POWER LAW MODEL (PLM) APPROACHES TO PREDICT THE PERFORMANCE OF THE SMALL-SCALE PV SYSTEM

Presented by: Dr AD KAPIM KENFACK

SAIP 2025

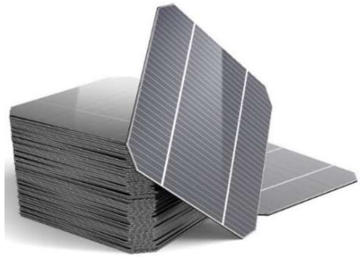
Tshwane University of Technology
We empower people

20 YEARS 2004-2024

Content

1. Introduction

1.1Overview on solar cell, PV system and main parameters



Monocrystalline silicon cell

Efficiency 24%

- High efficiency
- Expensive
- Huge energy consumption to manufacture
- Long lifetime(25 years)
- Stable
- Much energy to recycle
- Long time to manufacturer
- Band gap fix

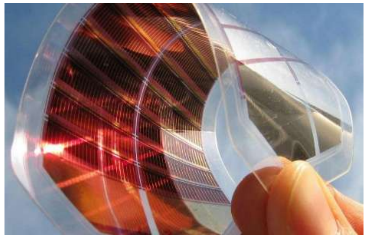
Fig 1: Monocrystalline silicon cell

Polycrystalline silicon cell

Efficiency 19%

- low efficiency
- Less expensive
- Huge energy consumption to manufacture
- Long lifetime (25 years)
- Stable
- Much energy to recycle
- Long time to manufacturer
- Band gap fix

Fig 2: Polycrystalline silicon cell



Perovskite solar cell 30%

- High efficiency
- cheap
- Very low energy consumption to manufacture,
- Fast to manufacturer
- Less energy to recycle
- Unstable
- Short lifetime (9months)
- Band gap adjustable

Fig 3: Perovskite solar cell

1.1.Overview on solar cell, PV system main parameters

Fig 4: Overview of a PV system

Parameters: Irradiance, temperature, wind speed, humidity

1.2. Existing analytical monitoring techniques

a) Model based on one diode without series resistance (STC)

b) Model based on one diode with series resistance (STC)

c) Model based on one diode with series and shunt resistance (STC)

d) Model based on two diodes with series and shunt resistance (STC)

e) Power law model (PLM) : STC
: solar cell
: high accuracy
: Few parameters

Aim: Use the Power law model (PLM) to predict the performance of PV system in real time out of the STC

2.Methodology

2.1.Presentation of Power Law Model (PLM)

$$i = 1 - \left[1 - \mu(G,T)\right] v - \mu(G,T) v^{m(G,T)} \qquad (1)$$

$$i = I / I_{sc} \qquad (2)$$

$$v = V / V_{oc} \qquad (3)$$

$$I_{sc} = \frac{G}{G_{ref}} \left[I_{scref} + K_i \left(T - T_{ref} \right) \right] \qquad (4)$$

$$V_{oc} = V_{ocref} - K_V \left(T - T_{ref} \right) \qquad (5)$$

G and, T Irradiance and temperature, respectively

$\mu(G,T)$ and, $m(G,T)$ Shape parameters

2.2. Extraction technique of shape parameters based on Newton-Raphson algorithm

$$p = i \cdot v \qquad (6)$$

$$\frac{\partial p}{\partial v} = v_p \left.\frac{\partial i}{\partial v}\right|_{i=i_p, v=v_p} + i_p = 0 \qquad (7)$$

$$\left.\frac{\partial i}{\partial v}\right|_{i=i_p, v=v_p} = -\frac{i_p}{v_p} \qquad (8)$$

$$\mu = \left(-\frac{i_p}{v_p} + 1\right)\left(\frac{1}{1 - m \cdot v_p^{m-1}}\right) \qquad (9)$$

$$\begin{cases} \mu = \left(-\frac{i_p}{v_p} + 1\right)\left(\frac{1}{1 - m \cdot v_p^{m-1}}\right) \\ i = 1 - \left[1 - \mu(G,T)\right] v - \mu(G,T) v^{m(G,T)} \end{cases} \qquad (10)$$

2.2. Extraction technique of shape parameters based on Newton-Raphson algorithm

$$m^{k+1} = m^k - \frac{f\left(m^k\right)}{f_p\left(m^k\right)} \qquad (11)$$

$$f\left(m^k\right) = -i_p + 1 - \left[1 - \mu\left(G,T,m^k\right)\right]v_p - \mu\left(G,T,m^k\right)v_p^{m^k} \qquad (12)$$

$$f_p = \frac{\partial \mu}{\partial m^k}v_p - \frac{\partial \mu}{\partial m^k}v_p^{m^k} - \mu \cdot \log\left(v_p\right)\cdot v_p^{m^k} \qquad (13)$$

$$\frac{\partial \mu}{\partial m^k} = \left[-\frac{i_p}{v_p} + 1\right]\left(\frac{v_p^{m^k-1} + m^k \cdot \log\left(v_p\right)\cdot v_p^{m^k-1}}{\left(1 - m^k \cdot v_p^{m^k-1}\right)^2}\right) \qquad (14)$$

2.2. Extraction technique of shape parameters based on Newton-Raphson algorithm

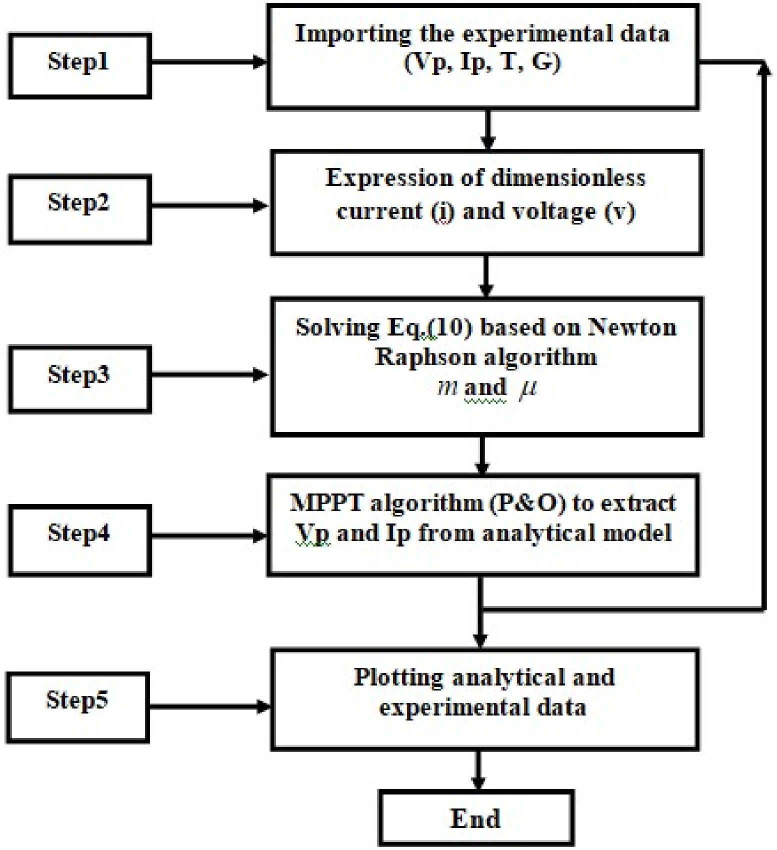


Fig 5: Flow chart of the extraction of shape parameters

2.3 Experimental setup

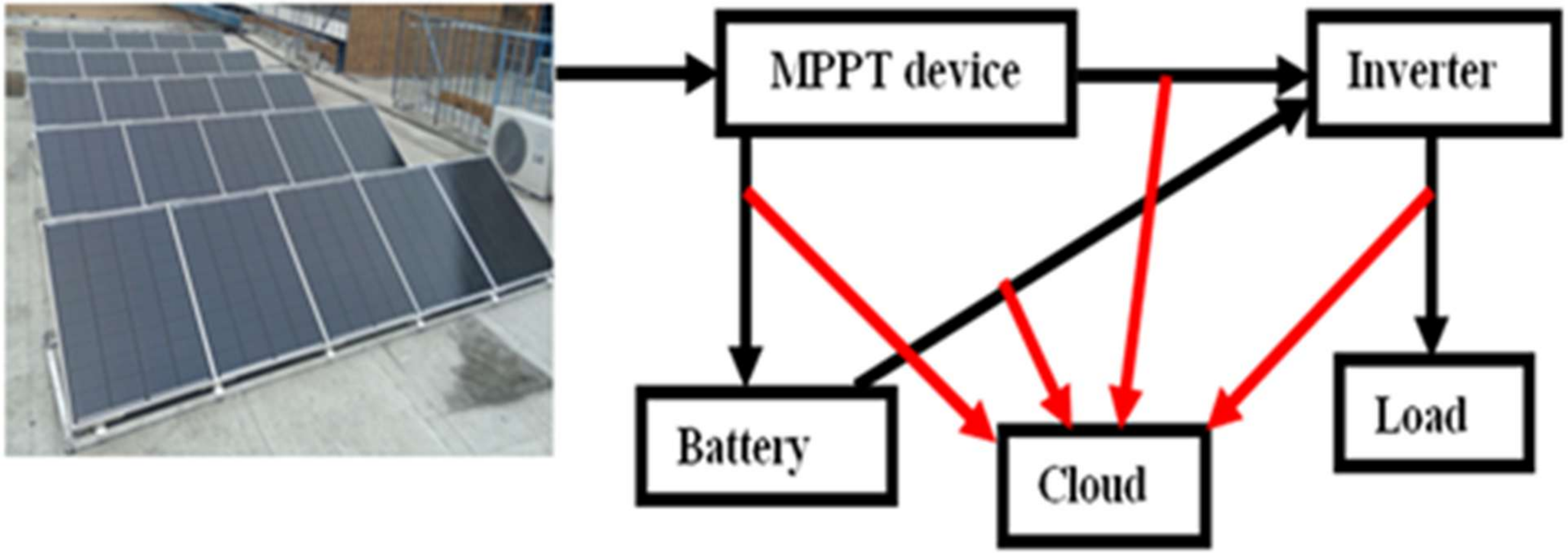


Fig 6: 2.2 kW PV system installed on the rooftop Arcadia campus TUT

3. Results and discussion

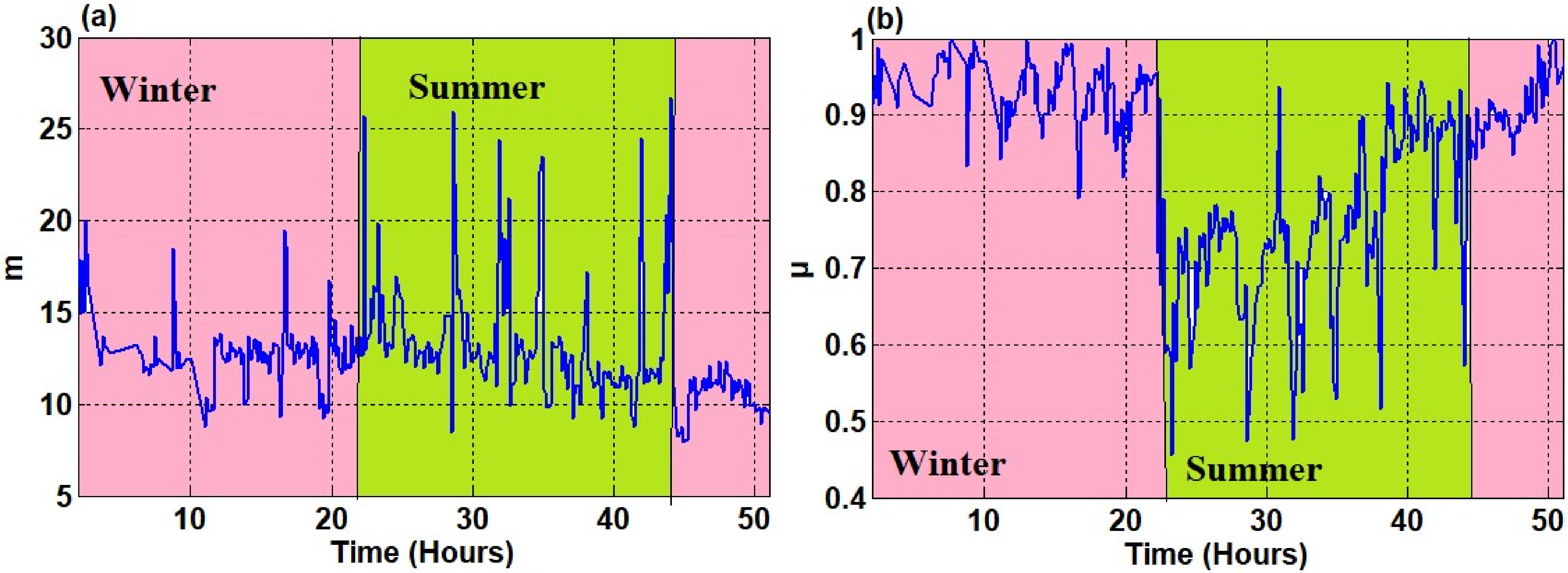
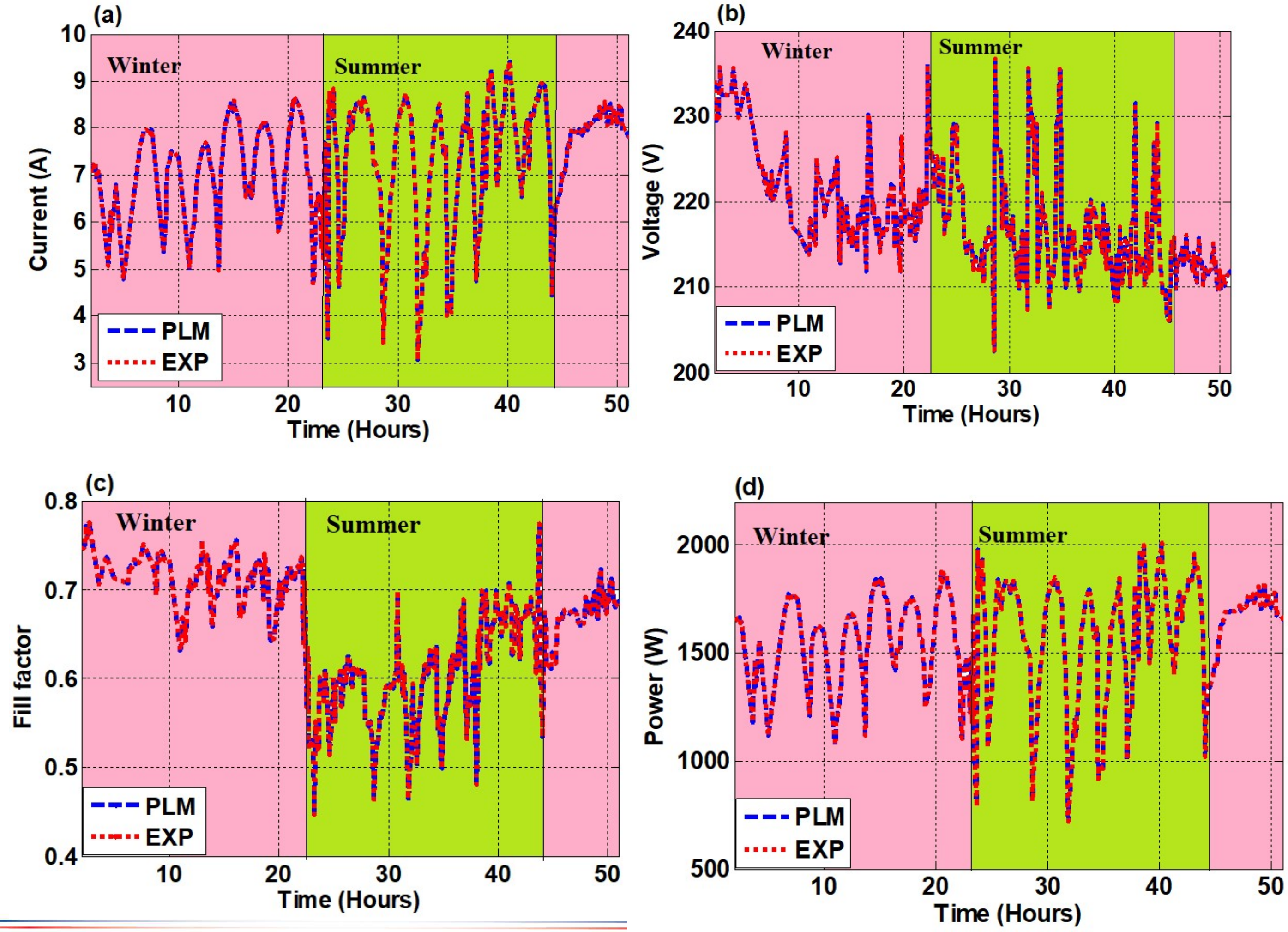


Fig 7: Variation of the shape parameters with time

3. Results and discussion

Fig 8: Output electrical parameters



3. Results and discussion

Table1: Correlation table

	I_p	V_p	FF	P_p	G	T	µ	m
I_p	1							
V_p	-0.567	1						
FF	-0.023	-0.024	1					
P_p	-0.439	-0.439	0.490	1				
G	0.814	-0.506	-0.130	0.794	1			
T	0.746	-0.631	0.296	0.695	0.628	1		
µ	0.478	-0.236	0.958	0.485	-0.110	0.296	1	
m	-0.427	0.784	-0.282	-0.334	-0.188	-0.201	-0.511	1

Table2: Performance metrics

	Fill factor	Current (A)	Voltage (V)	Power (W)	Mean value
R^2	0.99	0.99	0.99	0.99	0.99
RMSE	0.005%	0.2%	0.07%	12%	3.07%
r	0.99	0.99	0.99	0.99	0.99

4. Conclusion and limitations of the model

Aim: Use the Power law model (PLM) to predict the performance of PV system in real time out of the STC

Finding: Shape parameters are less correlated to the weather parameters
: They are more correlated to the output electrical parameters
: offers high prediction around 99%

Limitations: We need experimental data to determine the shape parameters
: We have no information about the quality of the device (ideality factor, saturation current, shunt and series resistance)

5. Acknowledgment

Thanks for your attention

Faculty of science
Department of physics

#fromGood2Great