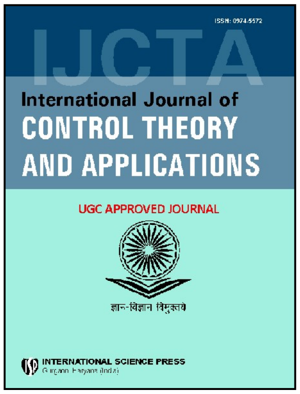

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MPPT Performance Analysis using an Online Measurement Method with an Outdoor Monitoring

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Abstract: This paper is intended to contribute to the conceptual design of an electronic helping tool to analyze the performance of maximum power point tracking systems(MPPT). Indeed, the MPPT is a device ensuring the connection between the PV generator and the rest of the PV conversion chain in order to extract and transfer the maximum of the electric power. In this work, we present a new method in analyzing MPPT performance witch the principle is based on the comparison of the maximum power(Pmp) that can be generated by the PVG and the power transferred to the DC load by the MPPT system. The measurement of these powers is realized outdoor with an online mode; i.e., the PV conversion chain is maintained in operation. The Pmp value obtained by measuring the couple (Isc, Voc). In this paper we will present the hardware implementation of the proposed technique. The measurement of climatic parameters such as, solar radiation and cell temperature are not taken into account, which characterizes the peculiarity of this method.

Keywords: PVG, Maximum power, MPPT, Online measurement, Analysis.

1. INTRODUCTION

The conventional electricity generation outcome from the hard consumption of fossil fuel sources, and causes an environmental problems. Photovoltaic panels and wind generators are the commonly used now as renewable power solutions[1]. Nowadays, solar energy is the most abundant and inexhaustible renewable energy resource. In a minute, the sun can provide energy that is needed by the world in a minute, the sun can provide energy that is needed by the world in a year and in a day, it can provide energy more than that of the world's required consumption for 27 years [2]. In fact, the production of this energy is nonlinear and it varies according to the temperature and solar radiation [3]. This nonlinear behavior is translated by a nonlinear output characteristics I-V curves of PV. Therefore, the maximum power can be provided at one point. Targeting this point by extraction of the maximum power from the PVG require maximum power point tracking controller(MPPT)[4]. A lot of research work revolves around the MPPT techniques have been intervening in the development of these systems, we can cite in general the most used techniques such as: Hill Climbing method according to [5]-[8], the Perturb and Observe (P&O) method used in [9]-[22], the Incremental Conductance (INC) cited in [23]-[30], the Neural Network, the Fuzzy Logic, Particle Swarm Optimization (PSO) and the Genetic Algorithms which are called the artificial intelligence methods and witch they are cited in [31]-[45].

In the last years, researchers and practitioners in PV systems have presented a comparative analysis of MPPT techniques [49]. In this paper we focused on the analysis of MPPT performance by adopting a new developed method based on an online measurement technique with an outdoor monitoring.

Otherwise, MPPT performance is important to system designers who are guaranteeing a certain system performance and need to know all of the system losses as well as to system operators who want to ensure that their system is operating per its specifications [50].

The identified methods to measure MPPT performance are mentioned in Table 1 divided into Laboratory (Indoor) and field (Outdoor) measurement.

Table 1
Overview on : MPPT Measurement Methods [50]
MPPT Measurement Methods

Laboratory (Indoor)	*Field (Outdoor)*
Assessment under static conditions	Switching between MPPT and I-V tracer
Assessment under dynamic conditions	Using a calibrated reference module
Assessment of energetic efficiency	Sampling MPPT input at high speed
Further tests	Using manual mode to obtain I-V curve
	Analysing monitoring data

The Laboratory measurement (Indoor) are made using a PV array simulator that generates DC power with the I-V curve characteristic under a variety of conditions and it must not interact with the MPPT [50].

The field measurements (Outdoor) was made in this work using five methods as [50];

- Switching between MPPT and I-V tracer.
- Using a calibrated reference module.
- Sampling MPPT input at high speed.
- Using manual mode to obtain I-V curve data.
- Analyzing monitoring data.

Therefore, a new method of performance analysis is presented in this paper which is based on an online field measurement.

(A) Basic unit of photovoltaic generator

The electrical equivalent circuit representing the static behavior of real PV cell which is modeled by a current source in parallel with a diode, a shunt resistance and a series resistance [50]. This simplified model allows us to model the behavior of the electrical power source from the PV array.

(B) The principle of seeking the maximum power point

The principle of these commands is to search the maximum power point (MPP) while ensuring perfect adaptation between the PVG and the load to transfer maximum power to the rest og the PV conversion chain.

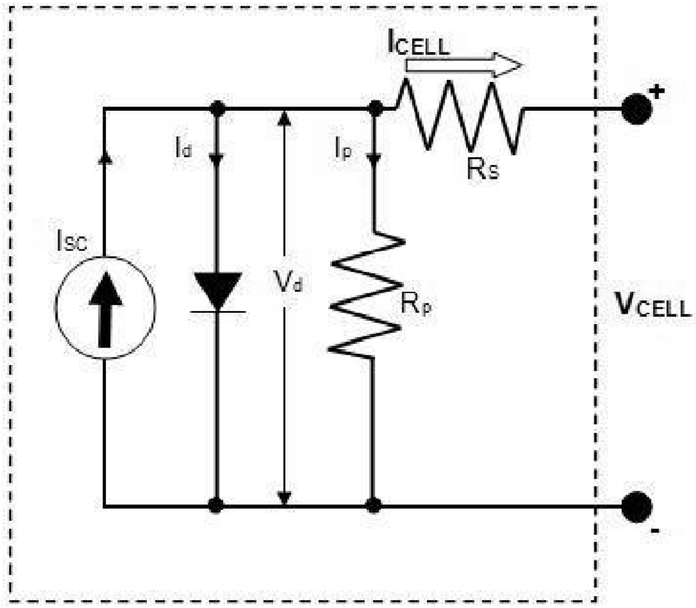

Figure 1: Equivalent circuit model of PV cell

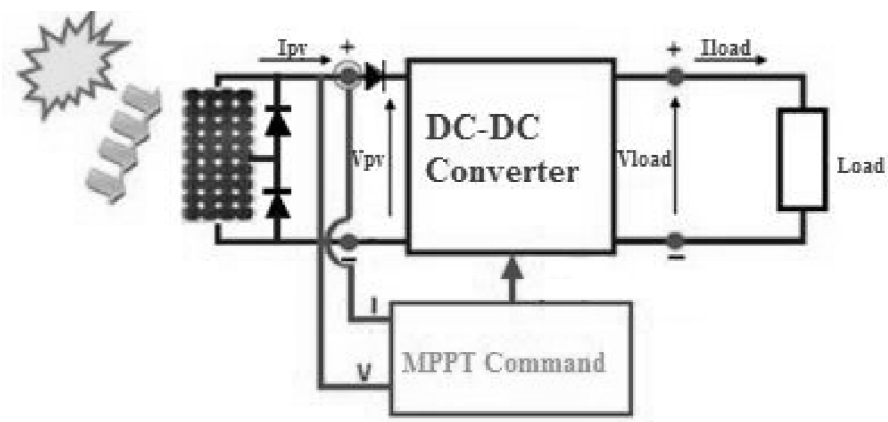

Figure 2: Elementary photovoltaic conversion chain

For instance, we often encounter the problem of optimizing the outcome of the PVG, which must be provided by the MPPT. It should be noted that there is little research according to the performance analysis of these systems (MPPT) few of them are mentioned below [50]. The purpose is this paper is the proposal of a new analysis method which provides a performance parameter in real time (in online mode) where the PV conversion chain is operating outdoor.

2. CONCEPT AND PRINCIPLE OF THE PROPOSED MPPT PERFORMANCE ANALYSIS TECHNIQUE

The occurrence of an abnormality is seen as variation of the MPPT performance to reach the maximum power point for instant weather compared to a reference value for the same conditions cited. The analysis concept in this paper is to detect these variations to distinguish those resulting from failures of those resulting from normal behavior, to decide whether these changes are actually significant compared to the uncertainties on the model and the reference and noise on the measured data.

(A) Principle of the proposed technique

A system called MPPT-PA (Maximum Power Point Tracking Performance Analyzer) will measure the values of the two powers by comparing component namely: the maximum power of PVG calculated by the MPPT (Pmp) and the DC output power delivered to the load (Pload). These measurements are outcomes by physically interconnecting the MPPT-PA system between the PVG and the MPPT for one side (far Upstream) and between the MPPT and load for the other side (far Downstream).

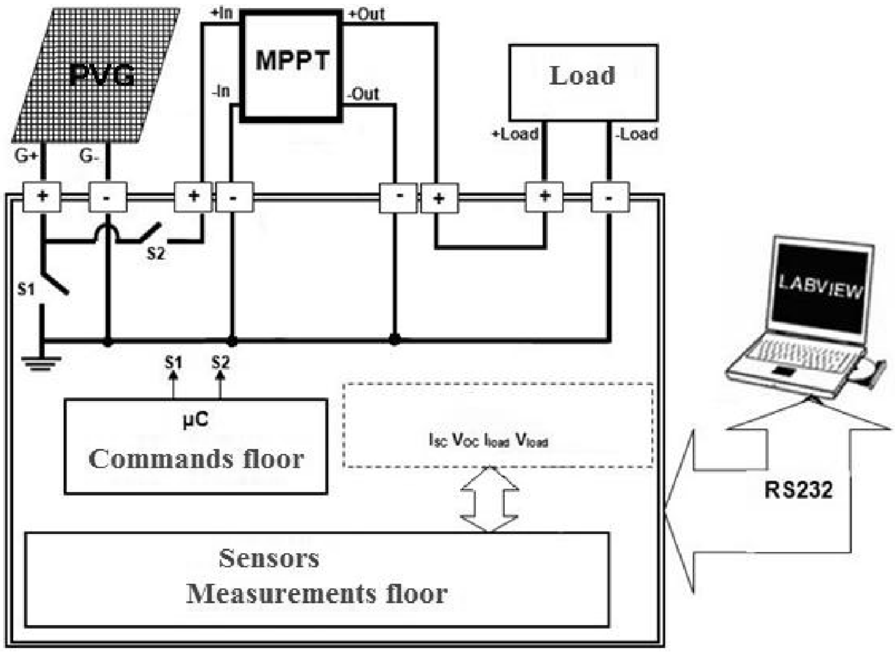

Figure 3: Block diagram of MPPT-PA system

(B) Maximum power reference (Pmp)

The maximum power reference (Pmp) is the maximum power that can be delivered by the PVG in an instant weather conditions. This power is the result of the arithmetic product of the maximum current (Imp) and the maximum voltage (Vmp) as:

$$Pmp = Imp * Vmp \quad (1)$$

with:

$$Imp = k_i * Isc \quad (2)$$

$$Vmp = k_v * Voc \quad (3)$$

(C) Choice of multipliers k_i and k_v

It has been verified experimentally that there is a dependency between the short circuit current (Isc) and the maximum current that can deliver a PVG (Imp), and for the open circuit voltage (Voc) and the PVG maximum voltage that can apply under certain climatic conditions [51].

k_i and k_v respectively represents the slopes of two straight curves. k_i and k_v are called respectively a current factor and a voltage factor and they are respectively equal to 0.86 and 0.71 [51]. By analogy, we can also define the product ($k_i * k_v$) by the form factor of PVG as:

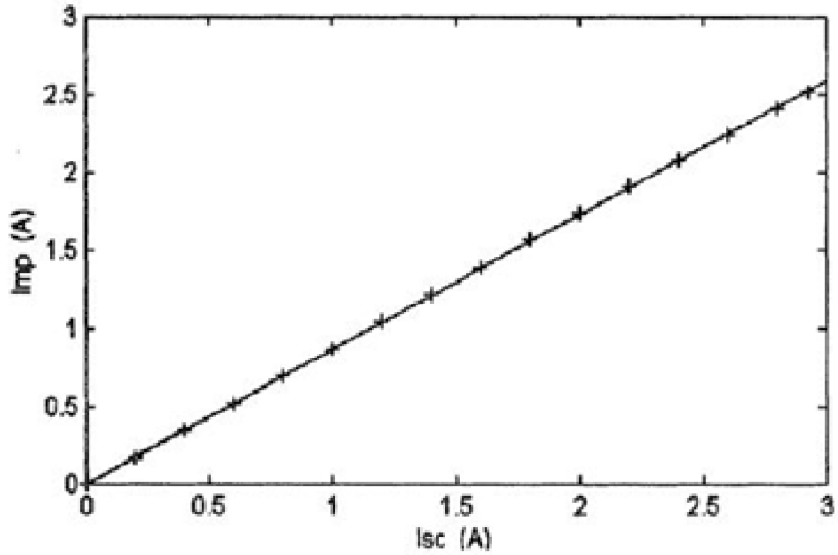

Figure 4: Dependence between "the current corresponding to maximum power" and "short circuit current" for an OFFC panel [51]

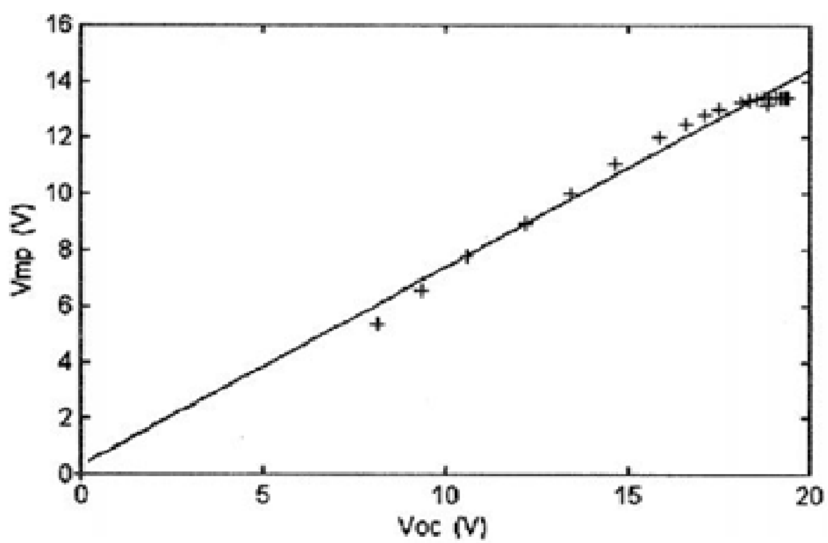

Figure 5: Dependence between "the voltage corresponding to the maximum power" and "open circuit voltage "for an OFFC panel [51]

$$FF = (Pmp / Isc * Voc) = k_i * k_v \quad (4)$$

(D) Output power delivered by MPPT

We called it Pload and it is the result of the arithmetic product of the current (Iload) and voltage (Vload) as:

$$Pload = Iload * Vload \quad (5)$$

(E) Performance factor

The performance factor (PF) is quite different from the energy efficiency of the MPPT. In fact, it is the ratio of the power extracted from the Pload and the maximum power that can generate the PVG (Pmp), under the same climatic conditions.

$$PF = (Pload / Pmp) * 100 \tag{6}$$

(F) Principle of the online measurement method

The principle of the proposed method resolves the sampling of the short-circuit current Isc and the open circuit voltage Voc in a Tsw period without a permanent disconnection of the MPPT from the PV conversion chain. Simply disconnect this MPPT during this period Tsw to take the open circuit voltage Voc then short-circuit the PVG to pick up the short-circuit current Isc then reconnect the MPPT to the PVG.

Given the temperature and radiation (two slow phenomena), these two main parameters that will modify the characteristic of a PV generator and which will cause a subsequent modification of the maximum power point, variations in time are negligible compared to the time switching period of the MPPT.

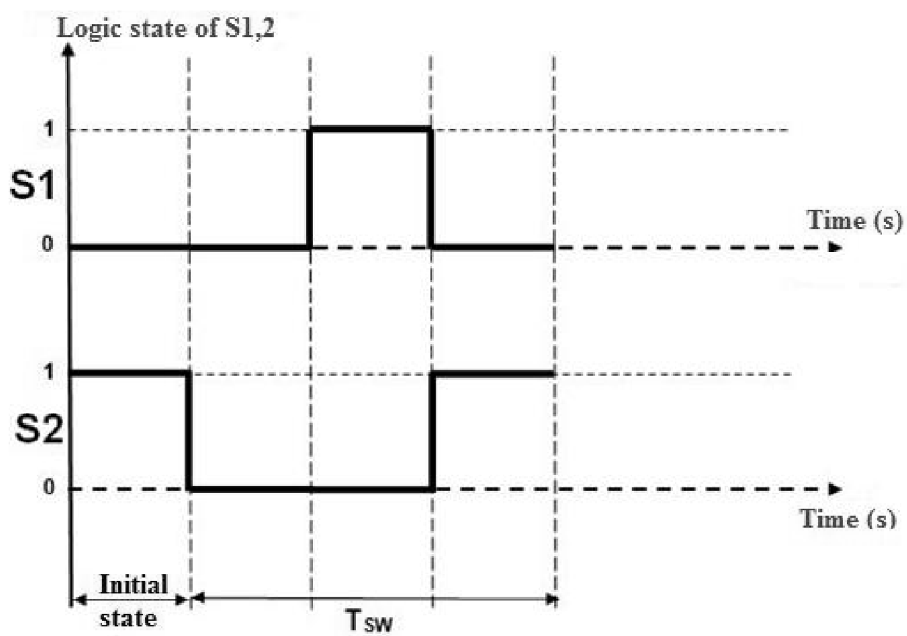

Figure 6: Logic state's chronogram of S1 and S2 for a Tsw period

with:

$$S_{1,2} = 1\text{: Switch On} \tag{7}$$

$$S_{1,2} = 0\text{: Switch Off} \tag{8}$$

Table 2
Switching scenario of S1 and S2 to ensure the online measure

STEP	*S1*	*S2*	*Action*
INITIAL	0	1	The MPPT is coupled to the PVG
1	0	0	Measuring the open circuit voltage Voc(PVG is isolated)
2	1	0	Measurement of short circuit current Isc current(PVG is shorted)
3	0	1	Measurement of current Iload and voltage Vload delivered to the load(MPPT is reconnected to the PVG)

(G) Measurement by redundancy

To ensure the reliability of our MPPT-PA system, we opted for the measurement by redundancy of the necessary values. This is resolved by the extent of N values of each parameter in one switching period Tsw and take the average of each parameter.

Table 3
Average of the parameter's values for the analysis

Parameters to measure	*Average value*
Short-circuit current Isc (A)	$\overline{I_{sc}} = \int_0^N \frac{I_{sc_n}}{N}$
Open circuit voltage Voc (V)	$\overline{V_{oc}} = \int_0^N \frac{V_{oc_n}}{N}$
Current delivered to the load by MPPT Iload (A)	$\overline{I_{load}} = \int_0^N \frac{I_{load_n}}{N}$
Voltage applied across the load by MPPT Vload (V)	$\overline{V_{load}} = \int_0^N \frac{V_{load_n}}{N}$

The switching device used in this work can reach a frequency up to 50hz which it can allow as to determine the time switching period Tsw for 10 samples using the equation below:

$$T_{SN} = N * t_{\text{one sample acquaring}} \tag{9}$$

with:

$t_{\text{one sample acquiring}}$: time to take single acquiring of four parameter's values.

(H) Errors in current, voltage and power

View that the performance factor is based on the relationship between the maximum power that can deliver the PVG and power delivering to load by the MPPT, this one can lead to errors on the components of powers mentioned previously (currents and voltages) as:

$$\Delta I = Imp - Iload \tag{10}$$

$$\Delta V = Vmp - Vload \tag{11}$$

$$\Delta P = Pmp - Pload \tag{12}$$

3. HARDWARE IMPLEMENTATION

MPPT-PA system includes a conversion part a transmission part a control part and a power switching part. Our MPPT-PA is designed on the basis of a Arduino uno card a current sensor's module a voltage divider as a voltage sensor's module and switch modules (relay).

4. SOFTWARE IMPLEMENTATION

The GUI has been completely developed in Labview environment provided by National Instruments. This allows great flexibility in relation to the available functions and adapts the test bench to the needs of the user.

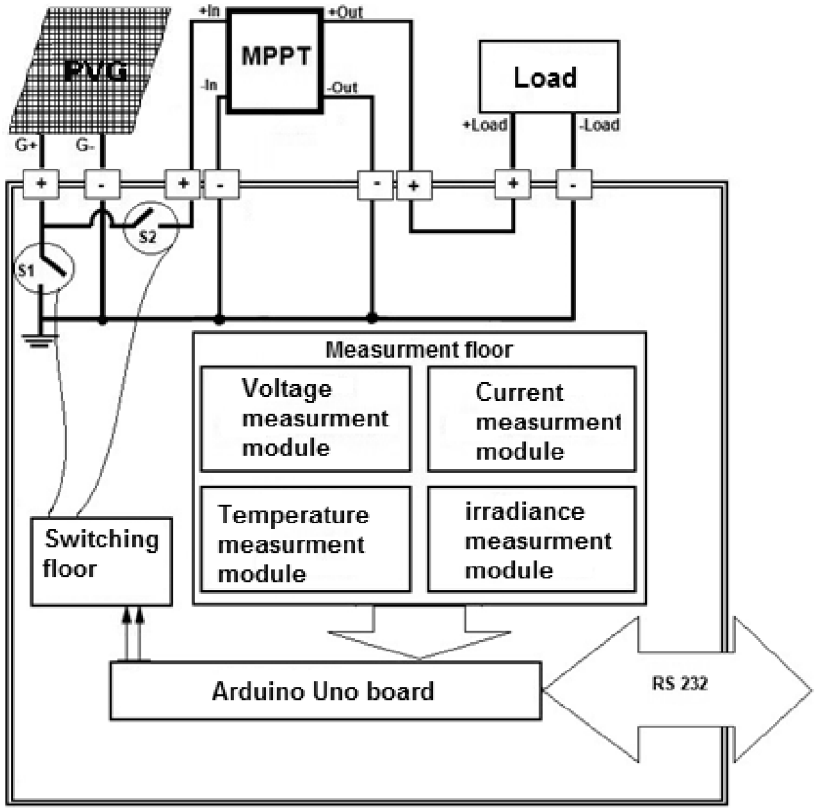

Figure 7: Block diagram of the modular structure of the MPPT-PA

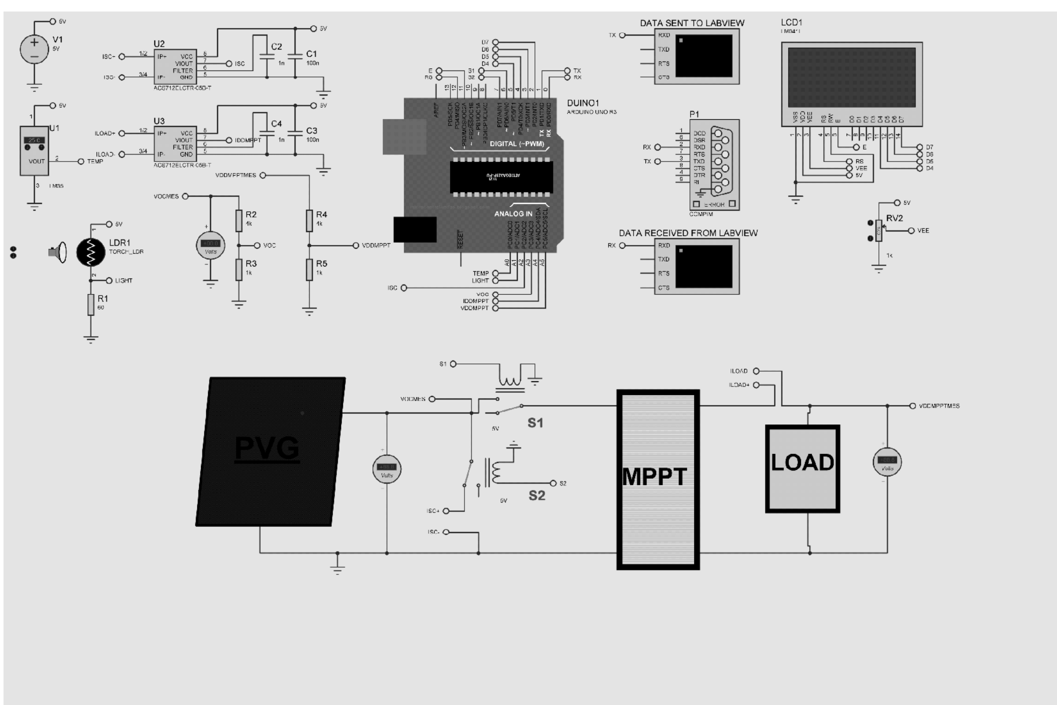

Figure 8: MPPT-PA implementation using ISIS-Proteus

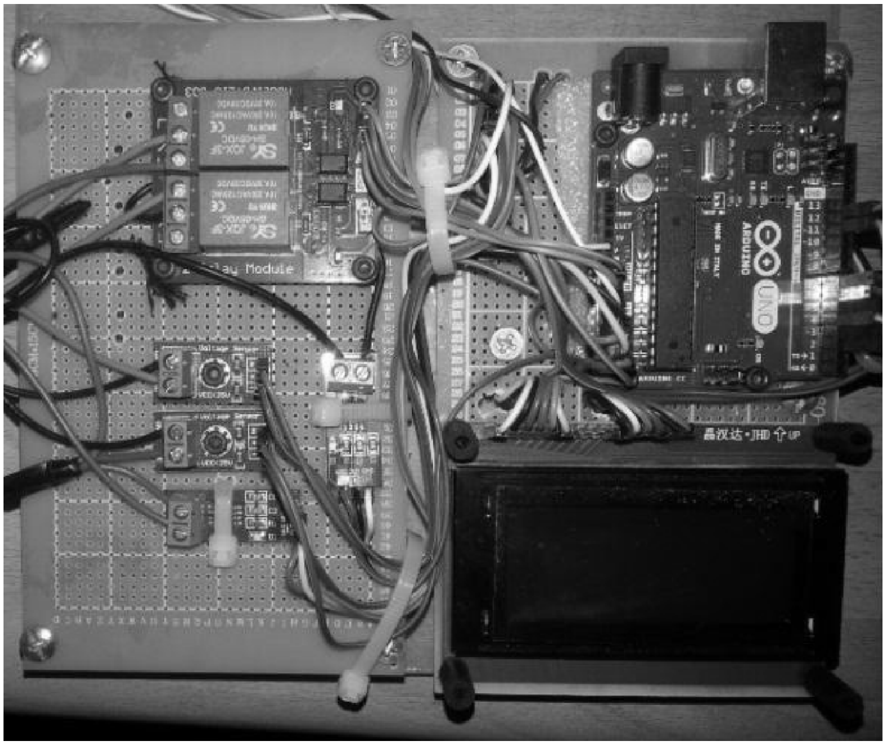

Figure 9: Developed MPPT-PA

Communication between this interface and the hardware part will be through the serial port by developing a well-studied protocol to prevent loss of information that can impact the judgment with respect to the performance of the MPPT.

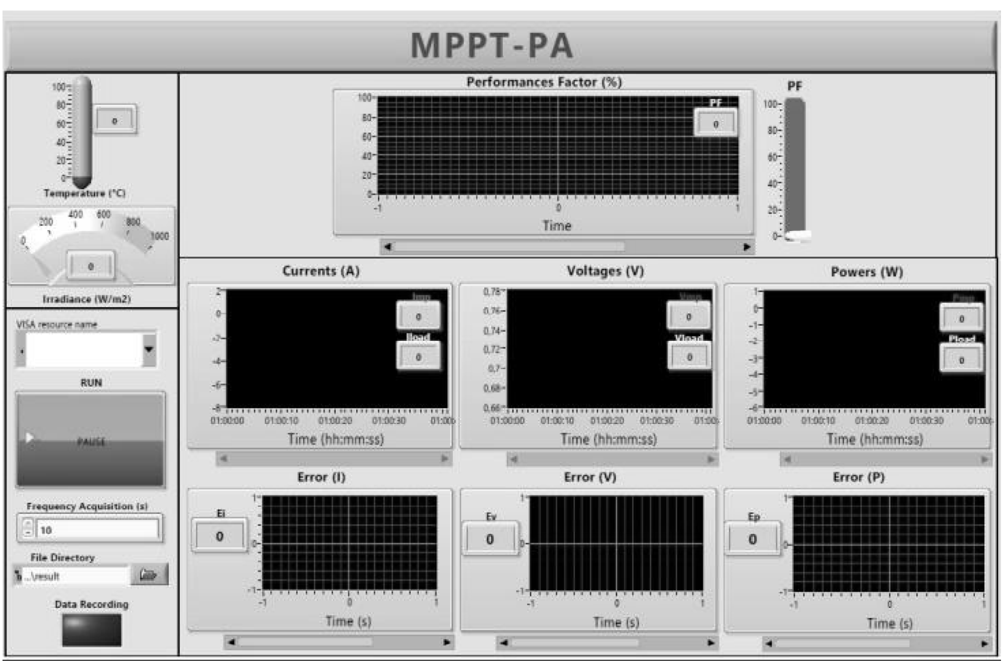

Figure 10: MPPT-PA GUI

It should be noted that the measure of two climatic parameters (temperature and irradiance) is made to have just an information on the conditions where the MPPT-PA device is working but they are not taken into account in the analysis process.

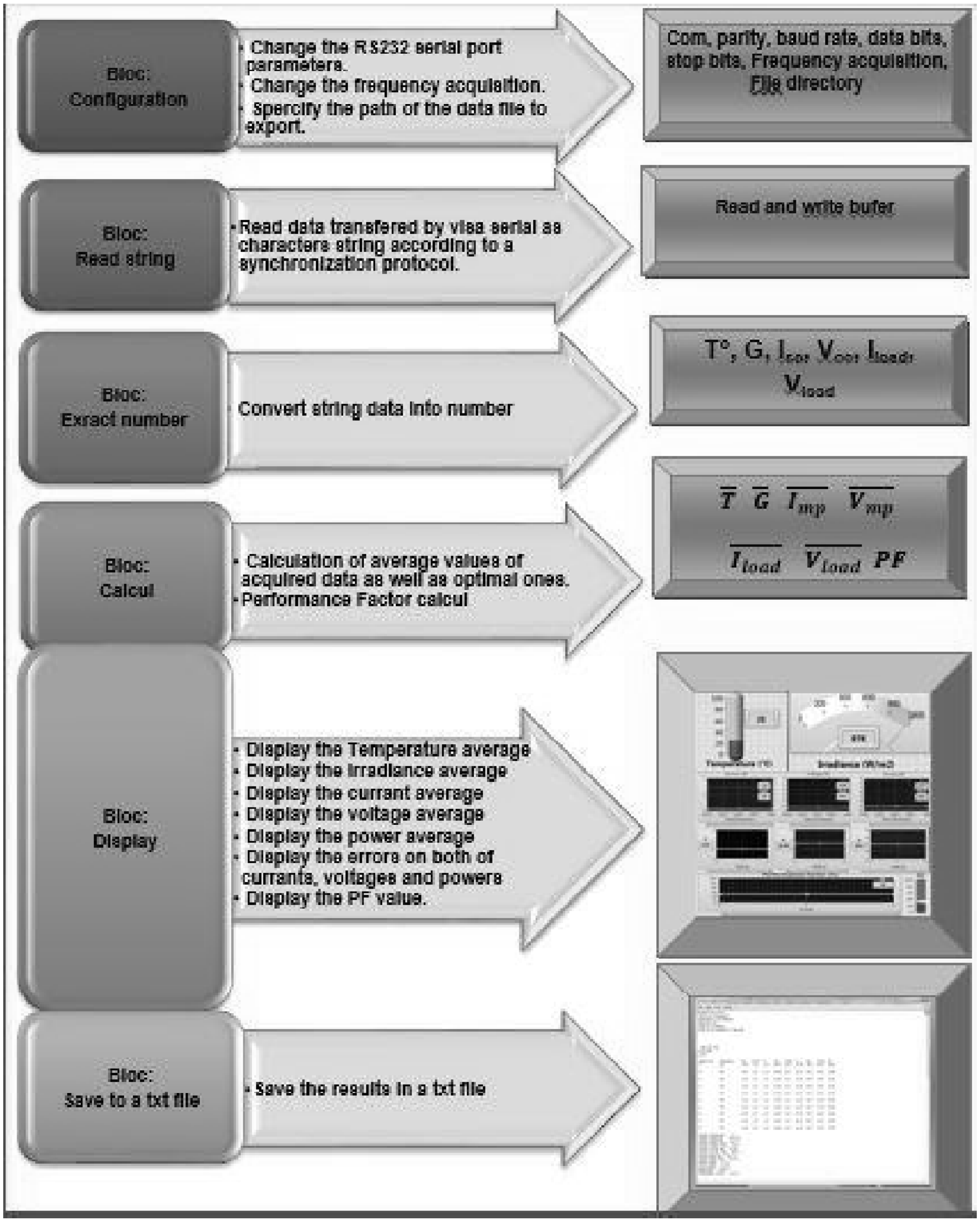

Figure 11: Schematic block diagram constituting the MPPT-PA interface

We used the Arduino Uno board it has the IC FTDI USB-to-serial. Instead of the usual serial port (DB9), it uses a Atmega8U2 programmed USB-to-serial converter. So this is to operate with a standard serial port RS232.

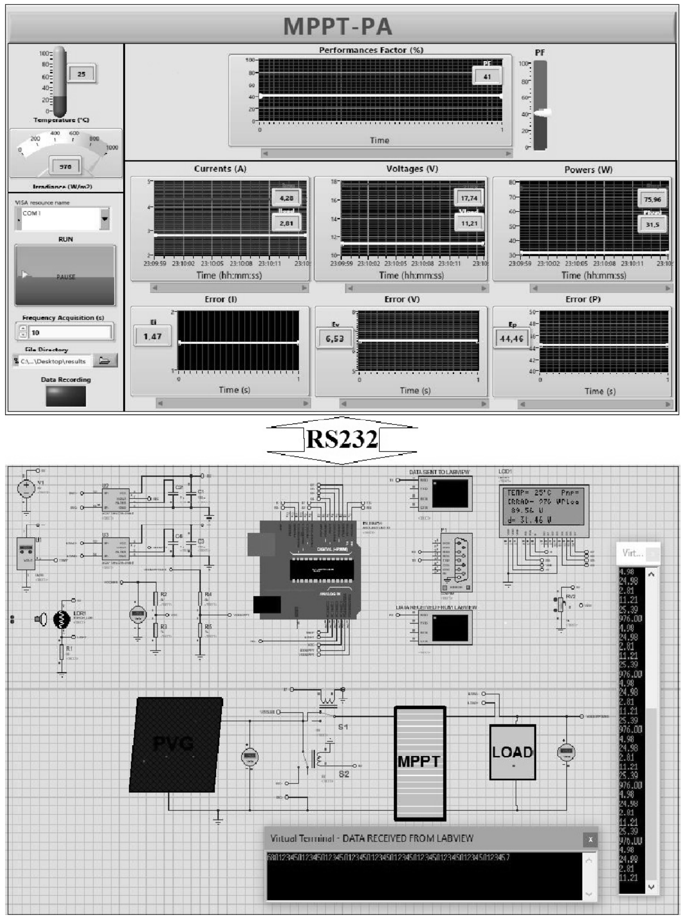

Figure 12: MPPT-PA simulation using ISIS proteus and GUI under Labview

To save the parameters describing the performance of the analyzed MPPT and the results of measurement and calculation, we used a VI that acquires an output file format txt.

MPPT-PA - Bloc-notes

Fichier Edition Format Affichage ?

MPPT-PA

Temperature	IRRADIANCE	Imp	Iload	Ei	Vmp	Vload	Ev	Pmp	Pload	Ep
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46
25	976	4.28	2.81	1.47	17.74	11.21	6.53	75.96	31.50	44.46
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46
25	970	4,28	2,81	1,47	17,74	11,21	0,53	75,90	31,50	44,40
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46
25	976	4,28	2,81	1,47	17,74	11,21	6,53	75,96	31,50	44,46

AVERAGE TEMPERATURE : 25 °C
AVERAGE IRRADIANCE : 976 W/m2
AVERAGE CURRENT Imp : 4,28 A
AVERAGE CURRENT Iload : 2,81 A
AVERAGE VOLTAGE Vmp : 17,74 V
AVERAGE VOLTAGE Vload : 11,21 V
AVERAGE POWER Pmp : 75,96 W
AVERAGE POWER Pload : 31,50 W
CURRENT ERROR : 1,47 A
VOLTAGE ERROR : 6,53 V
POWER ERROR : 44,46 W
PERFORMANCES FACTOR : 41,47 %

Figure 13: Output file in txt format

For example, we have established a significant PVG model using Isis-Proteus with Isc = 5 A and Voc = 25,5 V feeding a resistive load of 4 Ù.

Using the k_i and k_v method as mentioned in [51] the maximum power is calculated as:

$Pmp = K_i * I_{sc} * K_v * V_{oc} = 77.85$ W

As at MPPT, we calculated a Ropt optimum strength corresponding to the point of maximum power.

The test results are displayed on the user interface and the output file.

In this case, we can see that the MPPT system used in this simulation is operating with 41.47 % at its performance

5. CONCLUSION

In general, the photovoltaic conversion system include a photovoltaic generator and a power conditioning system with an MPPT control and a load. As the PV generator thereof, has a relative characteristic of power. The maximum power remains only a single operating point defined by a known voltage and a current, called the maximum power point. The change in the position of this point is expressed in terms of climate parameters (temperature and light). This requires a tracking system of this point so that the maximum power is continuously generated. The major problem of the MPPTs, is the difficulty to validate their performances. It should be noted that few studies (or almost no) addressing this problem are cited in the literature. Therefore, the main objective of this paper is the development of a new method of analyzing based on the outdoor measurement of maximum power in dynamic mode and also the development of an electronic device that could serve as an analyzer helping tool.

This device, which we called MPPT-PA will be responsible for monitoring the MPPT performance through a user interface developed in LABVIEW.

A performance factor was calculated to give an idea about at what percentage is this MPPT is performing.

It should be noted that the feature of this device is that the values of temperature and irradiance are not required in this process.

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