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Knee Point Power Equation Tracking of MPPT using Lagrange Interpolation

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Abstract:
A Solar Photovoltaic system normally requires the mechanism to regulate and absorb the maximum energy from the sun without fluctuations and disturbances. In this method, new algorithm is formulated for the tracking mechanism of the MPPT using the Knee Point graph of the Photovoltaic system. Maximum Power Point is at the voltage level corresponding to the Knee point in the VI characteristics of the PV system. Thus by deriving the polynomial equation of set of the Knee points for various intensity values is made. Here the Lagrange Interpolation technique is used for the calculation of the polynomial equation from the tabulated readings. The tracking and regulation of the MPPT is obtained easily by comparing the instantaneous power value and the Knee Point Power Equation directly. Instantaneous Power is power dependent on the load and it is checked with the range value from Knee point power equation. The MPPT point is traced by increasing or decreasing the voltage by Power converters to the desirable maximum power value. Output analysis is made through the Scilab Software. Efficiency, Power Regulation and speed of the MPPT tracking is maximized by this method.

Keywords: Maximum Power Point Tracking (MPPT), Knee Point Power Equation Tracking, Lagrange Interpolation, Mathematical model of MPPT, Interpolation technique.

I.INTRODUCTION

In the current day trend, the generation of the power using the renewable energy has been increased due to the largest Demand in the world. One of the greatest solutions to these problems is to shift towards the solar energy. Energy from the sun is abundant and it is available throughout the year. There are basically three main factors affecting the efficiency of the Solar Power. They are listed as follows

1. Illumination: The Illumination is the main factor for the generation of the solar Power. It is the irradiation of the sun. Effective mechanical tracking such as single axis or dual axis tracking can solve this.

2. Temperature: As the temperature increases the efficiency of the panel decreases. Thus the temperature of the panel must be reduced. Use of the water cooling with the Peltier can solve this issue.

3. Load Characteristics: This is the factor depending on the maintaining the correct voltage of the panel for the maximum power delivery using the Power converters. MPPT techniques come under this. MPPT is all about tracking of the Maximum Power Point from the VI characteristics of the Solar PV Cell. This involves mainly the algorithm to track the Maximum Power Point. Basically there are many algorithms for the MPPT. Some of the most common are as follows.

1. Perturb and Observe (P&O)
2. Incremental Conductance (InC)
3. Fractional open-circuit voltage (FOCV)
4. Fractional short-circuit current (FSCC).

These MPPT techniques are classified into Direct and Indirect methods. P&O and InC come under the direct method as they keep directly tracking the MPPT point from the Solar panel. The main draws backs are that they keep on oscillate around the MPP region and the construction is complex. Indirect method consists of the FOCV and FSCC. They are simple method of the MPPT as the constant value is being multiplied to the open circuit voltage in FOCV and in FSCC constant value is multiplied to the short circuit current value.

Thus the efficiency is low in the indirect method. There are also many such type of MPPT tracking methods in addition to these. Each of the method solves the drawbacks of the previous methods. In this Knee Point method of MPPT tracking, draw backs of the both direct and indirect methods are corrected. As this method of the algorithm needs the solution of two polynomial equations, the oscillation around the maximum power point is absent and the efficiency is improved. The analysis and the outcomes of this method described in the upcoming pages.

II. KNEE POINT IN VI CHARACTERISTICS OF THE PV CELL

The VI characteristics of the Solar panel are measurement of the Voltage against the Current for the change in the value of the resistor. There are different readings obtained for the various levels of the irradiation of the sunlight. Thus the readings at different timing of the day are noted.

The graph is drawn for the VI characteristics of the Solar panel. The Maximum power is obtained at the *knee point* of the graph. The slop of the graph is increasing till it reaches the knee point and it suddenly starts decreasing from that point. It is the transition point in the VI characteristics of the solar panel at that instance of the particular irradiation. Thus this knee point is the maximum power point for that irradiation level.

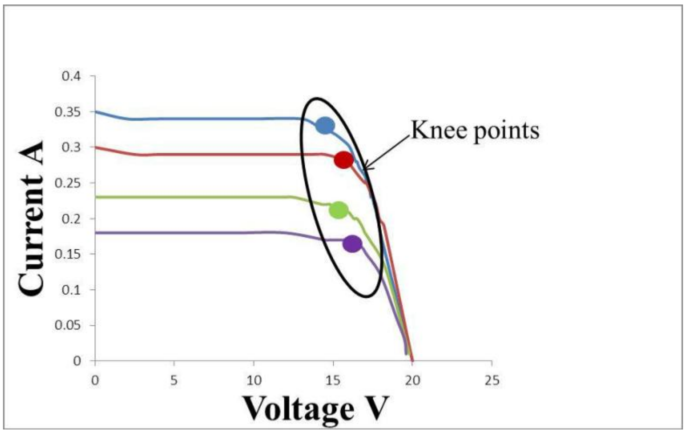

Figure.1. VI Characteristics and Knee points Plotting

In this graphical representation, the marked points represent the knee point in the VI characteristics of the solar panel. It can be observed that the knee point is unique for each and every irradiation levels.

III. FORMATION OF THE LAGRANGE KNEE POINT POWER EQUATION

A. Maximum Power Calculation

The reading of the panel for the various resistance values are noted and power at each instance is measured by multiplying the voltage and current at that instance. As the output of the solar panel is DC, the calculation does not involve the consideration of the power factor and the power angles Thus for finding of the power the formula used is

$$Power\ W = Voltage\ V \times Current\ I$$

From the calculated power for all the values of the readings, the value of the maximum power value is marked and noted for each irradiation values. The maximum power and the voltage corresponding to that are noted.

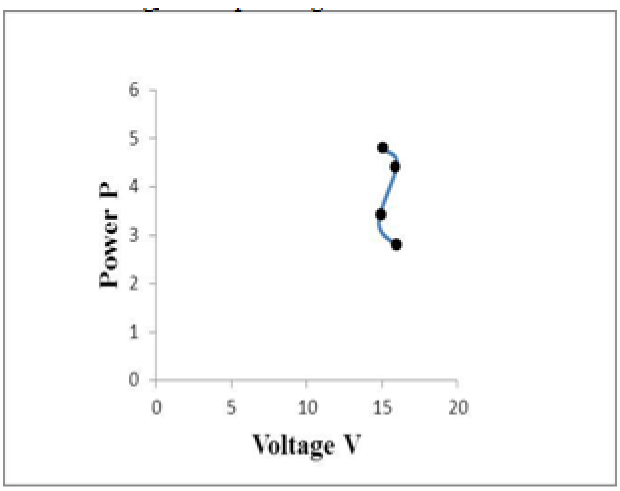

Figure.2. Tracing of the Maximum Power points (ie Knee Points) and corresponding voltages

B. Derivation of the equation for the Knee Point Graph

The graph is drawn using the obtained maximum power values and the corresponding voltage values. The equation for this graph is formulated using the Lagrange Interpolation technique. Lagrange Interpolation: It is considered as the one of the most simple and efficient method to formulate the polynomial equation for the set of points or from the graph. The formula of the Lagrange interpolation is given as follows

$$P(x) = \frac{(x-x_2)(x-x_3)\dots(x-x_n)(y_1)}{(x_1-x_2)(x_1-x_3)\dots(x_1-x_n)} + \frac{(x-x_1)(x-x_3)\dots(x-x_n)(y_2)}{(x_2-x_1)(x_2-x_3)\dots(x_2-x_3)} + \cdots + \frac{(x-x_1)(x-x_2)\dots(x-x_{n-1})(y_n)}{(x_n-x_1)(x_n-x_2)\dots(x_n-x_{n-1})}$$

Thus by substitution of the known values, the corresponding required polynomial equation for the power plotted at the knee points is obtained. This is termed as the Knee point Power equation of the Solar panel.

IV. KNEE POINT POWER EQUATION TRACKING OF MPPT ALGORITHM

A. Formulation of the knee Point Power Equation

The VI characteristics graph is made and the corresponding knee points were recorded. From the knee points of the solar panel, the corresponding polynomial equation is formed using the Lagrange Interpolation for the Knee point power and the voltage values. Thus with the polynomial equation of low order of Voltage is obtained. Power for each and every voltage can be obtained by the simple substitution. Example polynomial equation with the power and voltage Here P,v represents the Power and the voltages.

$$P_{KP} = av^3 \pm bv^2 \pm cv \pm d$$

B. Determination of the Instantaneous Power

The Instantaneous Power is one where the power consumed by the electrical load. The power is measured as the multiplication of the Instantaneous Current and the Voltage from the PV panel. For the instant if the value of the voltage is v and the current passing through is i, then the value of the Power is given as follows

$$P_{inst} = v \times i$$

C. Equating of both Power values

The Power values from the knee point power equation and the Instantaneous power values are equated. There are possibly 2 conditions. They are as follows.

Case 1: $P_{KP} = P_{inst}$
In this case if the knee point power is equal to the instantaneous value of the power calculated, the voltage correspondingly is present in the Maximum Power Point region.

Case 2: P_{KP} P_{inst}
In this condition, the value of the Power from the knee point graph is greater or lesser when compared to the instantaneous value of the power. Thus the power obtained lower when compared to the maximum obtainable power value. Then the value of the voltage has to be varied within that knee point range till the value of the power obtained equals.

D. Determination of the Voltage range

The voltage range is determined depending on the approximate value range of the voltages from the knee Point Power graph. The values of the voltage are varied within this set of range to obtain the stable and fast operation of the tracking. The graphical representation of the set of the voltage range is as follows.

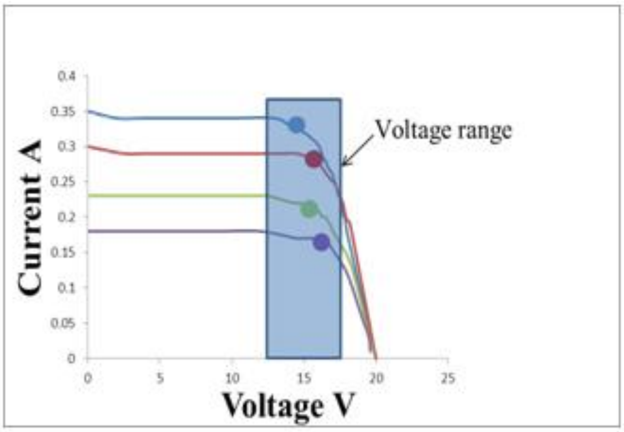

Figure.3. Range of the voltage in the VI graph

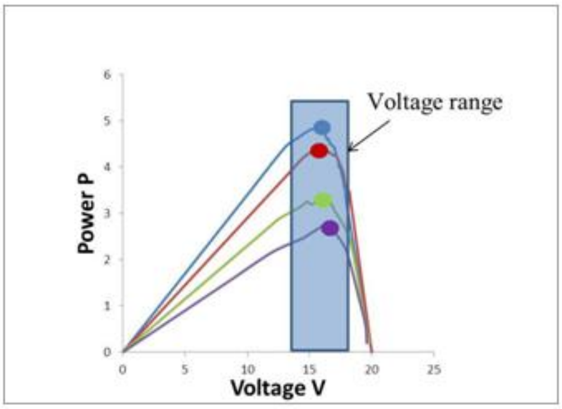

Figure.4. Range of the voltage in the PV graph

Thus from the both the graphs it can be noticed that the range value of the voltages are same in both the cases of the graph. The voltage value is varied at the small step value if the instantaneous power value and the Knee point power value are not equal. Voltage is incremented in the small step sizes of deltaV(V) till both the power values are equal. For P KP P inst value of the Voltage is varied

$$V_{next} = V \pm \Delta V$$

Till it reaches P KP = P inst

E. Block Diagram of the System

The functional Block diagram of the system is same as that of the Normal MPPT scheme with the Power DC-DC converters connected directly to the DC load or to the Inverter and AC load or Grid. In addition to these Power devices, the voltage and current has to be sensed which is delivered to the load.

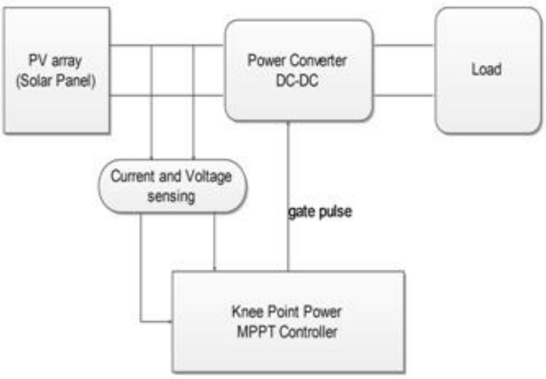

Figure.5. Block diagram of the Knee Point Power MPPT System

F. Flow chart

The flow chart of the system is as follows

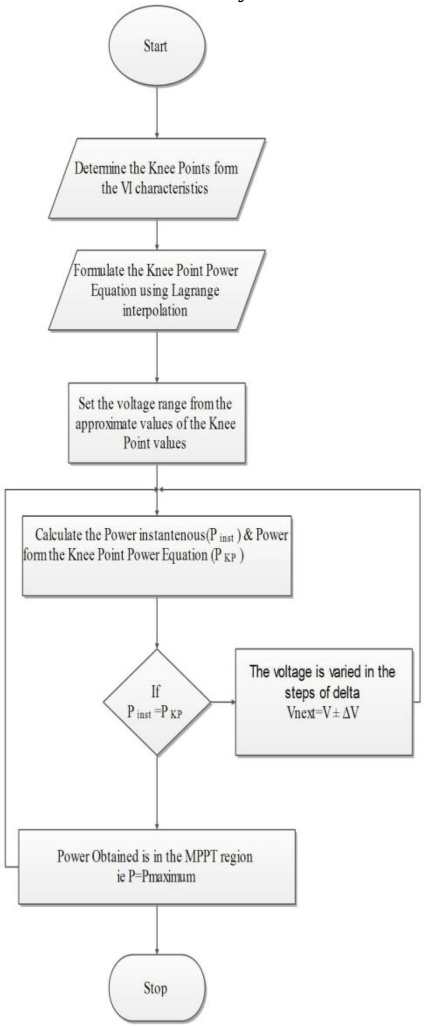

Figure.6. Flow Chart of the System

V.EXPERIMENTAL RESULTS

A. Readings

The readings corresponding to the maximum power points and the voltage values obtained from the set of readings of the VI Characteristic for the various intensity levels of the PV system. Table 1

S.NO	LUX (LX)	VOLTAGE (V)	CURRENT (A)	POWER (W)
1	173000	15.18	0.32	4.8576
2	122000	16	0.28	4.48
3	90000	14.8	0.22	3.256
4	75000	16.1	0.17	2.737

B. Graphical Representation

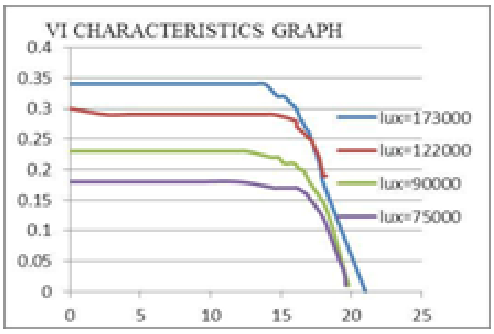

Figure.6. the Graph Showing the VI Characteristics of the solar panel for the various intensity values.

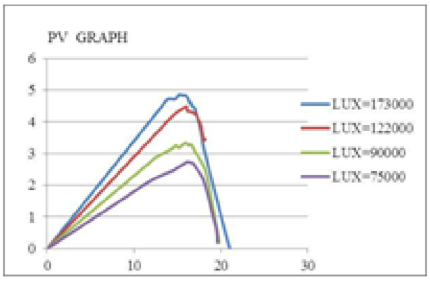

Figure.7. the graph showing the P vsV of the solar panel for the various intensity values.

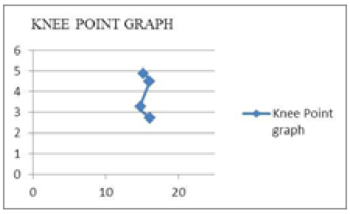

Figure.8. The graph joining the Knee Point at the maximum power point values.

C. Simulation of the Lagrange equation

The knee point power equation is simulated using the Lagrange Interpolation using the SCILAB software. The equation obtained is as follows.

$P=39295.236 -7761.7305x +510.6945x^2 -11.191616x^3$

This equation is the required knee point power equation using Lagrange Interpolation.

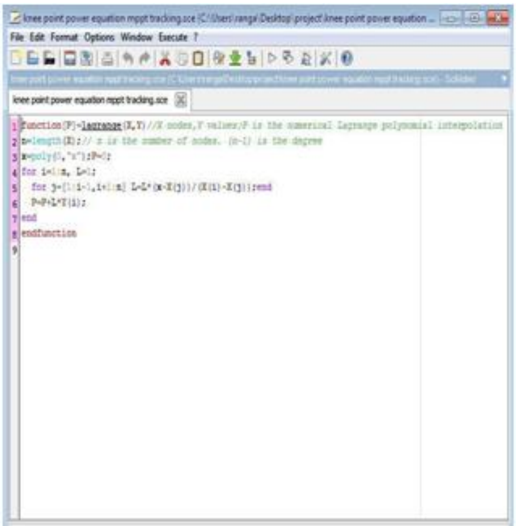

Figure.9. Simulation of the Equation in the Scilab program

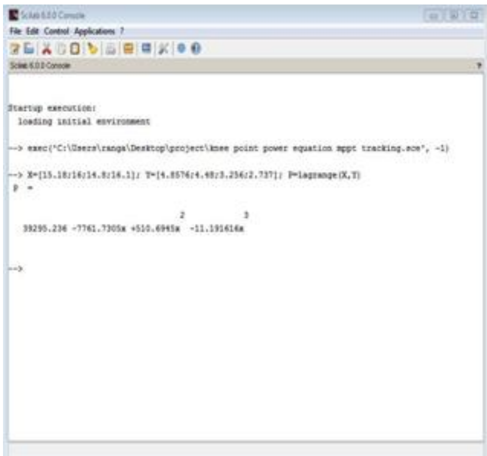

Figure.10. Simulation Output in the Scilab

VI. CONCLUSION

A Knee Point Power Equation Tracking method is the simple and the effective means of tracking the MPPT. This proposed solution can ensure the very fast tracking. For the effective varying of the step voltage can be made as in any other algorithm such as P&O or can be taken any approximate delta value. Further the knee point equation can be simulated for the various Wattages of the Solar panel in the microcontroller and for each wattage is made as separate mode of operations. The temperature is made constant for the whole experiment at 45°C .Thus for the various temperature ranges; the polynomial equation is generated using the high level languages. The prediction of the Temperature value depending on the location and date is made using the current day technology with the simple use of Internet. Thus simply can be linked to the IOT device, the prediction of the MPPT becomes so simple, fast and very accurate.

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