parameters in single-diode model are successively tuned using Powell's optimization method in order to guarantee good accuracy and high speed. Comparisons with conventional model are performed using crystalline PV panel sample and the results shows that the proposed model provides more accurate and uniform performance according to EN50530 standard.

1. Introduction

In photovoltaic (PV) generation system, obtaining the maximum available energy from PV source using highly efficient power conditioning system (PCS) is important issue. Because the characteristic of real PV panel is always changing with dynamic irradiance and temperature conditions, a PV simulator is necessary in the development of PCS (Cubas et al., 2014). PV simulator is a repeatable replication of PV source which enables tests of new power management algorithms and estimation of system efficiency under the dynamic environmental condition.

Even though the testing with hardware PV simulator is becoming one of essential step for the PCS developer, software PV simulator is still prerequisite to hardware productions especially in the early development phase, and circuit simulation tools provides flexible, convenient, and economical ways of testing PV system. Among various simulation tools, PSIM is one of the promising circuit simulation programs because of its fast simulation speed, immunity to convergence issue, and library extensibility using C-code block (PSIM User's Guide, 2010).

In software PV simulators, PV source is represented by a simulation block which emulates the source characteristic by a dedicated algorithm called "PV model" and hence it is the core part of the PV simulation. It is also valuable for hardware PV simulator, because once the software simulation has been finished, it can be re-used as a PV simulation engine which controls programmable DC power supplies in hardware simulators (Gonzalez et al.).

Because the PV model usually incorporates a single-diode equivalent model as shown in Fig. 1, its model parameter determination is very critical in model construction. The required model parameters are series resistance (R_s), shunt resistance (R_{sh}), diode ideality factor (A), photocurrent (I_{ph}), and dark current (I_o) as listed in Table 1. These parameters will be different for each cell type and will vary with the environmental parameters, and their determination process has been research topics in many literatures. Conventionally, the parameters have been constructed based on a bunch of real PV data acquisition: from a specimen solar cell, sets of real PV panel data have been collected across its operating range and fitted into a I-V curve of the equivalent model to extract model the parameter. In spite of the accuracy of data it may have, this method requires tedious and time-consuming measurement process.

Recently, techniques based on datasheet values have been presented (Crispim et al., 2007; Villalva et al., 2009; Sera et al., 2007;

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http://dx.doi.org/10.1016/j.solener.2016.12.003
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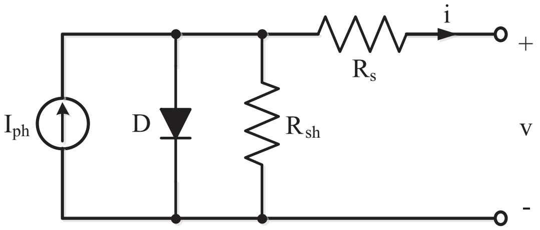


Fig. 1. Single-diode model for PV panel.

Table 1
Model parameters in the single-diode PV model.

Parameter	Description	Unit
I_{ph}	Photovoltaic current	A
I_o	Dark current	A
R_s	Series resistor	Ω
G_{sh} ($1/R_{sh}$)	Shunt conductance	S
A	Diode ideality factor	–

Park and Choi, 2015b). They are practically valuable because they can omit measurement process and thus provide rapid performance estimation with reasonable accuracy. However, these algorithms should be performed separately. For example, conventional PSIM PV model requires user to input the model parameter which should be extracted in advance by a separate parameter extraction program. There has been no study on the integration of parameter determination and simulation model.

In this paper, a novel PSIM simulation model for PV will be presented. The proposed model introduces the concept of dynamic datasheet to automate the parameter extraction process. This paper is divided into five sections: Existing PSIM method is analyzed in Section 2, and a novel model is presented in Section 3. Model performance will be compared and verified in Section 4, and conclusion will be drawn in Section 5.

2. Conventional PV model in PSIM

PSIM program offers two versions of PV models: level 1 model (functional model) and level 2 model (physical model). While the functional model describes PV output characteristic under standard test condition (STC), the physical model provide changing characteristic under dynamic environmental conditions. For These reasons, only the physical are investigated herein.

Fig. 2 shows the internal structure of the physical model (PSIM User's Guide, 2010). It adopts single-diode PV model whose I-V characteristic is both non-linear and implicit as

$$i = I_{ph} - I_o\left(e^{\frac{q(v+iR_s)}{N_sAkT}} - 1\right) - \frac{v+iR_s}{R_{sh}} \tag{1}$$

where N_s is the number of PV cells in series, k is the Boltzmann constant, q is the charge of an electron, and T is absolute temperature. Therefore, five model parameters – R_s, R_{sh}, A, I_{ph}, and I_o – should be determined in advance to simulate a given PV panel.

The parameter determination process is divided into two steps: one is off-line and the other is on-line process. At first, every parameter is directly obtained through a dedicated parameter extraction program called "solar module utility" shown in Fig. 3. This program extracts initial values of model parameters from the three kinds of user input data groups: one is the datasheet values such as V_{oc}, I_{sc}, and N_s, and the other is the manually calculated data such as the slope evaluated at V_{oc} in the I-V curve of datasheet, the third is R_{sh} and A that usually determined by heuristic methods or by trial and error. They are filled into the user input fields in Fig. 3. The following equations are used for the calculation of the parameters – $I_{ph,STC}$, $I_{o,STC}$, and R_s from the user-intentioned assumptions in A and R_{sh} (PSIM Tutorial; Singhal and Narvey, 2011; Gow and Manning, 1999).

$$I_{ph,STC} = I_{sc} \tag{2}$$

$$I_{o,STC} = \frac{I_{sc}}{e^{\frac{qV_{oc}}{N_sAkT}} - 1} \tag{3}$$

$$R_s = -\left.\frac{dv}{di}\right|_{@V_{oc}} - \frac{1}{X_V} \tag{4}$$

where

$$X_V = \frac{qI_{o,STC}}{N_sAkT}e^{\frac{qV_{oc}}{N_sAkT}} + \frac{1}{R_{sh}}. \tag{5}$$

Those equations are derived from Eq. (1) and Fig. 1. At $I = I_{sc}$, $V = 0$, I_{ph} can be approximated by I_{sc} as in Eq. (2) because the current flowing down the diode and the shunt resistance becomes very small. Eq. (3) assumes that the current flows mainly through the diode at $V = V_{oc}$ and $I = 0$. To yield Eqs. (4) and (1) has been differentiated and evaluated at $V = V_{oc}$ and $I = 0$ and rearranged in terms of R_s. In the above description, X_V denotes the incremental conductance of the p-n junction of photovoltaic panel including the internal leakage conductance. Therefore, R_s can be estimated from the slope in the I-V curve at V_{oc}. In this method, one approximation of a parameter relies upon the already approximated values of the other parameters.

After the off-line process, user should input the results of the off-line process into the PSIM simulation model through the user input window shown in Table 2. Once the simulation begins, the model adjusts I_{ph} and I_o according to the two external voltage sources: irradiance (S) and temperature (T) to obtain the changing output characteristic using the parameter update equation in Eqs. (6) and (7). The remaining three parameters – R_s, R_{sh}, and A, maintained fixed throughout the simulation process.

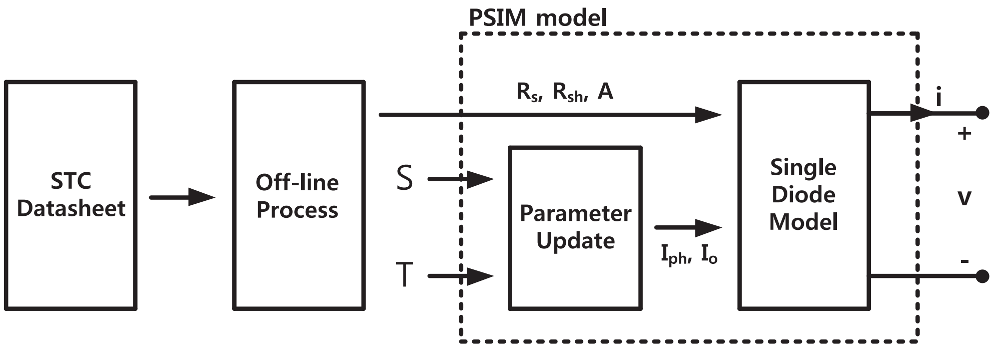
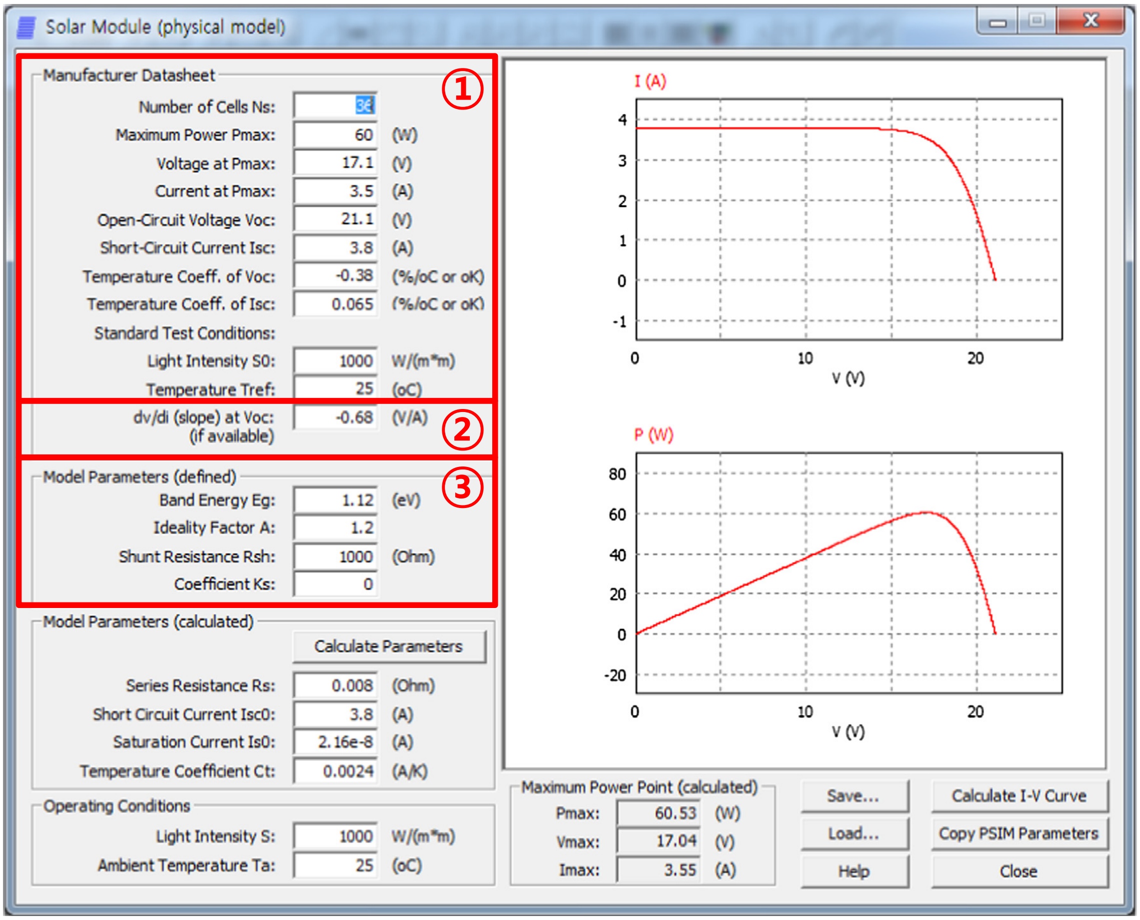


Fig. 2. Conventional PV model in PSIM.



Manufacturer Datasheet
Number of Cells Ns: 36
Maximum Power Pmax: 60 (W)
Voltage at Pmax: 17.1 (V)
Current at Pmax: 3.5 (A)
Open-Circuit Voltage Voc: 21.1 (V)
Short-Circuit Current Isc: 3.8 (A)
Temperature Coeff. of Voc: -0.38 (%/oC or oK)
Temperature Coeff. of Isc: 0.065 (%/oC or oK)
Standard Test Conditions:
Light Intensity S0: 1000 W/(m*m)
Temperature Tref: 25 (oC)
dv/di (slope) at Voc: (if available) -0.68 (V/A)

Model Parameters (defined)
Band Energy Eg: 1.12 (eV)
Ideality Factor A: 1.2
Shunt Resistance Rsh: 1000 (Ohm)
Coefficient Ks: 0

Model Parameters (calculated)
Series Resistance Rs: 0.008 (Ohm)
Short Circuit Current Isc0: 3.8 (A)
Saturation Current Is0: 2.16e-8 (A)
Temperature Coefficient Ct: 0.0024 (A/K)

Operating Conditions
Light Intensity S: 1000 W/(m*m)
Ambient Temperature Ta: 25 (oC)

Maximum Power Point (calculated)
Pmax: 60.53 (W)
Vmax: 17.04 (V)
Imax: 3.55 (A)

Fig. 3. PSIM solar module utility.

Table 2
User inputs for the conventional model.

Parameter	Description	Unit
Ns	Number of cells	–
S0	Irradiance level under STC	W/m^2
Tref	Temperature level under STC	K
Rs	Series resistance	Ω
Rsh	Shunt resistance	Ω
Isc0 (Isc)	Short circuit current	A
Is0 (Io)	Saturation current (dark current)	A
Eg	Band energy	eV
A	Ideality factor	–
Ct (ki)	Temperature coefficient for Isc	A/K
Ks	Coefficient	–

$$I_{ph} = I_{ph,STC}\frac{S}{S_{STC}} + C_t(T - T_{STC}) \tag{6}$$

$$I_o = I_{o,STC}\left(\frac{T}{T_{STC}}\right)^3 e^{\frac{qE_g}{Ak}\left(\frac{1}{T_{STC}}-\frac{1}{T}\right)} \tag{7}$$

In the above equations, S and T are irradiance and temperature, and the quantity with subscript STC denotes its value under STC. E_g is the bandgap energy of the panel.

In the conventional model, the off-line step in the determination of the model parameter causes inconvenience. Moreover, accuracy may deteriorate by three factors. First, obtaining the tangential slope at the open circuit voltage point in I-V curve of datasheet is inevitably error-prone. Secondly, because of no guideline for choosing R_{sh} and A, user should find them by trial and error. Thirdly, R_s, R_{sh}, and A are fixed even under dynamic conditions and it may further degrade the model performance. Above limitations will be overcome in the proposed to be model presented in the following section.

3. Proposed PV model

In order to increase the model accuracy, recent study of single-diode model states that all the five model parameters – R_s, R_{sh}, A, I_{ph}, and I_o – needs to be adjusted at the same time according to the dynamic conditions (De Soto et al., 2007). However, while the dependency of I_{ph} and I_o on temperature and irradiance is well described by p-n junction physics, the relation between the other three parameters – R_s, R_{sh}, and A, and the two environmental conditions are not clearly defined. Even if it is possible to setup the relation between them as in De Soto et al. (2007) and Celik and Acikgoz (2007), the proportionality constant is hard to be found without numerous measurements on real PV panel.

To tackle these problems, the proposed model introduces dynamic datasheet which can be updated in every simulation cycle. A block diagram of the proposed model is shown in Fig. 4. In this new model, off-line parameter determination step of the conventional scheme has been eliminated to increase usability and accuracy of the model. During each simulation step, the proposed model updates four datasheet parameters – V_{mpp}, I_{mpp}, I_{sc},

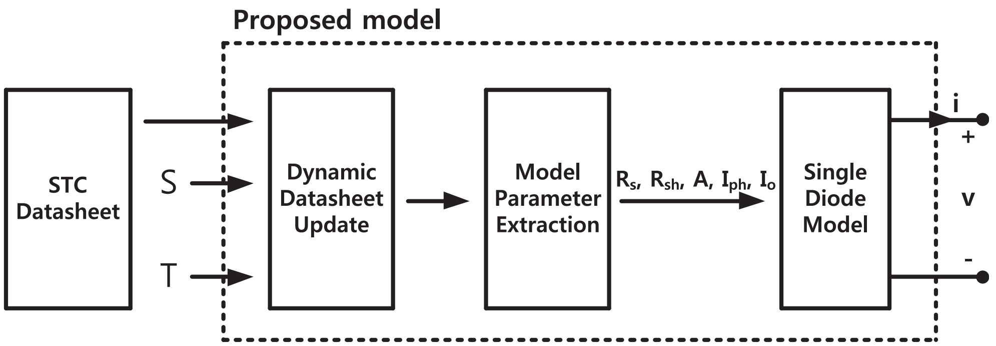


Fig. 4. Block diagram of the proposed PSIM model.

V_{oc} – for the current temperature and irradiance level. From this updated datasheet, fast optimization algorithm extracts a new set of model parameters of the single-diode PV model. The following section states individual steps in more detail.

In dynamic datasheet update process, directly changing parameter is not the five model parameters but the four datasheet parameters – I_{mpp}, V_{mpp}, I_{sc}, V_{oc}. The update rule is as follows. It is well known that the PV output current and the output voltage are linearly and logarithmically proportional to the irradiance level(De Soto et al., 2007; Celik and Acikgoz, 2007; Park and Choi, 2015a). As for temperature dependency, manufacturer already specifies temperature coefficients for current and voltage in the datasheet of PV panel. The current temperature coefficient, k_i and the voltage temperature coefficient, k_v represent how the short circuit point and the open circuit voltage will be effected by temperature, respectively. Consequently, the datasheet parameter update equations can be represented as

$$I_{sc} = I_{sc,STC}\frac{S}{S_{STC}}[1 + k_i(T - T_{STC})] \tag{8}$$

$$V_{oc} = V_{oc,STC} + N_s A_{STC}\frac{kT}{q}ln\left(\frac{S}{S_{STC}}\right) + k_v(T - T_{STC}) \tag{9}$$

$$I_{mpp} = I_{mpp,STC}\frac{S}{S_{STC}}[1 + k_{i,mpp}(T - T_{STC})] \tag{10}$$

$$V_{mpp} = V_{mpp,STC} + N_s A_{STC}\frac{kT}{q}ln\left(\frac{S}{S_{STC}}\right) + k_{v,mpp}(T - T_{STC}) \tag{11}$$

where S and T are irradiance and temperature, and the quantity with subscript STC denotes its value under STC. In the above equations, every quantity except A_{STC}, and $k_{i,mpp}$, and $k_{v,mpp}$ is usually specified in the manufacturer's datasheet. The diode ideality factor evaluated under STC, A_{STC}, is determined in the initialization routine and will be discussed later. The other two unknown constants, $k_{i,mpp}$, and $k_{v,mpp}$ are the temperature coefficients of maximum power point (MPP) variation. Though they are not usually found in datasheet, approximation (12) can be used instead of real value. In (Soon and Low, 2012), such an approximation has been successfully used to estimate the temperature dependency of MPP and, what's more, it is reported that the error in the output current caused by this approximation is trivial. And the error in the voltage, even if it is slightly large, is less than 5%. (King et al., 1997) Therefore, it is reasonable to use the k_i and k_v instead of $k_{i,mpp}$ and $k_{v,mpp}$ to express the thermal drift of the datasheet parameters.

$$k_{i,mpp} \cong k_i, \ \ k_{v,mpp} \cong k_v \tag{12}$$

Once the datasheet has been updated, next step is to extract model parameters from the dynamic datasheet values. At this stage, every datasheet-based method presented in Crispim et al. (2007), Villalva et al. (2009), Sera et al. (2007), Park and Choi (2015b) can be a viable solution. However, parameter extraction should be done as fast as possible in the proposed model structure, because this step repeats at every simulation cycle and calculation time required for the parameter determination may result in very long simulation time for the overall system. To enhance the algorithm speed, the proposed model adopted the optimization method presented in

```
Step 1:  Choose initial $X_1$, $N_c$(number of cycle)
         Determine the $\varepsilon$ : tolerance
         Calculate $f(X_1)$;
         Set j = 1; (initialize powell cycle)
         For i = 1; (initialize univariate cycle)
         $S_i = e_i$ (univariate step)
Step 2:  For each cycle j
         For i = 1:3;
         If (j >= 2) $S_i = S_i+1$
         $X_{i+1} = X_i + \alpha_i \cdot S_i$
         → $\alpha$ is determined by minimizing $f(X_{i+1})$
         End (i cycle)
         $S_j = X_4 - X_1$
         $X_j = X_4 + \alpha_j \cdot S_j$
         Calculate $f(X_j)$
Step 3:  $\Delta f = f(X_{j+1})-f(X_j)$
         $\Delta X = X_{j+1} - X_j$
         If $|\Delta f| \leq \varepsilon$; stop
         If $\Delta X^T \Delta X \leq \varepsilon$; stop
         If $j = N_c$; stop
         $X_1 = X_j$;
         j = j+1;
         Go to Step2
```

Fig. 5. Pseudo code of Powell's optimization.

Venkataraman (2009). This method is very simple because it uses only two datasheet parameters – V_{mpp} and I_{mpp} – to find R_s, R_{sh}, and A. And I_{ph} and I_o are found by solving simple simultaneous equations.

Cost function for the algorithm can be derived using the following process. First, Eq. (1) and MPP condition are used to obtain the following equality.

$$I_{ph} - I_o e^{\frac{q(V_{mpp}+I_{mpp}R_s)}{N_S AkT}} - \frac{V_{mpp}+I_{mpp}R_s}{R_{sh}} = I_{mpp} \tag{13}$$

Using the differential power shown below

$$\frac{dp}{dv} = \frac{d(iv)}{dv} = i + \frac{di}{dv}v \tag{14}$$

and evaluating (14) at MPP, the following relation can be obtained.

$$I_{mpp} - V_{mpp}\frac{\frac{1}{R_{sh}}\left(\frac{q(I_{sc}R_{sh}-V_{oc}+I_{sc}R_s)}{N_S AkT}e^{\frac{q(V_{mpp}+I_{mpp}R_s-V_{oc})}{N_S kT}}+1\right)}{1+\frac{R_s}{R_{sh}}\left(\frac{q(I_{sc}R_{sh}-V_{oc}+I_{sc}R_s)}{N_S AkT}e^{\frac{q(V_{mpp}+I_{mpp}R_s-V_{oc})}{N_S kT}}+1\right)} = 0 \tag{15}$$

Most appropriate model parameters are the values which minimize the cost function given by

$$E(R_s, G_{sh}, A) \equiv (f(R_s, G_{sh}, A) - I_{mpp})^2 + g^2(R_s, G_{sh}, A) \tag{16}$$

where the function f(.) and g(.) represent the expression in the left hand side of Eqs. (13) and (15), respectively.

Among various optimization schemes, Powell's method is one of the fastest algorithms. It is so fast that model parameter determination is finished within a few iteration steps and thus is adopted as a main parameter determination algorithm in the proposed model. The pseudo-code is shown in Fig. 5 and three unknown model parameters, R_s, R_{sh}, and A are extracted from I_{mpp} and V_{mpp}, I_{ph} and I_o are then calculated from I_{sc} and V_{oc} by solving the following simultaneous equations.

$$I_{ph} = I_o e^{\frac{qV_{oc}}{N_S AkT}} + \frac{V_{oc}}{R_{sh}} \tag{17}$$

$$I_o = [I_{sc} - (V_{oc} - I_{sc}R_s)/R_{sh}]e^{-\frac{qV_{oc}}{N_S AkT}} \tag{18}$$

The proposed model's search range is defined as

$$0 \leqslant R_s \leqslant \frac{V_{oc} - V_{mpp}}{I_{mpp}} \tag{19}$$

$$0 \leqslant G_{sh} \leqslant \frac{I_{sc} - I_{mpp}}{V_{mpp}} \tag{20}$$

$$1 \leqslant A \leqslant 2 \tag{21}$$

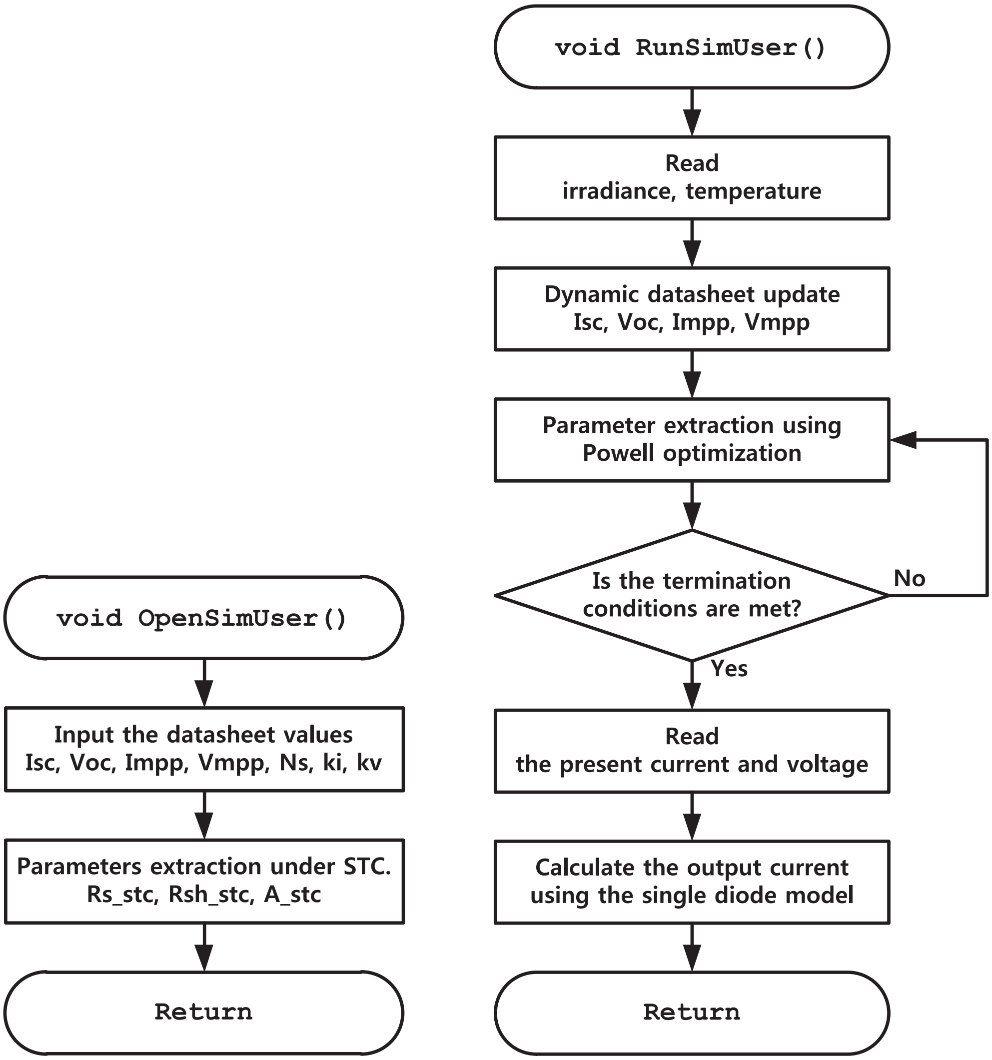


Fig. 6. Flow chart for C-block implementation.

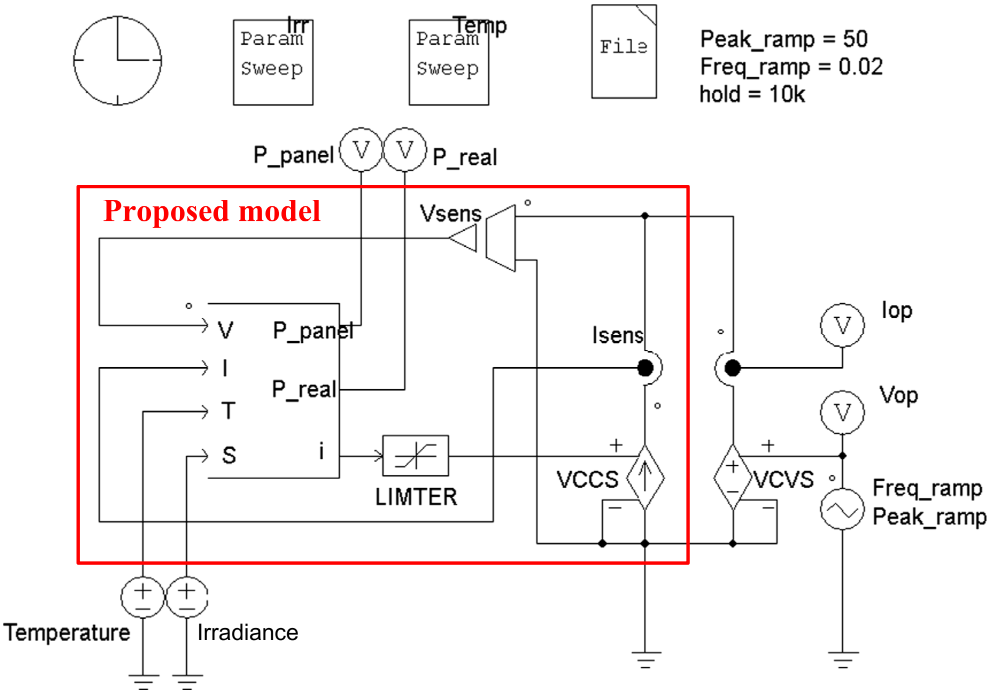


Fig. 7. PSIM schematic including the proposed model.

and initial value is defined as follows.

$$X_1 = [R_{s,1} G_{sh,1} A_1] = [0, 0, 1] \tag{22}$$

In this way, model parameters are extracted from the dynamic datasheet in each simulation cycle. Consequently, the proposed model can construct single-diode model using only four datasheet values and easily obtain the output of PV model under varying conditions.

The proposed model can improve the accuracy by adjusting all of the five parameters – R_s, R_{sh}, A, I_{ph}, and I_o, and increases usability by automating the parameter extraction process. Utilizing only datasheet simplifies the modeling process and eliminating the trial and error process enhances the immunity. User only needs to know the manufacturer datasheet values to initialize the dynamic datasheet.

In order to implement the proposed model, PSIM C-block has been used. PSIM C-block provides two subroutines which are called by the simulation engine and programed by user: `void OpenSimUser()` and `void RunSimUser()`. The former is called only once in the beginning of the simulation and the latter is called at every simulation step. Therefore, initialization process such as getting datasheet values – $I_{sc,STC}$, $V_{oc,STC}$, $V_{mpp,STC}$, and $I_{mpp,STC}$ from user and generating initial model parameter – $R_{s,STC}$, $R_{sh,STC}$, A_{STC}, $I_{ph,STC}$, and $I_{o,STC}$ – by a single execution of optimization algorithm has been programed in the `OpenSimUser()`. On the contrary, being repeatedly called in every simulation step, `RunSimUser()` continuously updates dynamic datasheet according to temperature and irradiance and generates model parameters. Fig. 6 shows flow chart of the proposed algorithm.

Table 3
Parameters in the dynamic datasheet.

Parameter	Description	Unit
(a) User inputs		
$I_{sc,STC}$	Short circuit current under STC	A
$V_{oc,STC}$	Open circuit voltage under STC	V
$I_{mpp,STC}$	Maximum power current under STC	A
$V_{mpp,STC}$	Maximum power voltage under STC	V
N_s	Number of cells	–
k_i	Temperature coefficient of I_{sc}	A/°C
k_v	Temperature coefficient of V_{oc}	V/°C
(b) Internally updating parameters		
I_{sc}	Short circuit current under	A
V_{oc}	Open circuit voltage	V
I_{mpp}	Maximum power current	A
V_{mpp}	Maximum power voltage	V

The overall PV model is shown in Fig. 7. The C-block has four input ports and three output port. It cooperates with neighboring blocks to constitute the PV simulation model. All the ports are interfaced through voltage information with other PSIM blocks. Among the four input variables, temperature, T and irradiance, S are connected externally to the time varying external voltage source profile. On the contrary, the sensed output voltage, V_{sens} and the sensed output current, I_{sens} are used internally to manage the single-diode relation in Eq. (1). Because the equation is implicit, the output current of the next step is calculated based on the present step information: those extra sensor blocks monitor the voltage and the current and feed them as inputs to the C-block. After calculation, the output current information will be output as a voltage quantity and then drives the voltage-controlled current source (VCCS) block. At this time, user can observe the output of the model using the additional output ports, P_{panel} and P_{real}. P_{panel} means the maximum achievable power and P_{real} is the real output power of the PV model at every calculation time.

4. Comparison and verification of model

For verification, both conventional and proposed one are implemented in PSIM schematic. KC65GT, KC200GT, and SQ160PC are chosen as standard specimens because their manufacture provides a lot of I-V curves under different temperature and irradiance and thus they have been widely used in other papers which deal with

Table 4
Datasheet values of each panel.

	I_{sc} (A)	V_{oc} (V)	I_{mpp} (A)	V_{mpp} (V)	P_{mpp} (W)	N_s	k_i (A/°C)	k_v (mV/°C)
KC65GT	3.99	21.7	3.75	17.4	65	36	$1.59 \cdot 10^{-3}$	−82.1
KC200GT	8.21	32.9	7.66	26.7	200	54	$3.18 \cdot 10^{-3}$	−123
SQ160PC	4.9	43.5	4.58	35	160	72	$1.4 \cdot 10^{-3}$	−161

modeling issue. The datasheet values are shown in Table 4. To use conventional model, the model parameter was extracted using solar model utility. During the process, the tangential line at the open circuit voltage is difficult to be obtained from the datasheet curve and thus three different candidates are chosen. The diode ideality factor is also undetermined and three different candidates are used in the modeling. The extracted model parameter in Table 2 is fed into the conventional PSIM model. On the contrary, only datasheet values in Table 3 (a) are input to the proposed model. For both model, the I-V and P-V curves are plotted by sweeping load voltage and by changing external temperature and irradiance profiles as in Fig. 7.

For reasonable comparisons, curves generated by two models are compared based on error in P-V curve, where it is defined by following equation (IEC EN50530).

$$Total\ \varepsilon_P = \frac{1}{V_{oc}} \int \left| \frac{p_{model}(v) - p_{datasheet}(v)}{p_{datasheet}(v)} \right| dv \tag{23}$$

where it evaluates the overall accuracy of the model and subscript ‘model’ and ‘datasheet’ present the PSIM model curve and datasheet curve respectively.

The comparison results for KC65GT, KC200GT, and SQ160PC are shown in Figs. 8–10 respectively. In each figure, (a) is for results

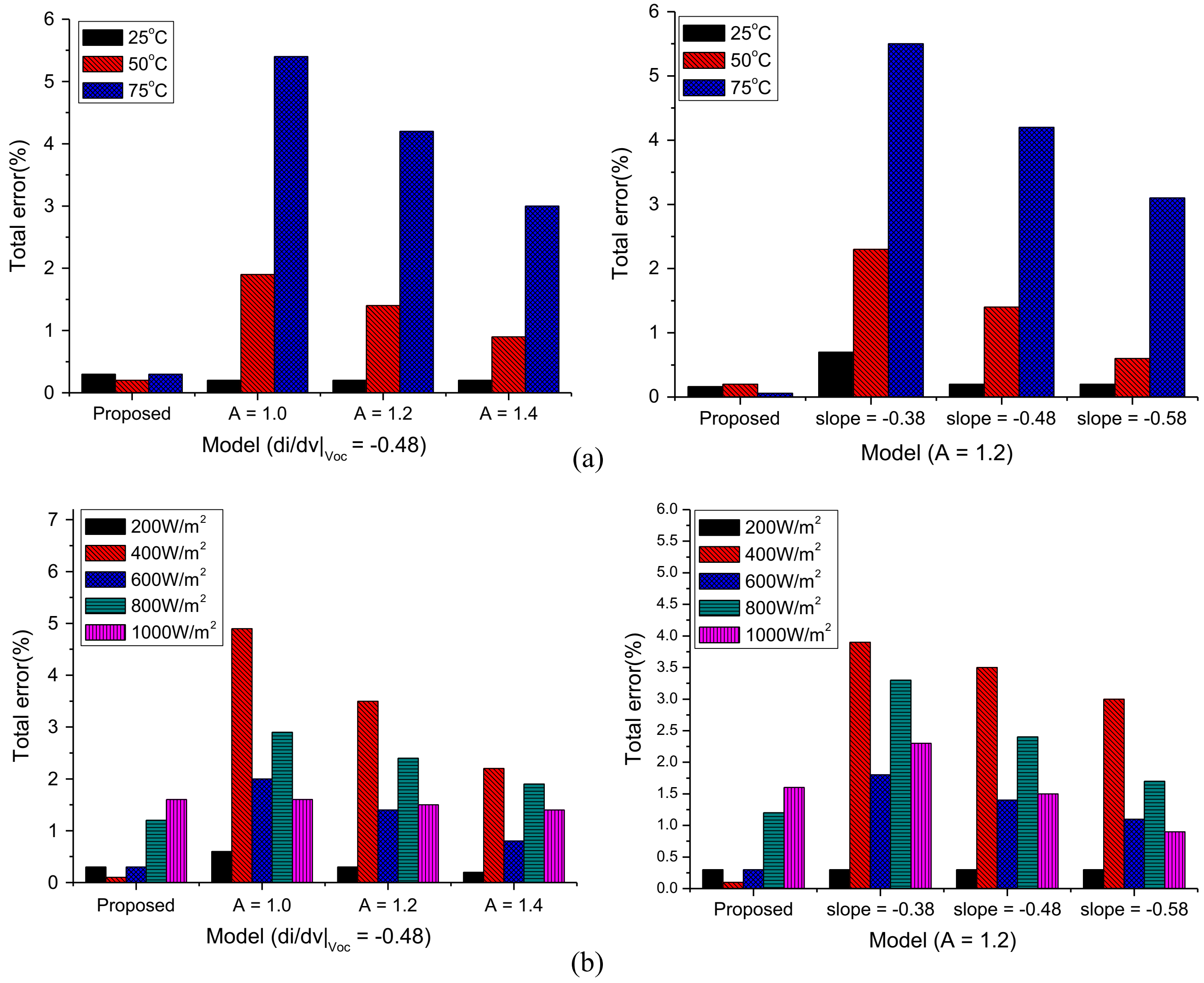


Fig. 8. Model accuracy under varying temperature and irradiance of KC65GT (a) temperature (b) irradiance.

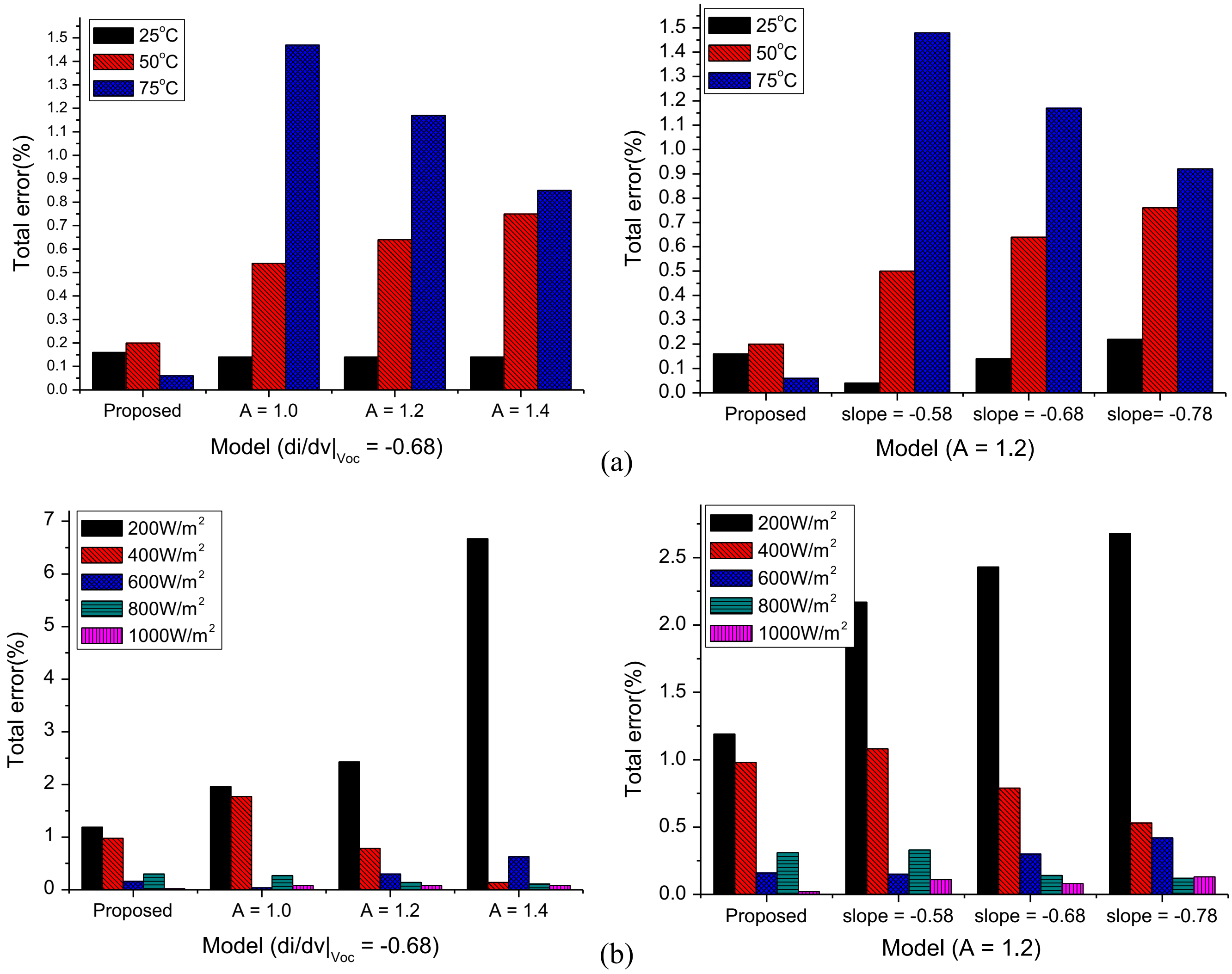


Fig. 9. Model accuracy under varying temperature and irradiance of KC200GT (a) temperature (b) irradiance.

under varying temperature and (b) is for results under varying irradiance. In order to test the effect of incorrect user information on the model accuracy, A's are changed in the left figure and the tangential slope information is changed in the right figure. As for the temperature variation, the proposed model is superior to the conventional model in the three panels. Regarding the irradiance change, the proposed model shows good performance especially under low and medium irradiance level in KC65GT and KC200GT. Even though the conventional model shows better results in SQ160PC, the performance is highly dependent on the user defined parameters. It should be noted that EN50530 standard specifies two kind of dynamic ramp test conditions in the irradiance levels: one is from low to medium level (100–500 W/m^2) and the other is from medium to high level (300–1000 W/m^2). Therefore, not only the accuracy itself but also the uniformity of the performance is very important. It is clear from the results that the conventional model does not always guarantee the model accuracy under all operating conditions, and what's more, user dependent parameters may impair the model uniformity. Consequently, the proposed model provides better accuracy and uniformity.

5. Conclusion

This paper presents a new PSIM PV model. By introducing the concept of dynamic datasheet, the proposed model continuously updates the internal datasheet values from which fast optimization algorithm extracts a new set of model parameters of the single-diode PV model. The proposed model can improve the accuracy by adjusting all of the five model parameters – R_s, R_{sh}, A, I_{ph}, and I_o, according to the time-varying irradiance and temperature conditions and increases usability by automating the parameter extraction process. Performance has been verified with different PV panels and the proposed model shows good accuracy. Moreover, utilizing only datasheet simplifies the modeling process and eliminating the trial and error process enhances the immunity to error and guarantees uniform results. Parameters being tuned in online, user only needs to know the manufacturer's datasheet values, temperature, and irradiance information to simulate a PV panel. It is expected that the proposed method will be not only applied to the other simulation programs but also used as the PV simulation engine in PV hardware simulators.

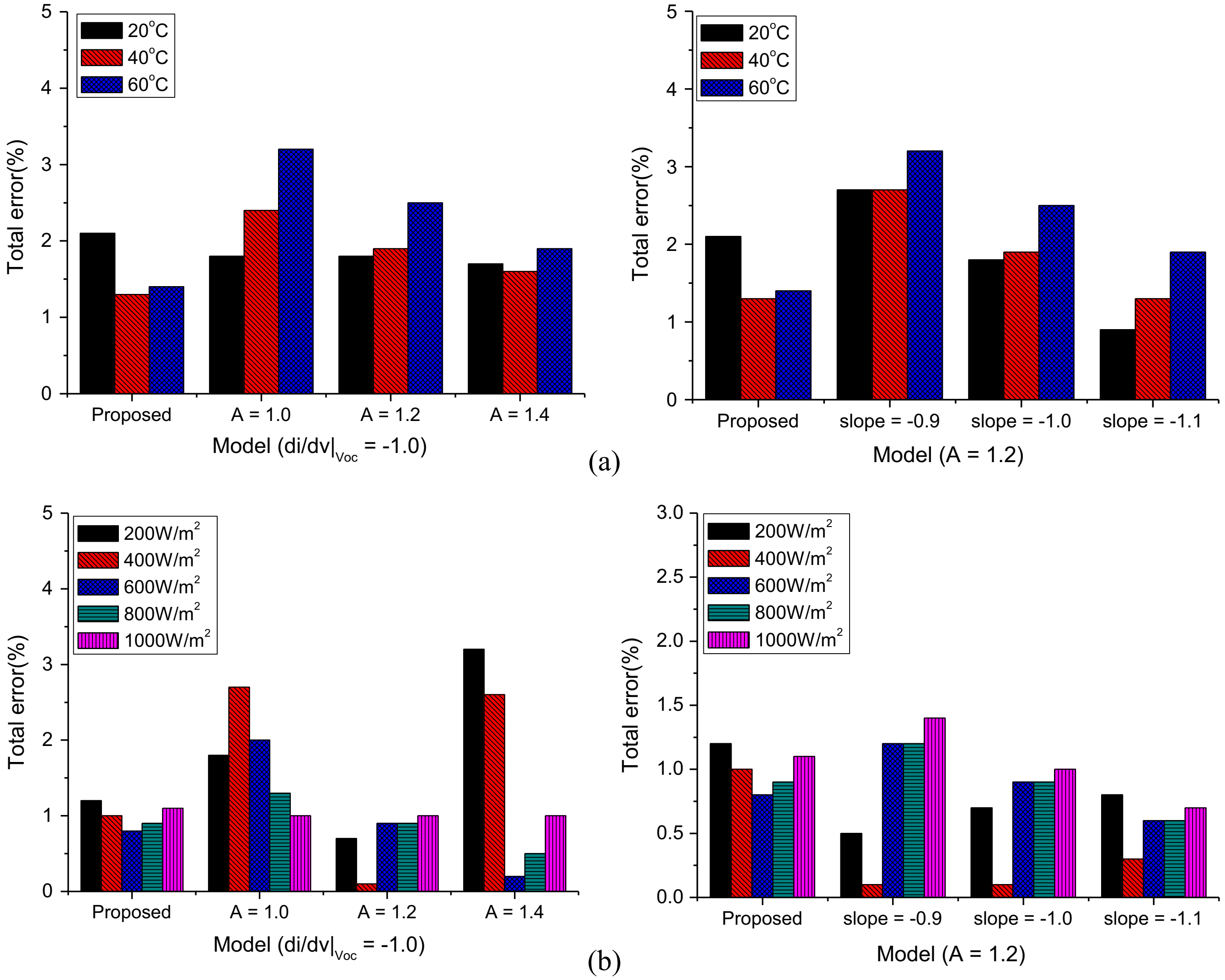


Fig. 10. Model accuracy under varying temperature and irradiance of SQ160PC (a) temperature (b) irradiance.

Acknowledgement

This work was supported by the 2014 Research Fund of University of Ulsan, Republic of Korea.

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