New quality factor to study the behavior of a solar panel

[a]Leila Ouzeri*, [a]Farouk Hannane, [b]Pierre Petit, [b]Michel Aillerie, [b]Jean-Pierre Charles, [a]Feriel Adli

[a]*Laboratory of Theoretical Physics and Radiation-Matter Interactions (LPTHIRM), University of Saad Dahlab Blida 1, Algérie*

[b]*The optical materials, photonics and systems* laboratory *(*LMOPS*), University of Lorraine, Centrale Supélec, France*

Corresponding author: Ouzeri Leila Tel: +213 662894896 e-mail: ouzleila@gmail.com

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Abstract

Curves are an important tool to study any system. Our main idea is to use the shape of the curves to study the behavior of photovoltaic systems. We remarked that we can use the relationship between power and the area under the curves. The shape and the area depend on the Irradiance and the temperature. The area can be considered as a representation of the energy received by the panel. This idea has led us to define a new quality factor to study the behavior of a photovoltaic system (ratio between the delivered maximum power and the area under the corresponding I-V characteristic curve). The remarkable quantities of these curves have been calculated.

Till now, the known quality factor, called the fill factor (FF), defined as the ratio of the delivered power and the product of the open circuit voltage and the short circuit current. The new definition proposed in this article, closer to reality, gives originality and open new perspectives to researchers. This work also shows that the maximum power delivered is perfectly linearly correlated with the area under the characteristic curve. The use of the Design of Experiments to model and simulate the behavior of a photovoltaic panel was for the first time by our team in 2013, in the LMOPS laboratory [1]–[3]. This method proposes simple models (polynomials) expressed directly as a function of the environmental conditions and it allows to simulate and optimize the behavior of the panel in real time.

Keywords: *Solar panel, Modelling, Simulation, Fill Factor, Efficiency, Quality, Design of Experiments.*

Symbols

A engineering (or actual) value of a factor	P_{in} incident power of sunlight (W/m^2)
$A_0 = \frac{A_{min} + A_{max}}{2}$	P_{max} delivered maximum power (W)
csv centered and scaled variable	S area under the characteristic curve (W)
η efficiency (%)	$step = \frac{A_{max} - A_{min}}{2}$
$FF = \frac{P_{max}}{V_{oc} \times I_{sc}}$ fill factor	T temperature ($°C$)
I current (A)	V voltage (V)
I_m maximum power point current (A)	V_m maximum power point voltage (V)
I_{sc} short circuit current (A)	V_{oc} open circuit voltage (V)
$NQF = \frac{P_{max}}{S}$ new quality factor	x centered and scaled variable

1. Introduction

There are two methods to model and simulate the behavior of a photovoltaic panel. The first method can be described as the method of the physicist or the electronic engineer. The scientific literature on the modeling of photovoltaic panels and the estimation of their parameters is very numerous and scattered. The article [4] gathers in a comprehensive document the most important works on this subject, in order to have an overview. Most of these works are based on the use of an equivalent electrical circuit with one or two diodes.
The second method, which can be called the method of the mathematician and statistician and which we use in this work is unfortunately not as well known and applied as it should be. It is the Design of Experiments method (DoE), although it is used in many different fields. These two methods are complementary. The DoE method considers any system as a closed space, i.e. we are only interested in the inputs (factors) and outputs (responses), while completely ignoring the internal structure of this system (*Figure* 1).

We then perform a series of experiments by varying the factors according to a well-defined design (conventional design) or by randomly distributing the experimental points in the experimental domain (non-conventional design) while measuring the value of the response corresponding to each trial. We use an unconventional design in this work. The model of each response is a relationship between that response and all the considered factors. The model is established from the values of the measurements made.
It is interesting to make a general literature survey in order to explore historical aspects of DoE method, provide state of the art of its application, its evolution in research as well as its application in the different concerned fields [5]. We will then approach a more thorough bibliographic survey for the last decade and concerning its specific application to photovoltaic panels.
To the years before 1920, experiments were conducted using the so-called "one factor at a time" method, in which only one factor was changed while all others were held at fixed values. Although this method is easy to understand, it does not allow for the study of how one factor affects a system in the presence of other factors. It has been shown that it does not identify interactions between factors or optimize the system. The best way to study a system is to vary all factors simultaneously. The modern principles of experimentation (i.e., varying all factors simultaneously) originated in the 1920s, primarily in agricultural research, from the work of mathematician-physicist Ronald Aylmer Fisher. In 1935, Fisher published his world-famous book, "The Design of Experiments", which is in a way a synthesis of the studies he had carried out and devoted to agronomic research in order to increase the yield of crops [6].

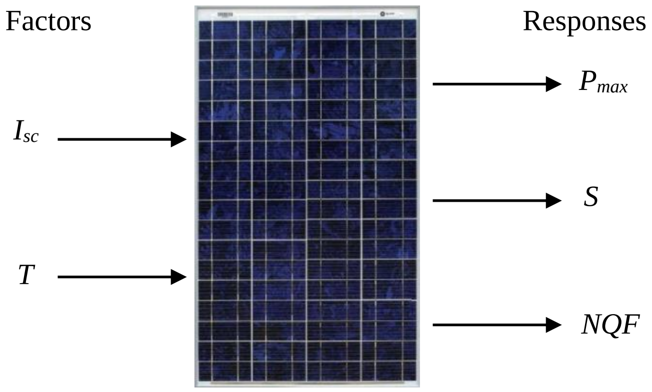

Figure 1 : The photovoltaic panel BPSolar 350 considered as a black box.

2. More about DoE method

Figure 2 illustrates the evolution of the application of the DoE method in the world and in different scientific fields between 1920 and 2017 [7]. We can consider roughly two periods on the evolution of the application of the designs of experiments: the four decades 1920-1960 during which its application in the research was negligible and the period 1960-2017 which saw a considerable evolution from 1960 thanks to the appearance of data processing. Today, many DoE software exist such as: Hide [8], Statistica, JMP, Modde, Minitab, Design Expert…

The fact that the system is considered as black box gives power to the method in order to be used in many disciplines. This method based on mathematics and statistics does not replace the results obtained by other methods, but brings complementary information. It allows, for example, to gather in one relation (which is always a polynomial) all the information brought separately or jointly by each of the factors, to obtain certain practical results and specially to optimize and simulate and even to confirm experimentally theoretical results. 50% of researches use Design of Experiment method.

The chart shows in percentages that the DoE method is most popular in Medicine (18%), then in engineering and biochemistry (10% each); although physics and computer science (7% and 6%). DoE method has been also used in administration, marketing, hospitals, pharmaceutical [9], food industry [10], energy and architecture [11], and chromatography [12]. DoE method is applicable to physical processes as well as computer simulation models [13]. The DoE method has expanded rapidly, including product and process quality improvement, product optimization and services over the last two decades. It has also been applied in wind power [14] and mathematics [15].

With regard to journals, it can be noted, for example, that the titles Biometrika and Journal of Agricultural Science, which published numerous articles on experimentation from the beginning of the 20th century, were launched in 1900 and 1905 respectively, whereas Technometrics and Journal of Quality Technology date from 1959 and 1969 respectively. New journals were created, such as Statistics in Medicine and Statistical Methods in Medical Research, in 1982 and 1992 respectively. Finally, other areas of use of experimental designs could also be considered (educational sciences, marketing, etc.).

An extensive literature review shows that before 2013 there is no publication in which DoE is used to model a photovoltaic panel. The aim of study [1], published in 2013 is to show how the Design of Experiments method can be put into use as a practical method to model an operating photovoltaic PV generator. Mathematical models describing the variations of the open circuit voltage V_{oc}, the short circuit current I_{sc} and the delivered maximum power P_{max}, versus solar irradiance level and temperature, were obtained. These models are predictive models. With the help of the Hide software [8], we can simulate the PV panel behavior and forecast, in real time, the variations of V_{oc}, I_{sc} and P_{max} anywhere in the surveyed experimental domain. In the paper [3] published also in 2013, experimental designs are used to detect any malfunction of a photovoltaic (PV) panel in operation. Any deviation between the maximum power values calculated by the model and the measured values indicates a malfunction of the PV panel. In [16] the physicist's approach (equivalent electrical circuit) and the statistician's approach (Design of Experiments) are briefly used to model a photovoltaic panel. The software used is Modde 5. Given a known level of solar irradiation and temperature, it is possible to automatically estimate the electrical power output using the DoE method and to trigger an alarm in the event of an accidental shadow [17]. The Response Surface Methodology (RSM) used in the investment of photovoltaic plants allows the parameters of the investment (Net Present Value, Internal Rate of Return, Return on Investment, etc.) to be determined in real time from the technical, economic, financial and positional data, dependent or objective functions. By appropriately varying the independent variables, it is possible to obtain a sensitivity analysis on the dependent variables. This allows different investment valuations to be obtained in several predefined scenarios [18]. DoE method is also used for modeling and optimization of a photovoltaic panel in papers [19], [20].

Finally, in a forthcoming publication the two modeling approaches (the physicist's and the statistician's) will be compared and the authors will draw the advantages and complementarities of each [2], [21].

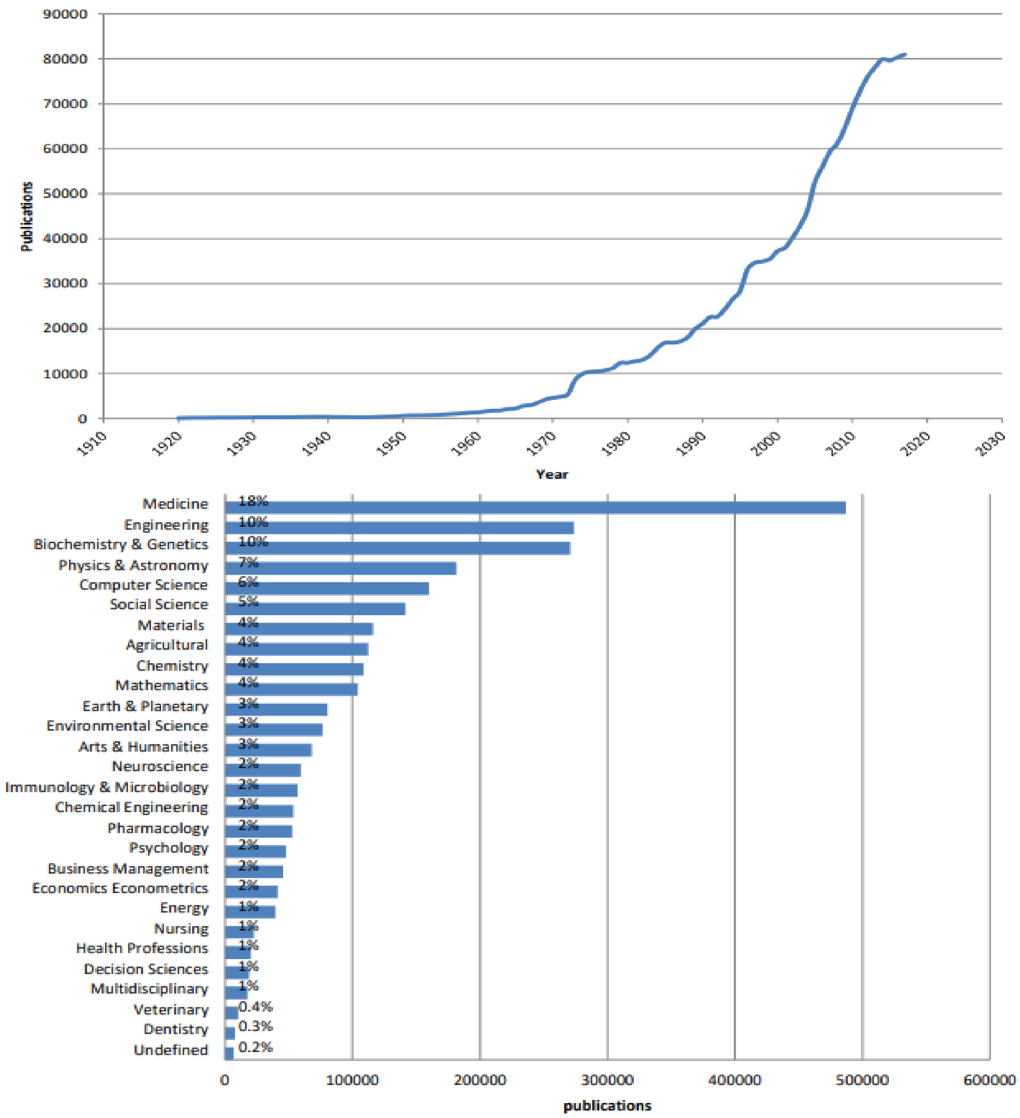

Figure 2 : DoE method application in scientific research and scientific area.[5]

3. Experimental setup and measurements

Experiments were done on a commercial Solar panel BP 350 including 72 multicrystalline silicon cells arranged in a 4x18 matrix connected in 2 parallel strings of 36 in series. The panel and its datasheet are shown in *Appendix* B. The illumination is provided by DELTALAB illumination sources with 6 quartz-halogen bulbs (1 *Kw* each) in batteries with reflectors. The best way to measure irradiance in W/m^2 would be to use a pyranometer. Unfortunately, we did not have such a device at our disposal during the measurements. As we are only interested in the variation of the irradiance, three levels of irradiance were obtained by varying the source distance (*SD*) of the light from the panel: *SD* =1; 2; 2.8 m, corresponding respectively to I_{sc}= 2.5;1.5 and 1 *A* [1].
We will show later that the short circuit current and the output powers are perfectly correlated. Furthermore, for a fixed irradiance, the influence of temperature on the short-circuit current is not much considered comparing to the influence of Irradiance. Therefore, the short-circuit current will be the measure of irradiance in all this work. Temperature is measured with an infrared thermometer and lowered by a fan. Eleven trials were carried out varying the source distances *SD* (Source Distance) and temperature values. *Figure* 3 shows the distribution of trials in the study domain.

4. Experimental space and study domain

In general, we limit the variation of factors between two levels, the low level (-1) and the high level (+1). See *Table* 1.

Factors	Low level (-1)	Middle level (0)	High level (+1)
$I_{sc}(A)$	1	1.75	2.5
$T(°C)$	25	42.5	60

Table 1 : Factors and study domain. The low and high levels take the values -1 and +1.

To illustrate graphically an experimental space, we use a two-dimensional area (*Figure* 3). Mathematically, this gives a Cartesian plane that defines an Euclidean space in two dimensions. This area is called the experimental space. The experimental space is composed of all the points of the plane factor 1×factor 2 where each point represents an experimental trial. This domain is defined by the union of the domains from the different factors. We will use the Centered and Scaled Variables x (csv).

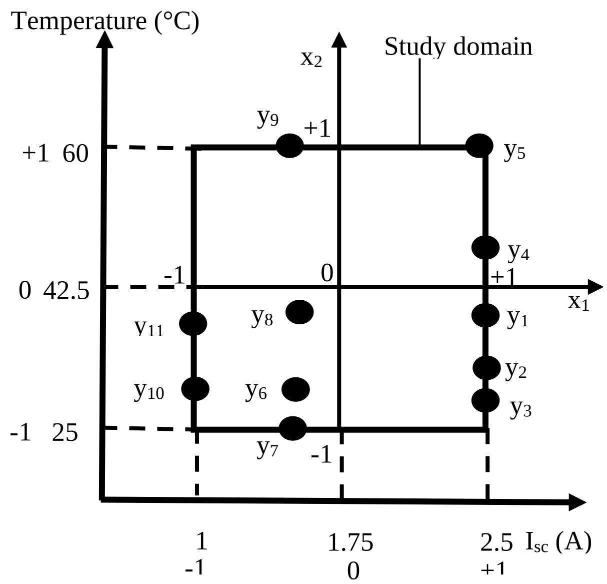

Figure 3 : Distribution of the experimental points inside the study domain.

5. Characteristic curve of trial 1 and Calculation of its main remarkable quantities. The results

Figure 4 shows the characteristic curves of Trial 1, with and without the measuring points, as well as the main remarkable values. In order to obtain best precision for I_{sc}, V_m, I_m, V_{oc} and S the curve is divided into two portions: the first corresponding to the short circuit region and the second corresponding to the open circuit voltage region. Least square method is used to get respectively the following two second order polynomials p_1 and p_2 :

$$p_1 = -0.0003x^2 - 0.0213x + 2.5 \qquad p_2 = -0.1150x^2 + 3.0321x - 17.0531$$

where p_1 and p_2 stand for the current (expressed in Amps) and x stands for the voltage (expressed in volts). Intersection of p_1 with current axis gives $I_{sc} = 2.5\ A$ and $V_{oc} = 18.30\ V$ is the highest root of p_2. V_m and I_m the coordinates of *MPP* (Maximum power point) are equal to $I_m = 2.05\ A$ and $V_m = 15.94\ V$. The maximum power delivered is equal to P_{max}. The maximum power point (*MPP*) is positioned near the bend in the I-V characteristics curve.

$$S_1 = \int_0^{V_m} p_1 dx = 36.54 \qquad S_2 = \int_{V_m}^{V_{oc}} p_2\, dx = 2.63 \qquad S = S_1 + S_2 = 39.17$$

Calculation of the New Quality Factor NQF and Fill Factor FF:

$$NQF = \frac{P_{max}}{S} \qquad FF = \frac{P_{max}}{V_{oc} \times I_{sc}}$$

In *Table* 3 (*Appendix* A) we have gathered all the results concerning the main values of the characteristic curves, the calculated results (actual values) and the predicted values by the models that will be established later.

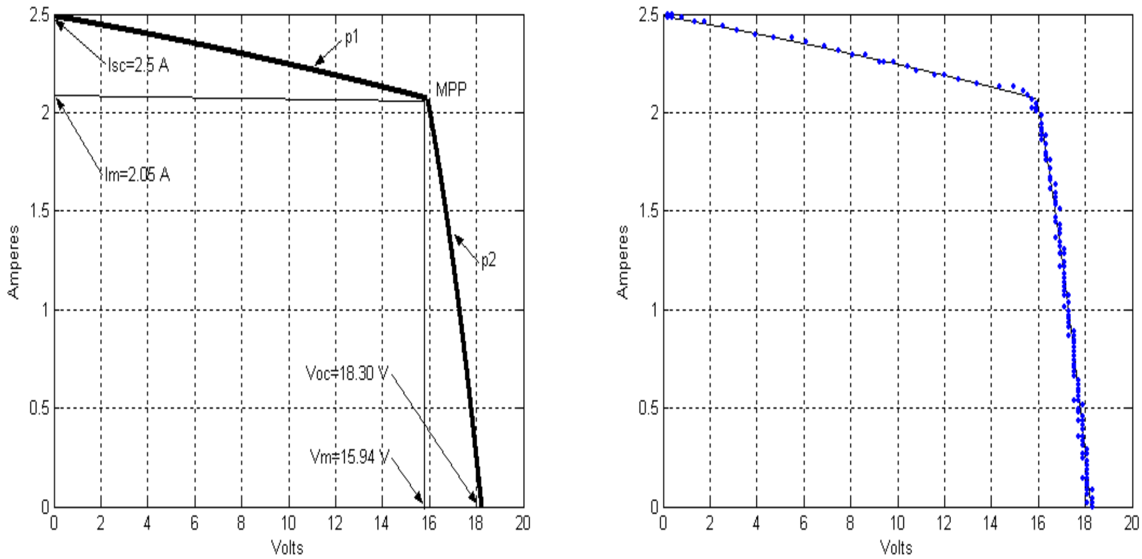

Figure 4 : Characteristic curve of trial 1, with and without points. Including remarkable values: I_m, V_m, I_{sc}, V_{oc}, MPP.

6. Interpreting the results of calculations- Correlations

Since both the maximum power output and the area under the characteristic curve depend on the irradiance and the temperature, a question arises: what is the relationship between them? To find out we need to calculate the correlation coefficients between factors, between responses and between factors and responses. We notice that the short circuit current is perfectly correlated with the maximum power output and the area which means that it is the factor that has the greatest influence on them. On the other hand, the temperature correlates very poorly with both the short circuit current and the four responses. We also notice that the maximum power delivered is perfectly correlated with the area under the characteristic curve, so we can draw the line that links them. Knowing one we can deduce the other *Figure* 5.

	I_{sc}	T	P_{max}	S	NQF	FF
Isc	1.00	0.17	1.00	1.00	0.94	0.47
T	0.17	1.00	0.10	0.10	0.07	-0.32
P_{max}	1.00	0.10	1.00	1.00	0.94	0.51
S	1.00	0.10	1.00	1.00	0.94	0.50
NQF	0.94	0.07	0.94	0.94	1.00	0.73
FF	0.47	-0.32	0.51	0.50	0.73	1.00

Table 2 : Correlations between factors and responses.

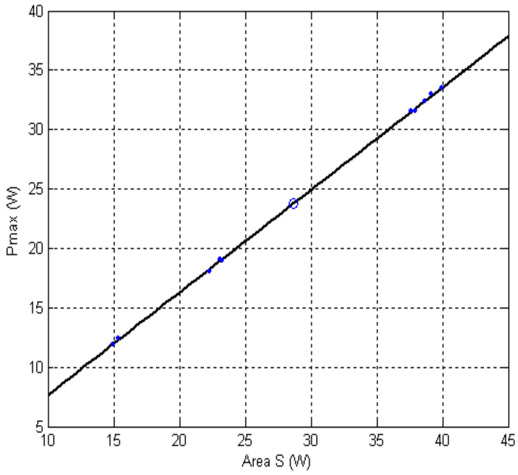

Figure 5 : Least squares line P_{max}.

7. Efficiency

Efficiency is defined as the ratio of energy output from the solar panel to input energy from the sun. In addition to reflecting the performance of the solar panel itself, the efficiency depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. The efficiency of a solar panel is determined as the fraction of incident power which is converted to electricity.

$$P_{max} = S.NQF \qquad \eta = \frac{S.NQF}{P_{in}}$$

where P_{in} is the incident power of sunlight. We can use also the fill factor

$$P_{max} = V_{oc}.I_{sc}.FF \qquad \eta = \frac{V_{oc}.I_{sc}.FF}{P_{in}}$$

The efficiency (%) of a panel is calculated by the maximum power rating (*W*) at STC (Standard Test Conditions), divided by the total panel area in square meters.

$$\eta = \frac{P_{max}}{Area \times 1000 w/m^2} \quad \text{where} \quad Area = Panel\ Area(m^2)$$

Most solar panels have efficiencies between 15% and 20%. In reality, cell generally produces well depending on the ambient air temperature, wind speed, time of day and amount of solar irradiance.

8. Models of the three responses

The adopted models have the polynomial following form: $y = a_0 + a_1x_1 + a_2x_2 + a_{12}x_1x_2$.
Where x_1 and x_2 are respectively the values of irradiance and temperature in a considered point of study domain expressed in coded units and y is the corresponding response expressed in actual value. The coefficient a_0 called intercept is the value of the response in the center of the study domain ($x_1 = 0, x_2 = 0$). The coefficients a_1 and a_2 are called main coefficients. It is these last two coefficients that allow us to study the relative, the quantitative and the qualitative influence of irradiance and temperature on responses. The interaction coefficient of the two factors a_{12} can be compared to the main coefficients. Using the results of *table* 3, the software Hide [5] provides the following models for the maximum power output, the area under the characteristic curve and the quality efficiency factor:

$$P_{max} = 22.20 + 9.86x_1 - 0.50x_2 - 0.47x_1x_2$$
$$S = 26.81 + 11.70x_1 - 0.57x_2 - 0.49x_1x_2$$
$$NQF = 0.83 + 0.006x_1 + 0.002x_2 - 0.007x_1x_2$$

Predicted values by these models are presented in *Table* 3. These models can also predict the values of the responses of any point inside or on the limits of the study area (*Appendix* C). Outside, it is possible to guess the results, but these results should never be taken conclusions without holding additional verification trials. It is important to note that the models used by the DoE method are always of polynomial form. If the coefficients of the statistician's model do not have a physical meaning as in the physicist's models, they do reflect the behavior and the global functioning of the system they represent. In this article, we will not explain how the models were established. This would take too long, as it is necessary to apply the theory of DoE. This will be the subject of a later publication. We will therefore limit ourselves to showing how to use these models and draw results.

9. Graphic illustrations

The Hide software [8], dedicated to the DoE method, gives a good idea of the contribution of computer science to the DoE and of the assistance that an experimenter can expect. The construction of the designs is simplified, the computational difficulties are removed. It also allows the rapid visualization of graphs that give a unique insight to illustrate the results and multiplies the reasoning power of the experimenter to increase the understanding of the phenomenon.

- **Histograms and sector representations (*Appendix* D)**

Histogram representation in *Figure* 8 allows to see the relative, the quantitative and the qualitative influence of the two factors (irradiance and temperature) on the responses through the values of the main coefficients a_1 and a_2. The absolute values give us information on the influence, the signs on the direction of variation. For maximum power P_{max}, $a_1 = +9.86$ and $a_2 = -0.50$. Thus, irradiance has a greater influence than temperature on maximum power. Maximum power increases (sign+) when irradiance increases and decreases (sign-) when temperature increases. This applies for *S*. On the other hand, *NQF* increases when irradiance and temperature increase (sign+ for both coefficients). The interaction is non-negligible compared to the main factors and has a negative influence.

The sectoral representation does not allow the direction of variation of the responses to be given according to that of the factors, but it does give the quantitative influence in percentage of each of these factors and interactions on the responses. For P_{max} (Influence of irradiance, temperature and interaction represents respectively ($a_1 = 91.04\%$, $a_2 = 4.62\%$, $a_{12} = 4.34\%$of the total), for S ($a_1 = 91.69\%$, $a_2 = 4.47\%$, $a_{12} = 3.84\%$) and for NQF ($a_1 = 40\%$, $a_2 = 13.33\%$, $a_{12} = 46.67\%$).

- **Response surfaces and corresponding contour lines (*Appendix* E)**

Each point in the study domain corresponds to a response. Together, all the points in the study domain correspond to a collection of responses located on a surface. Drawing the response surface (*Figure* 9) allows the following objectives to be achieved: to discover the location of the optimal solution and to follow the evolution of the response as a function of the factors. The responses surfaces of P_{max} and S show that the maximum is reached when the short circuit current is at its high level ($x_1 = +1$) and temperature at its low level ($x_2 = -1$). The value of P_{max} within the study domain can be therefore calculated with equation of the model: P_{max}. In the same way the maximum area inside the study domain is : $S = 26.81 + 11.70 + 0.57 + 0.49 = 39.57\ W$. The responses surfaces show that the maximum power and the area increase with irradiance and decrease with temperature while the new efficiency factor increases with both irradiance and temperature. The corresponding contour lines confirm that the temperature has almost no influence on $P_{max}$and S since these lines are almost parallel to the temperature axis. Because the *NQF* model equation has a larger second degree interaction coefficient a_{12} than the others, the response surface has some curvature. All the response surfaces are represented in real coordinates, while the corresponding contour lines are represented in coded units.

- **Simulation of the behavior of the panel (*Appendix* C)**

Finally, to illustrate the use of the dedicated software Hide [5], allowing for a user to simulate the behavior of the panel in real time. The contour lines are drawn in the same graph (*Figure* 10). Moving the cursor of the mouse inside the study domain or on its limits we can obtain for any point its real coordinates and corresponding responses like for Trial 1 detected by a cross on the screen.

10. Conclusion

Efficiency is the most common parameter used to compare the performance of one solar panel to another. In this paper we have shown that the area under the I-V characteristic curve correlates perfectly with the delivered maximum power, which was not obvious at first sight. This result is important. We then defined a new quality and efficiency factor providing scientists and researchers with a new orientation to study the photovoltaic cells and panels. Three responses, namely the maximum power output, the area under the characteristic curve and the new efficiency factor, were modeled using the statistical DoE method, thus allowing results to be drawn, above all, to simulate and optimize this operation in real time. However, the quality and the efficiency of a panel depends on many other factors: the spectrum and intensity of the incident sunlight, shading, the design of the cells which play an important role and their arrangement, the doping, the type of silicon, the size of the panel and many others. Therefore, the conditions under which the efficiency is measured must be carefully controlled. The DoE method is well suited to investigate a large number of factors while reducing the number of tests. In addition, it allows both numerical and categorical factors to be studied. Researchers are continually looking for ways to improve the efficiency of photovoltaics' panel to get the most out of solar energy. The DoE method is an excellent tool for this purpose as it allows several factors to be used and varied at the same time.

In next works, we can add a third categorical factor which is the type of semi-conductor of the panel. For example Cu(InGa)Se2/CdS [22] and CdTe/CdS [23] which will take the -1 and +1 levels respectively in centered and scaled variables. This would allow a comparison of the efficiency of these two semi-conductors.

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Appendix A

							Actual values				Predicted values			
Trial	*SD* *m*	I_{sc} *A*	*T* *°C*	V_m *V*	I_m *A*	V_{oc} *V*	P_{max} *W*	*S* *W*	*NQF*	*FF*	P_{max} *W*	*S* *W*	*NQF*	*FF*
1	1.1	2.5	40	15.94	2.05	18.30	32.7	39.2	0.83	0.71	32.19	38.66	0.83	0.71
2	1.1	2.5	30	15.94	2.02	18.30	32.2	38.6	0.83	0.70	32.74	39.27	0.84	0.71
3	1.1	2.5	26	16.13	2.07	18.68	33.4	40.0	0.84	0.72	32.97	39.51	0.84	0.71
4	1.1	2.5	44	15.15	2.07	18.11	31.3	37.9	0.83	0.70	31.97	38.42	0.83	0.71
5	1.1	2.5	60	15.15	2.07	17.32	31.3	37.6	0.83	0.72	31.08	37.44	0.83	0.71
6	2.0	1.5	30	14..96	1.28	17.71	19.2	23.1	0.83	0.72	19.16	23.20	0.82	0.72
7	2.0	1.5	25	14.96	1.28	18.11	19.2	23.3	0.82	0.71	19.25	23.32	0.82	0.72
8	2.0	1.5	40	15.35	1.26	17.71	19.3	23.3	0.83	0.73	18.96	22.97	0.82	0.72
9	2.0	1.5	60	14.17	1.30	17.12	18.4	22.3	0.83	0.72	18.57	22.51	0.83	0.73
10	2.8	1.0	31	14.96	0.81	17.12	12.1	14.9	0.81	0.71	12.36	15.17	0.81	0.72
11	2.8	1.0	38	13.78	0.91	16.93	12.5	15.4	0.81	0.74	12.35	15.13	0.82	0.73

Table 3 : Results of experimental and predicted values of all 11 trials.

Appendix *B*

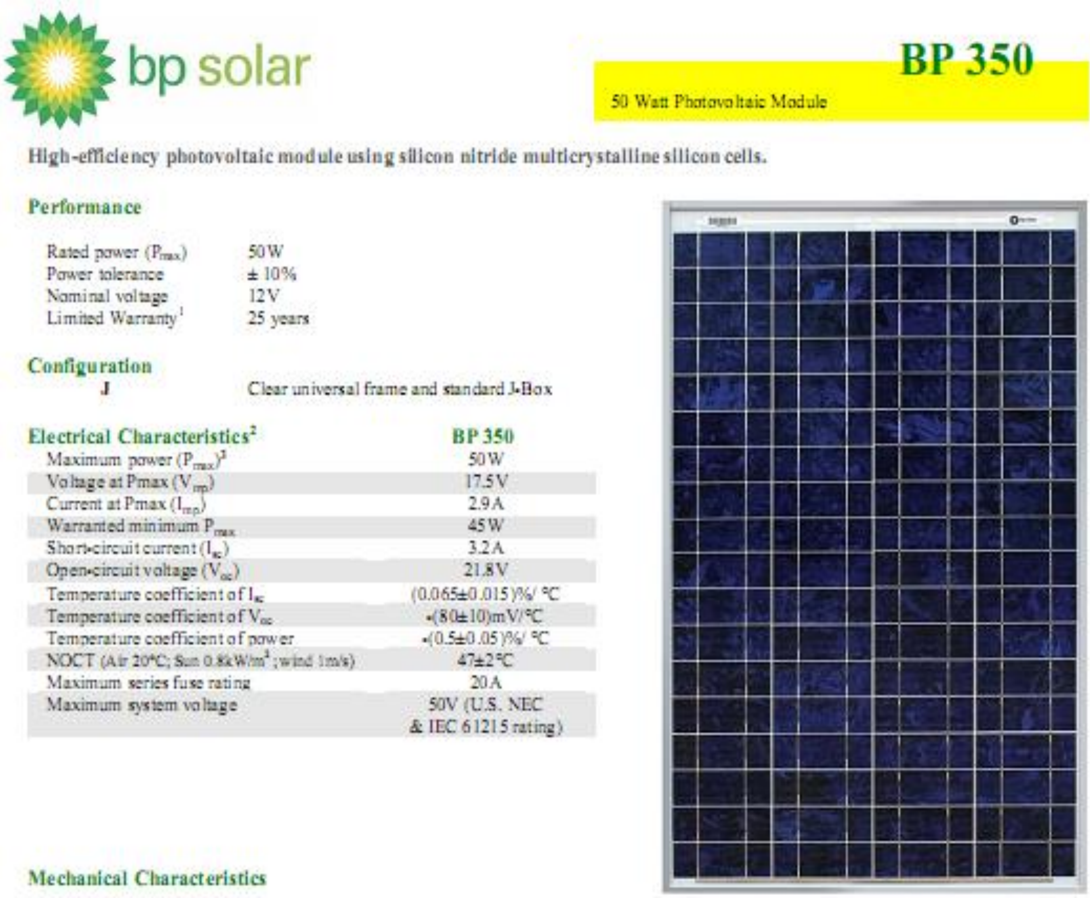


Figure 6 : The BPSolar 350 panel and its datasheet.

Appendix C

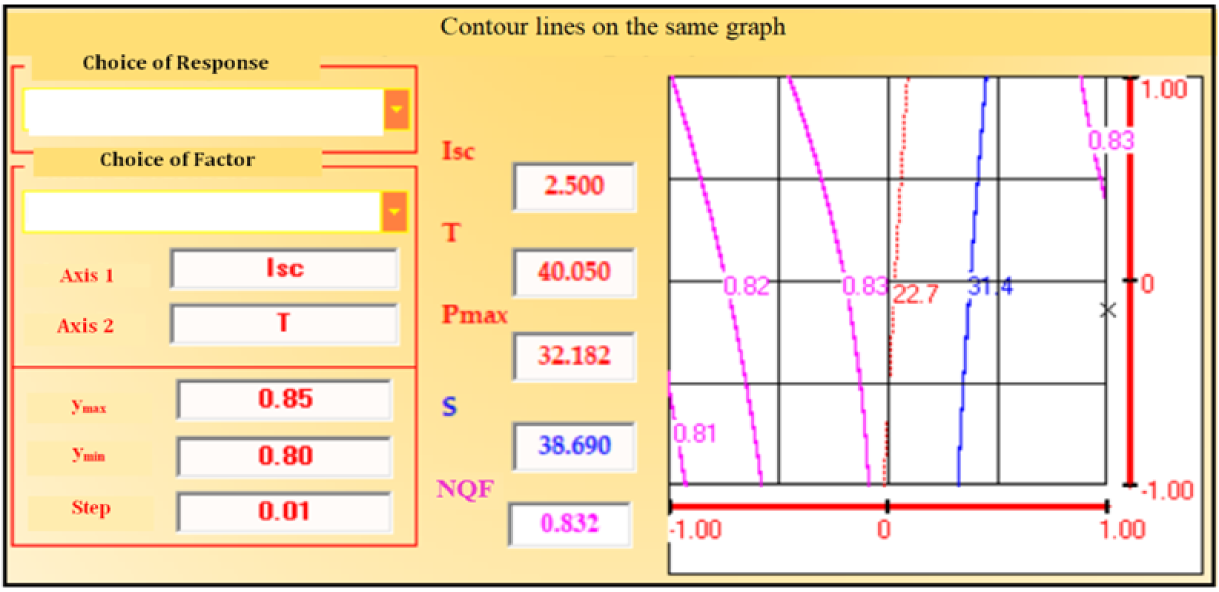


Figure 7 : Simulation of the behavior of the panel for P_{max}, S and NQF.

Appendix D

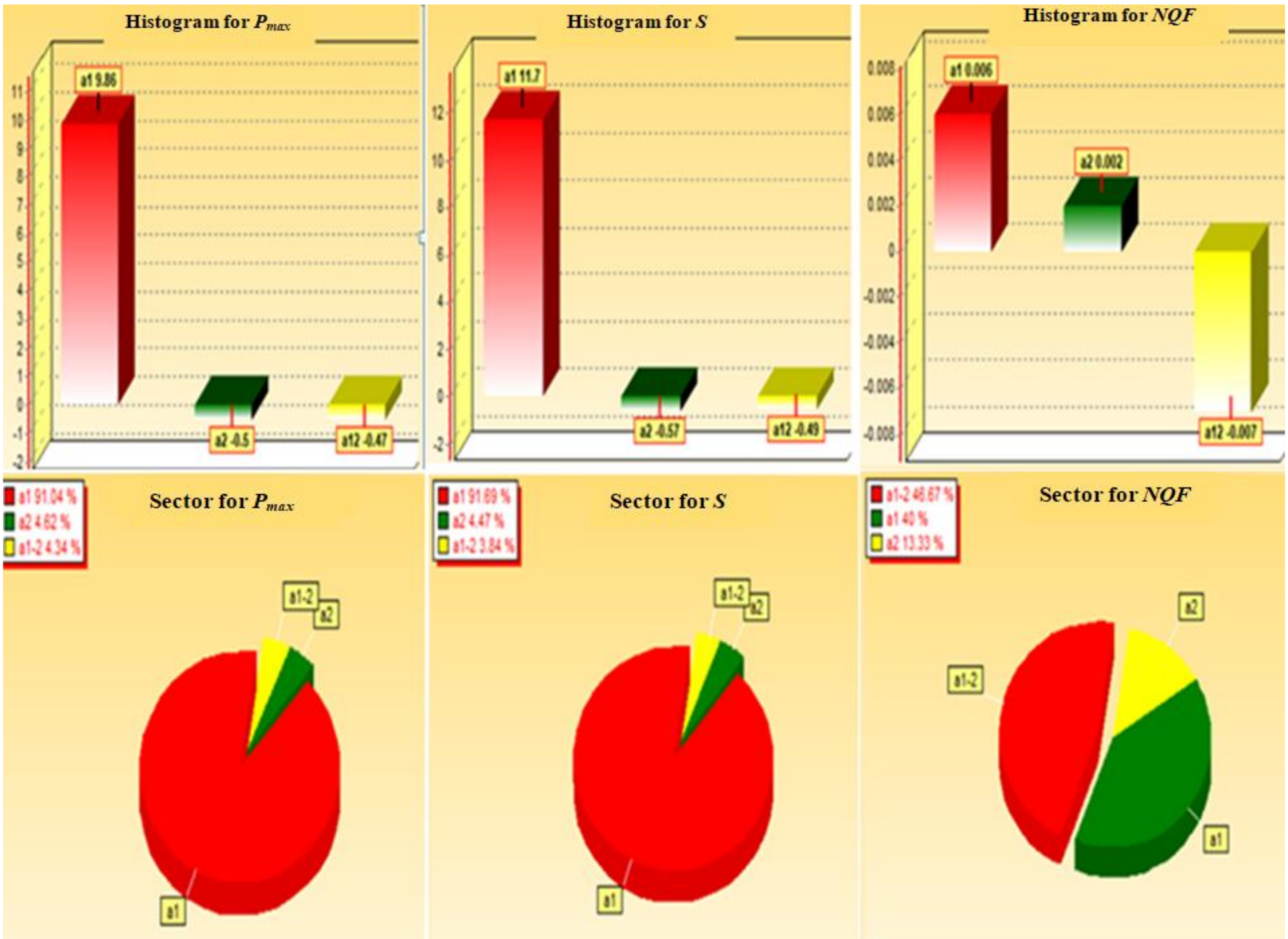


Figure 8 : Histograms and sector representations for P_{max}, S and NQF.

Appendix E

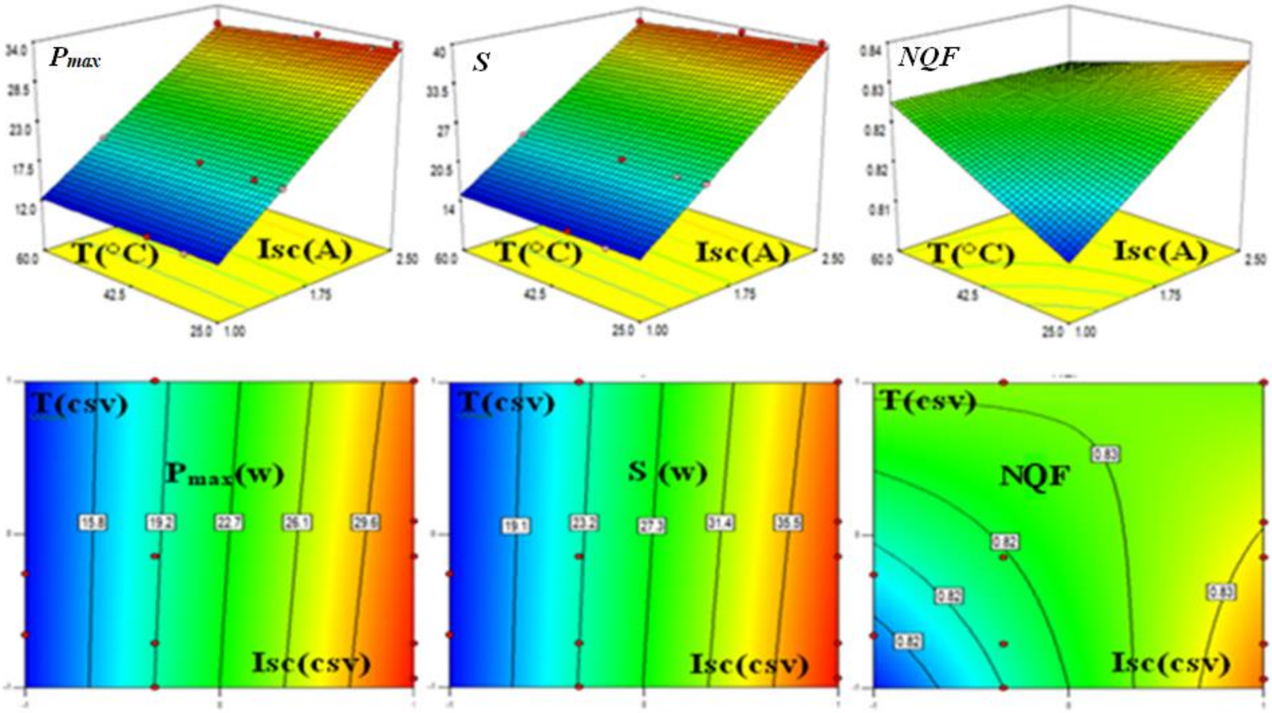
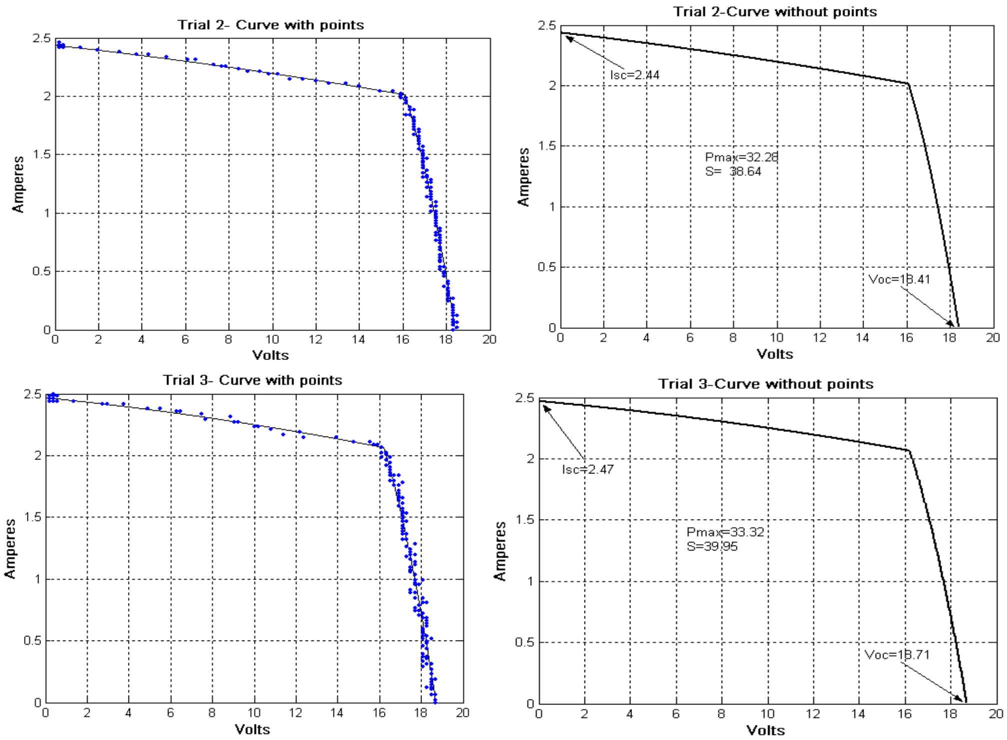
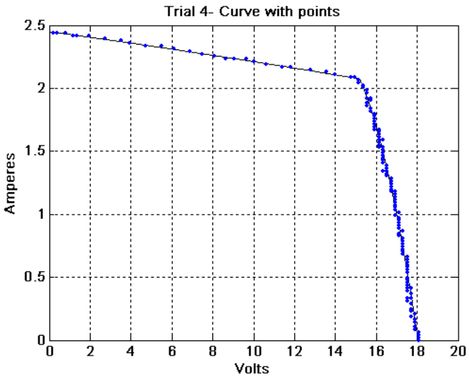
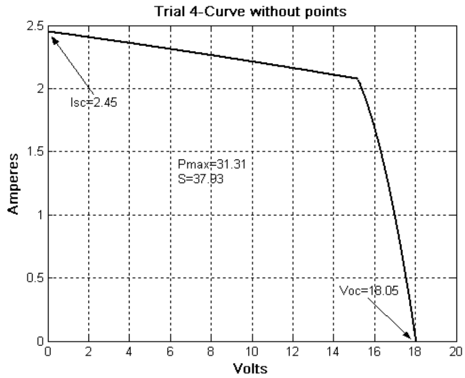
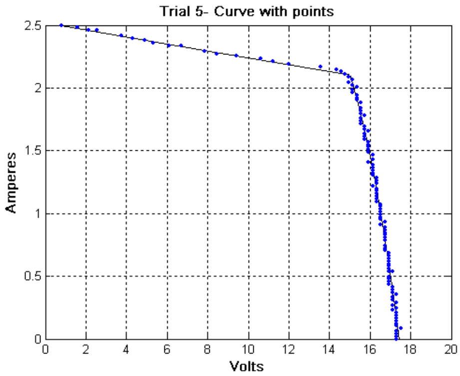
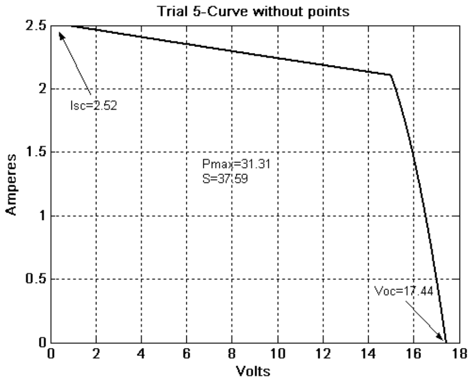
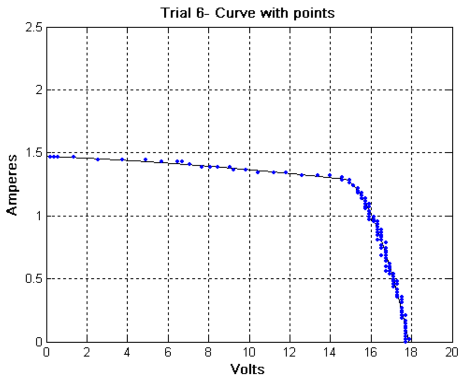
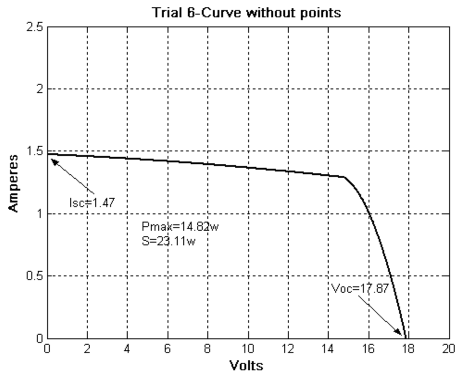
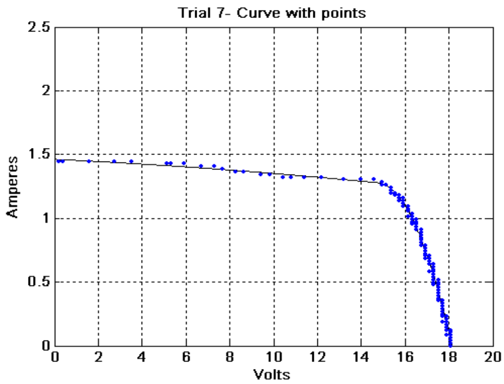
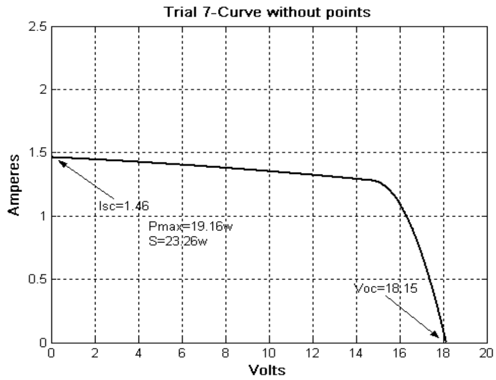


Figure 9 : Response surfaces and corresponding contour lines for P_{max}, S and NQF.

Appendix F




Trial 4- Curve with points
Amperes
Volts

Trial 4-Curve without points
Isc=2.45
Pmax=31.31
S=37.93
Voc=18.05
Amperes
Volts

Trial 5- Curve with points
Amperes
Volts

Trial 5-Curve without points
Isc=2.52
Pmax=31.31
S=37.59
Voc=17.44
Amperes
Volts

Trial 6- Curve with points
Amperes
Volts

Trial 6-Curve without points
Isc=1.47
Pmak=14.82w
S=23.11w
Voc=17.87
Amperes
Volts

Trial 7- Curve with points
Amperes
Volts

Trial 7-Curve without points
Isc=1.46
Pmax=19.16w
S=23.26w
Voc=18.15
Amperes
Volts

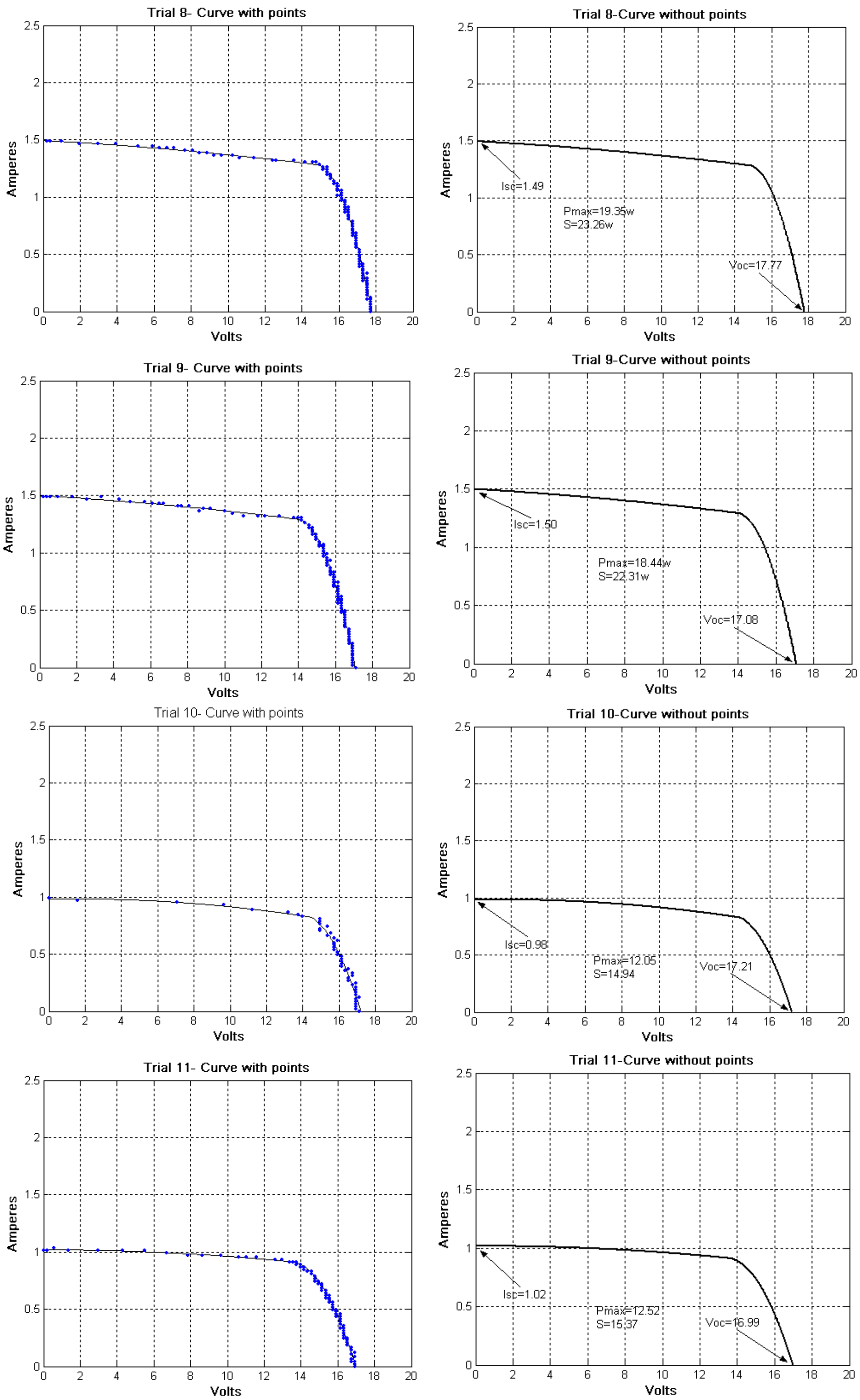


Figure 10 : I–V characteristic curves - 10 trials, with and without points – Include the values of P_{max} and S.

V(V)	I(A)	V.I(W)	V(V)	I (A)	V.I(W)
A= 15.94	2.04	32.60			
15.74	2.06	32.53	B= 18.30	0.02	0.37
15.54	2.08	32.44	18.30	0	0
15.35	2.10	32.35	18.10	0.02	0.37
14.95	2.12	31.83	18.30	0.04	0.75
14.360	2.12	30.57	18.30	0.08	1.51
13.38	2.14	28.75	18.10	0.10	1.87
12.59	2.16	27.32	18.10	0.12	2.24
12.00	2.19	26.29	18.10	0.16	2.99
11.61	2.19	25.43	17.90	0.26	4.81
10.82	2.21	23.93	17.90	0.33	5.92
10.43	2.23	23.27	17.71	0.35	6.22
9.84	2.25	22.16	17.71	0.43	7.68
9.44	2.25	21.27	17.71	0.47	8.41
9.25	2.25	20.83	17.90	0.51	9.25
8.65	2.29	19.85	17.71	0.61	10.97
8.06	2.29	18.50	17.51	0.68	11.94
7.47	2.31	17.30	17.51	0.72	12.66
6.88	2.33	16.08	17.51	0.78	13.75
6.10	2.35	14.37	17.51	0.80	14.11
5.51	2.37	13.09	17.31	0.86	15.02
4.72	2.37	11.22	17.31	0.92	16.10
3.93	2.39	9.43	17.31	1.03	17.89
3.14	2.41	7.61	17.12	1.09	18.74
2.55	2.43	6.23	17.12	1.13	19.45
1.77	2.45	4.35	17.12	1.21	20.87
1.37	2.45	3.38	16.92	1.28	21.68
0.78	2.47	1.95	16.72	1.36	22.81
0.39	2.47	0.97	16.92	1.40	23.77
0.19	2.47	0.48	16.72	1.46	24.54
0.19	2.47	0.48	16.72	1.54	25.92
0.19	2.47	0.48	16.53	1.61	26.64
0.19	2.47	0.48	16.53	1.67	27.66
0.19	2.47	0.48	16.53	1.71	28.35
0.39	2.47	0.97	16.33	1.79	29.36
0.19	2.47	0.48	16.33	1.88	30.71
0.19	2.50	0.49	16.13	1.94	31.34
0.19	2.47	0.48	16.13	1.98	32.00
0.39	2.50	0.98	15.94	2.00	31.94
			15.94	2.04	32.60

Table 4 : Experimental results for Trial 1. Measures of V(V), I(A) and V.I(W).