Comparison of First Order Differential Algorithm, Perturb and Observe (P&O) and Newton Raphson Methods for PV Application in DC Microgrid Isolated System

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***Abstract* — The necessary for energy always increases every year, so it is necessary energy alternative to overcome the phenomenon. From some alternative energy that is currently widely developed is solar energy. Unfortunately the use of solar energy with the help of solar panels produces power that varies according to the irradiation received and the temperature on the solar panel. Irradiation is the emission of energy coming from the sun. This parameter causes the output power characteristic curve to be non-linear. And the power generated by PV has not reached the maximum power point. To overcome this problem requires an arrangement to find the maximum power point and make it stable at that point. Therefore, this paper proposes "Comparison of First Order Differential Algorithms, Perturb and Observe(P&O) and Newton Raphson Methods for PV Application in DC Microgrid Isolated System" so that the maximum power point can be achieved quickly and accurately. In this paper we tried to compare 3 methods of First-order Differential, P & O (Perturb and Observe) and Newton Raphson by using ZETA Converter as its object in switching settings. By using the simulation can be obtained the results of tracking speed and maximum power level. The results of the simulation show that error power the First-order Differential is 4%, P & O is 0.26389% and Newton Raphson is 0.45178%. It is evident that Raphson's newton algorithm is superior to speed and accuracy.**

Keywords : Solar Panel, Maximum Power Point Tracking (MPPT), First-Order Differential, Perturb and Observe (P&O), Newton Raphson Method.

I. INTRODUCTION

Technological advances and industry growth make the demand for electrical energy growing every year. As we know, fossil fuels as the main source of power generation are very few. So much use of renewable energy to solve the problem. Solar energy is one of the energy that is currently being promoted its use because of its abundance. It takes solar panels to convert solar light energy into electrical energy. But the energy transfer generated by solar panels is still relatively weak. The solar cell output power is a nonlinear function against temperature and light intensity [1]. MPPT is one of the methods used to improve the effectiveness of energy harvesting using PV [2]. In Trishan's research, E (2007) described 19 MPPT algorithms including Hill Climbing, Perturb and Observe, Fuzzy Logic Control, Neural Network, ANFIS [3,4] etc. The MPPT algorithm can be used to trace the maximum power that photovoltaic can generate [5]. P&O is one of the most useful methods used. The power output from using this method is better than without using the tracking method.

II. SYSTEM DESCRIPTION

A photovoltaic cell is basically a PN semiconductor junction diode and this cell converts solar energy into electricity [6]. Generally, a PV module consists of 36 cells or 72 cells. In this system used PV with 100 Watt power as can be seen in table 1. Block diagram of the system used is shown in Fig. 1.

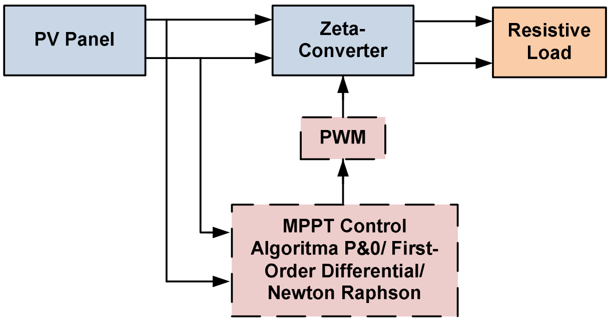

Fig. 1. Block Diagram of PV System

The output of the solar panel is a zeta converter input controlled by the algorithm to determine the exact PWM duty cycle to obtain the maximum power point.

A. Pv modelling

Photovoltaic is a tool that serves to convert or convert solar energy into electrical energy. The PV power output depends on sunlight irradiation and the temperature received by PV. The PV model is described as a simple circuit consisting of a current source representing a solar panel connected in parallel with the diode and two resistors as shown in Fig. 2. The mathematical expression of each cell are shown in equation 1 until 5.

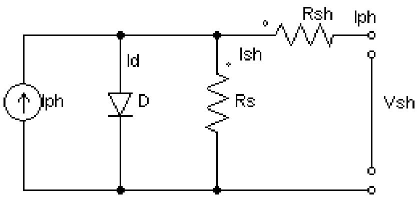

Fig. 2. The series of solar cell equations

$$I_L = I_{PH} - I_S\left(\exp\left(\frac{qVd}{AK_BT}\right) - 1\right) - \frac{(Vd)}{R_{sh}} \quad (1)$$

$$I_{PH} = \left(I_{SC} - K_1\left(T_c - T_{Ref}\right)\right)G \quad (2)$$

$$I_S = I_{RS}\left(\frac{T_C}{T_{Ref}}\right)^3 \exp\left[qE_g\left(\frac{1}{T_{Ref}} - \frac{1}{T_c}\right)/K_BA\right] \quad (3)$$

$$I_{RS} = \frac{I_{SC}}{\left[\exp\left(\frac{qV_{OC}}{N_SKAT_C}\right) - 1\right]} \quad (4)$$

$$I_L = N_pI_{ph} - N_pI_s\left[\exp\left(qV/N_sKT_cA\right) - 1\right] \quad (5)$$

Where

I_{PH} Photo-current
I_L Current at the output terminal
I_S Saturation current of the diode
I_{RS} Reverse saturation current
T_C Cell working temperature
T_{ref} Reference temperature
R_{RS} Series Resistance
K Boltzmann's Constant (1.3806.10-23 J.K-1)
Vd Voltage of diode
G Solar Insolation
q Electron charge

The above equations 1 to 5 are used in simulations using the PSIM software to obtain the characteristics of the solar cell output, as shown in Figures 3 and 4. This curve shows that the characteristics of the solar cell output are nonlinear and strongly influenced by solar radiation and temperature. In general, there is a maximum point on the V-I curve or the V-P curve, called Maximum Power Point (MPP). Where on at that point, solar cells work at maximum efficiency and produce the most output power. The corresponding values for voltage and current in each maximum power are called Vmp and Imp [7].

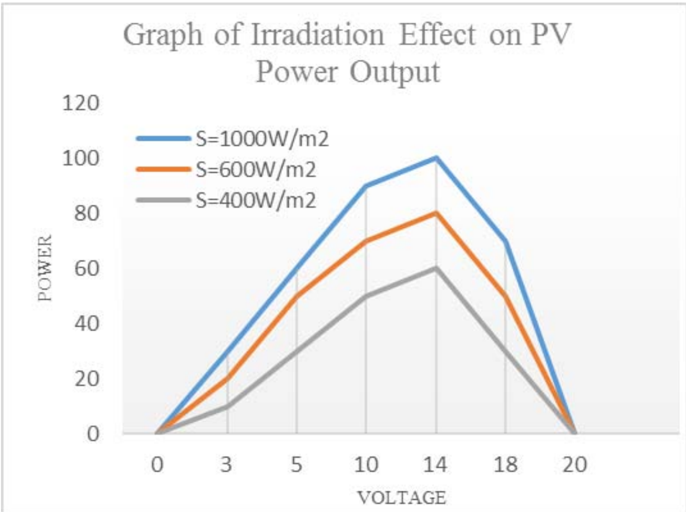

Fig. 3. Graph of Irradiation Effect on Power

Fig. 3 shows the effect of irradiation on power and output voltage of solar cell. The larger the irradiation makes the solar panel output power bigger.

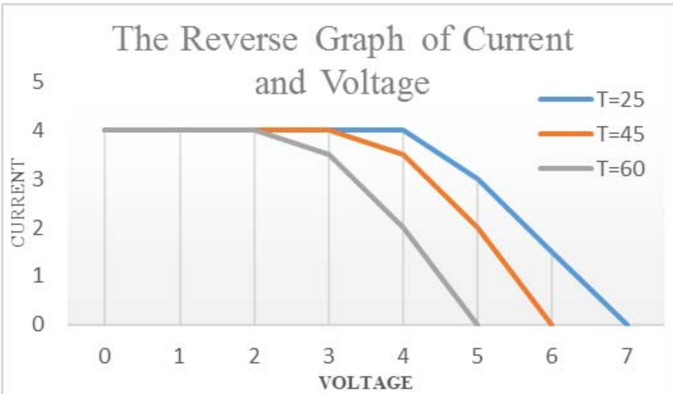

Fig. 4. The Reverse Graph of Current and Voltage

While in Fig. 4 shows the effect of the surface temperature of solar cells on curve IV. When the irradiance is kept constant at 1000 W/m^2 and temperature varies from 25°C to 60°C. With the increment in the temperature short circuit current increases but the open circuit voltage of cell decreases.

So the I-V characteristics shift to the left to previous curve. Power output of cell is also decreased [8].

B. The P & O Method

As it is known that the characteristics of solar cell output power are influenced by solar radiation and surface temperature of solar cells, an algorithm is needed to find the maximum power point (MPP) and maintain at that point of work. P & O is also called the hill climbing method [5], which refers to the V-P characteristics of the solar cells. As in Fig. 3. Flowchart of this algorithm as follows:

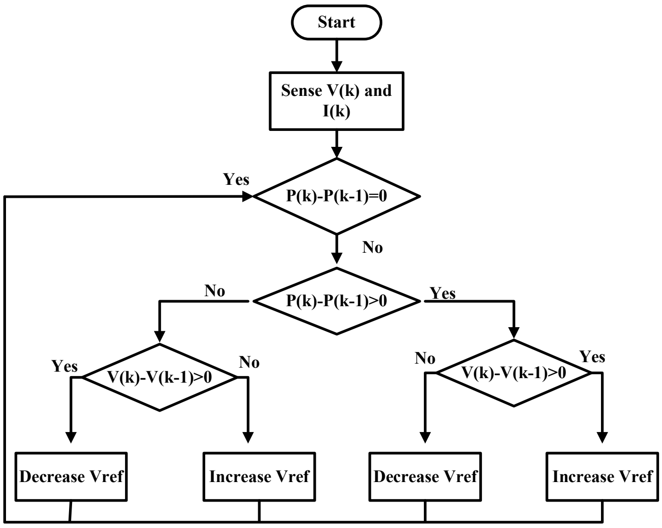

Fig. 5. Perturb and Observe Algorithm

From this flowchart the algorithm starts by measuring the voltage V (k) and current I (k) to obtain P (k). Perturb d (V) is given to observe the output power value P (k). The value of P (k) is then compared with value of P (k-1). If the value of P (k) is greater than P (k-1) it can be concluded that the perturb value performed is correct. Conversely, if the value of P (k) is smaller than P (k-1) then perturb should be done in the reverse direction. Thus the value of Maximum Power Point (MPP) can be obtained.

C. Newton-Raphson Algorithm

Newton method is one method to approach the equation of f(x) 0 = iteratively. The Newton Raphson method uses a starting derivative and its derivative value for subsequent gain. This method is based on the linearization of nonlinear equations and solving yields repeated linear equations [9]. In Newton Raphson's method we determine the value of almost the initial root of the so-called x0 and then determine the value of x1, x2, ...xn where the value of xn is a value almost closer to the true root value (exact solution). The value of xn is obtained by the formula

$$x_n = x_{n-1} - \left(\frac{f'(x_{n-1})}{f'(x_{n-1})}\right) \qquad (6)$$

The closer the initial value to the true root value the faster convergent. The calculation process can be based on absolute difference, relative error, or maximum iteration. The calculation process can be stopped when the known error is smaller than the error in the calculation or has reached the maximum iteration.

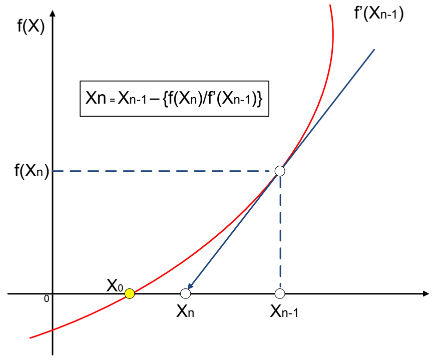

Fig. 6. Iteration Graph of Newton Raphson Method

The proposed method using a Newton Raphson variable, will allow us to compute the current Ipv with the initial value $x^{(0)}$ = I_{ph} as shown in Fig. 7.

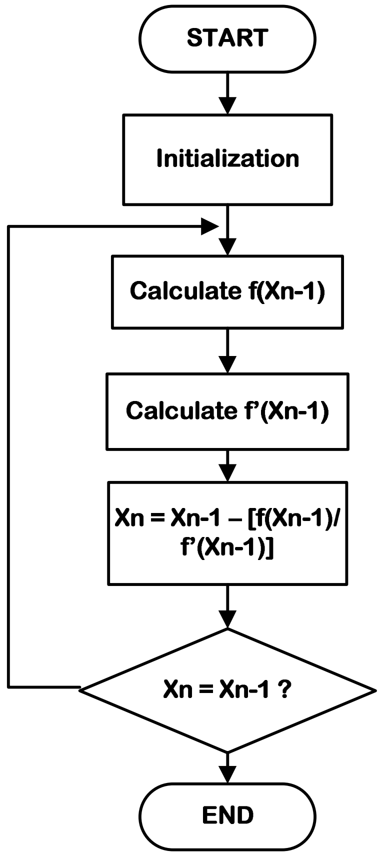

Fig. 7. Flowchart of The Proposed Method

From the flowchart in figure 7 used to get the highest point of the P-V chart. By initializing the current and the output voltage of the solar panel will be obtained solar panel output power. Formula $x_n = x_{n-1} - \left(\frac{f(x_{n-1})}{f'(x_{n-1})}\right)$ will iterate repeatedly until it gets the highest point of output power of the solar panel.

D. ZETA CONVERTER

Fig. 8 is an image of the Zeta converter topology. Due to a single switch, this converter has very good efficiency and offers boundless region for MPPT [9][24-25]. This converter is operated in continuous conduction mode (CCM) [26] resulting in a reduced stress on its power devices and components. The Zeta converter consists of a Mosfet as a switch, a diode, two capacitors, two inductors and a load. In Zeta converter there are two state circuit in one switching period. The first is when the switch is in conduction condition (ON), and the second is when the switch is in the condition of not conduction (OFF). In the first state, the inductor L1 and L2 are in charge energy phase, the second state inductor L1 and L2 releases the previously discharged energy (energy discharge) energy. The energy that has been released from the L1 inductor is used to charge the capacitor C1, while the energy from L2 is transferred to the load.

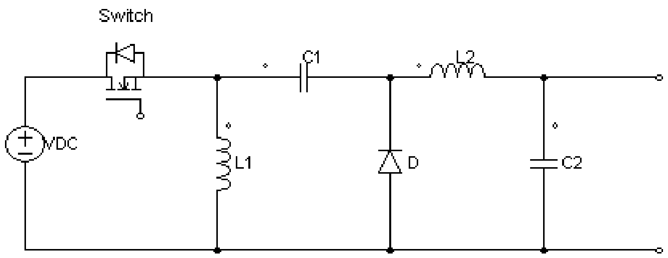

Fig. 8. Zeta Converter

$$V_0 = \frac{D}{D-1} \tag{7}$$

$$L_1 = L_2 = \frac{Vin \ x \ D}{\Delta IL \ x \ Fs} \tag{8}$$

$$C_1 = \frac{Iout \ x \ D}{Vout \ x \ Fs} \tag{9}$$

$$C_2 = \frac{Iout \ x \ D}{Vout \ x \ 0.8 \ x \ Fs} \tag{10}$$

Switching used is 40 KHz. By using high frequency the output signal from zeta converter will be smoother compared to buck-boost converter. Table I shows the specifications of the zeta converter used in the simulation according to calculations using equations 7 to 10.

TABLE I. PARAMETER SPECIFICATION AND DESIGN

Parameter	***Symbol***	***Value***	***Unit***
Input Voltage	Vin	21.2	V
Switching Frequency	f	40	KHz
Output Voltage	Vo	15	V
Rated Output Power	Po	100	W
Current Ripple	ΔIL	0.1	%
Voltage Ripple	ΔV_c	2	%
Inductor 1	L1	170	uH
Inductor 2	L2	170	uH
Capacitor 1	C1	1640	uF
Capacitor 2	C2	2300	uF

III. RESEARCH AND DISCUSSIONS

A. System Design

The proposed system is the search for MPP points using several different algorithms, namely P & O, First-order Differential and Newton Raphson. These three methods have the same level capabilities so that the most accurate and fast algorithm is obtained in the search for MPP points on solar panels. This MPPT uses a zeta converter. Solar panel specifications are shown in Table II.

TABLE II. SOLAR PANEL SPECIFICATIONS

Item	**Value**
Nominal Maximum Output (Pin)	100 W
Nominal Open Circuit Voltage (Voc)	21.2 V
Nominal Short Circuit Current (Isc)	6.46 A
Nominal Maximum Output Voltage (Vmpp)	17.1 V
Nominal Maximum Output Current (Impp)	5.84 A

Table II is a specification of the solar panels used in this paper. It is expected that the output power is always maximum 100 W with Vmpp 17.1 Volt and Impp 5.84A.

B. Simulation and Results

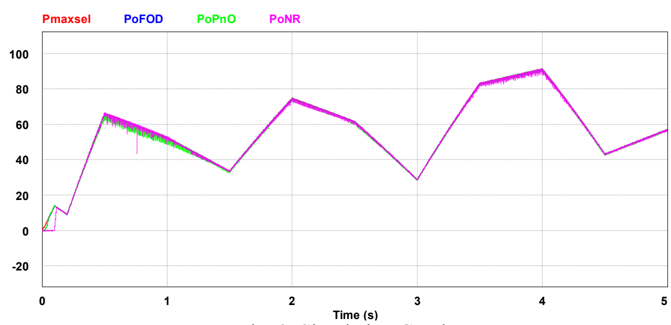

Fig. 9. Simulation Graph

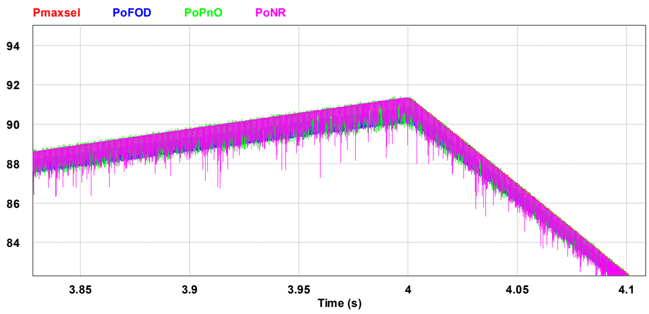

Figure 10. Graph of Simulation On Peak Shoot

The simulation data was taken by making irradiation changes 12 times and a constant temperature of 25ºC. Irradiation is given with varying values to determine whether the method applied is able to follow the changes in irradiation given. Figure 9 shows that the simulated First-order Differential, P & O and Newton Raphson method is able to follow the change of power according to the solar panel output. Figure 10 shows in detail the value of peak power from the use of these three methods. It can be seen that all three methods have different output power ripples. The P & O method has the largest output power ripple compared to the First-order Differential method and Newton Raphson. This can be affected by the value of the variable used to increase or decrease the value of the zeta converter duty cycle. With a large variable value, the ripple is large enough to be less accurate but fast in achieving maximum power. Whereas with a small variable value will be more accurate so that the power ripple is also small but requires a long time to reach the maximum power point of PV. The use of the First-order Differential and P & O methods has an output power value that is almost the same but lower compared to the Newton Raphson method. The similarity of power between the First-order Differential and P & O methods cannot be separated from the influence of the program between the two because in accordance with the flowchart program the First-order Differential and P & O methods are also almost the same. While the use of Newton Raphson method has the largest output power so that it approaches the maximum output power of solar panels. The output power values from the application of the P & O method, First-order Differential and Newton Raphson are presented in Table III.

TABLE III. COMPARISON OF POWER OUTPUT ACCURACY RATE OF PV

Irradiation	**The Power of PV**			
	The Maximal Power of PV	***First-order Differential***	***P&O***	***Newton Raphson***
0	0	0	0	0
100	95.906763	94.87394	95.76175	95.72824
300	29.38648	29.38684	29.41071	29.34592
350	34.0697	34.06901	33.92645	34.06944
450	43.35609	43.34881	43.2278	43.35646
550	52.308009	52.28332	52.20914	52.29478
600	56.96502	56.99589	56.99421	56.86321
650	61.65181	61.61213	61.51994	61.5755
700	65.60733	65.55677	65.39567	65.59921
800	74.35686	74.08333	74.25765	74.36466
900	83.26597	82.64179	83.33411	83.3357
1000	91.16	90.09459	90.52474	90.74816

TABLE IV. COMPARISON OF ERROR VALUE

Irradiation	**% Error Power of PV**		
	First-order Differential	***P&O***	***Newton Raphson***
0	0%	0%	0%
100	1.07690%	0.15120%	0.18614%
300	0.00123%	0.08245%	0.13802%
350	0.00203%	0.42046%	0.00076%
450	0.01679%	0.29590%	0.00085%
550	0.04720%	0.18901%	0.02529%
600	0.05419%	0.05124%	0.17872%
650	0.06436%	0.21389%	0.12378%
700	0.07706%	0.32262%	0.01238%
800	0.36786%	0.13342%	0.01049%
900	0.74962%	0.08183%	0.08374%
1000	1.16873%	0.69686%	0.45178%
Average %Error Power of PV	4%	0.26389%	0.12120%

Table III shows the output of the solar panel in each given irradiation. PV power is the maximum power of solar panels compared to PV power using the First-order Differential, P & O and Newton Raphson methods. Almost the same value (approaching) between PV power and power usage of these three methods shows that the use of the method is able to follow the maximum output power of PV. Table IV shows the error value of the power output obtained from the difference between the PV power output power and the use of the three methods. As long as the percent error data from the First-order Differential method is obtained 4%, P & O is 0.26389% and Newton Raphson is 0.12120%. So it can be seen that the use of Newton Raphson method has a smaller error compared to the First-order Differential and P & O methods.

IV. CONCLUSIONS

From the Comparative study the First-order Differential, Perturb and Observe and Newton Raphson Algorithm methods on MPPT-Zeta obtained PV power output data with the three methods applied which is close to the maximum value of PV output power. So that shows that all three methods can be used in finding Maximum Power Point Tracking. Among the First-order Differential, P & O and Newton Raphason methods each has advantages and disadvantages as described above. However, it can be concluded that the Newton Raphson method has the best accuracy and speed in achieving maximum power PV. This is intended by using the Newton Raphson method to have the power output that is closest to the maximum PV power with the smallest power error value compared to the First-order Differential and P & O methods. As with simulation data where the First-order Differential method has a power error of 4%, P & O is 0.26389 & Newton Raphson has only a power error of 0.12120%.

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