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Optimising power of PV module using modified MPPT for standalone load

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ABSTRACT

The maximum power point tracking (MPPT) has been common terminology among the researchers for those who deal with solar energy. A lot of techniques involving MPPTs have been investigated, evolved and proposed by researchers. But those techniques have got some advantages and suffer from limitation to some extent. The gravity of limitations varies from case to case. In current work, it has been investigated the MPPT based Boost Converter without and with MPPT which is perturb and observe (P&O) type. After observing its limitation, this method of MPPT is modified so as to make it suitable for extracting the maximum power from PV unit at all different load conductance's. In order to validate this concept, the mathematical model is developed using a MATLAB/Simulink environment and this Modified MPPT technique is implemented. The whole model is simulated and compared with conventional method. This concept is quite new and the proposed one exhibits better performance as compared to conventional methods.

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1. INTRODUCTION

The boost converter is known as a prominent member in family of DC-DC converter having action similar to alternating current (AC) transformer (i.e., stepping up input DC voltage) but without any intermediate ac stage. The boost converter plays now-a-days an important role in extracting power from solar power unit. A photovoltaic (PV) cell is smallest unit of solar power generating unit and its basic characteristic (I~V) is mostly non-linear in nature. The modeling of PV cell is presented in [1], [2]. The estimation of parameters, which is required for modeling, is presented by authors in [2]. Since the boost converter is major component in solar power unit, so its comprehensive reviews are detailed and critically investigated [3]. The maximum power point tracking (MPPT) is common phenomenon among researchers in the field of solar technologies and the various techniques of MPPT are detailed and compared [4]. In this comparison, the positive aspects of each technique and its limitations are included. Out of these techniques, though some techniques are simple to implement but they differ from others in terms of complexities of implementations and performances. The researchers [5]–[10] have focused on design, simulation and implementation of solar photovoltaic system. These researchers focus both standalone load and grid connected system for solar PV system. Also the researchers [11] have investigated the issues of power quality associated with solar PV system. The application of solar based system associated with DC-DC converter is extended to water pumping system [12]. The multilevel inverter for power conditioning in wire distribution system using solar PV system is well documented [13]. The analog multiplier MPPT controller of solar PV-based dc power supply [14] is proposed for rural and islanded people. For better performances, the optimal performance for solar power systems are focused [15]. The comparative analysis for tracking maximum power under variable perturbations is demonstrated [16]. In order to have better utility, the researchers [17]–[27] have opined the approach of hybrid controller for tracking maximum power and later this is extended to microgrid standalone photovoltaic system.

In current research work, the perturb and observe (P&O) MPPT technique is investigated with details and its limitations are pointed out. So, a flow-chart is developed in order to overcome the problem and accordingly the MPPT technique is modified. The Simulink block is formulated and the complex logical thinking is embedded in state flow block of Simulink and the complete Simulink program is simulated to validate the justifications.

2. ANALYSIS OF PV MODULE

The mathematical model of PV cell is described by following equations:

i) The photo current is (1);

$$I_{ph} = [I_{sc} + k_i(T - 298)]G/1000 \tag{1}$$

ii) The saturation current is (2);

$$I_o = I_{rs}\ (T/T_n)^3\ \ exp[\frac{qE_{go}(1/T_n - 1/T)}{nK}] \tag{2}$$

iii) The reverse saturation current is (3);

$$I_{rs} = \frac{I_{sc}}{exp(\frac{q\,V_{oc}}{n\,N_s\,KT}) - 1} \tag{3}$$

iv) The output current is (4);

$$I = I_{ph} - I_d - I_{sh}$$

or

$$I = I_{ph} - N_p I_o [exp\{\frac{q(V+IR_s)}{nKN_sT}\} - 1] - \frac{(V+IR_s)}{R_{sh}} \tag{4}$$

v) The power is (5).

$$P = VI = [I_{ph} - N_p I_o \{exp(\frac{q(V+IR_s)}{nKN_sT}) - 1\} - \frac{(V+IR_s)}{R_{sh}}] \tag{5}$$

Where,

- Iph: photo-current (A), Isc: short-circuit current (A), T: temperature (degree kelvin)
- Tn: nominal temperature (degree kelvin) =298, G: solar irradiation (W/m^2)
- q: electron charge (C)=1.6e-19 coulomb, V_{oc}: open-circuit voltage (V)
- n: Ideality factor of the diode = 1.3, ki: short circuit coefficient of the cell (A/0K)
- 25 degrees centigrade and at G = 1000 W/m^2) = 0.0032, K: Boltzman's constant = 1.38 e-23
- Ego: Band gap energy of the semiconductor (eV) =1.1, Ns: number of cells in connected in series of a module
- Np: No of PV modules connected in parallel, Rs: series resistance (Ω)
- Rsh: shunt resistance (Ω)
- The parameters of a specific PV module are taken into consideration for analysis and investigation.
- Isc: 8.21 A, ki: 0.0032, V_{oc}: 32.09, Ns: 54. Np: 1, Rs: 0.22 Ω, Rsh: 415.41 Ω, G<=1000 W/m^2.

Considering (4) and (5), the current and power curves with respect to voltage for different irradiation (i.e., symbolically represented as 'G') are shown in Figure 1 for a fixed temp. It shows that at a fixed temp, the open-circuit voltage (V_{oc}), the short-circuit current (I_{sc}) and peak power (i.e., indicated as dashed line) decreases with decrease in irradiation. At same time, it is observed that with significant reduction in irradiation, the voltage corresponding to maximum power (V_{mp}) remains more or less constant.

In Figure 2 the characteristic of power, current and load conductance ($Y=I_{pv}/V_{pv}$) of PV unit with respect to its terminal voltage (V_{pv}) without MPPT are shown. The load conductance 'Y' goes on decreasing from maximum towards zero with respect to gradual increase in terminal voltage of the circuit from zero to open-circuit condition (V_{oc}). The load conductance is reciprocal of load resistance. So higher load conductance leads to lower load resistance and vice-versa. With reference to peak power, there corresponds to current (I_{mp}), voltage (V_{mp}) and conductance (Y_{mp}). So Y_{mp} is the load conductance that corresponds to maximum power. Between peak power to open-circuit voltage (V_{oc}), the power falls drastically, as the conductance is tending towards zero. Similarly, between short-circuit position (i.e. v=0) to voltage corresponding to peak power (V_{mp}), there is gradual change in increase of power.

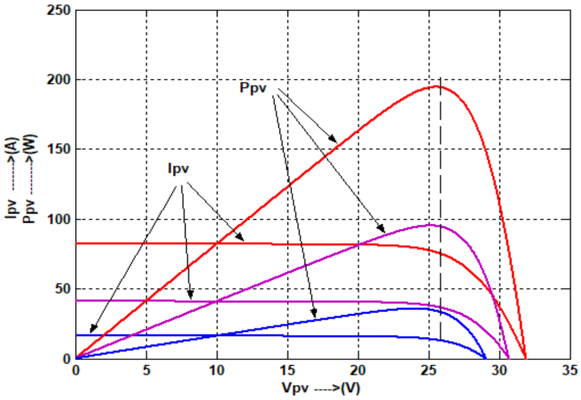

Figure 1. Curves of current and power with of PV unit at different irradiations (i.e.,1000, 500, 200 W/m^2), but with fixed temperature (T=30 ^{o}C), Scale: Ipv(1:10), Vpv (1:1), and Ppv (1:1)

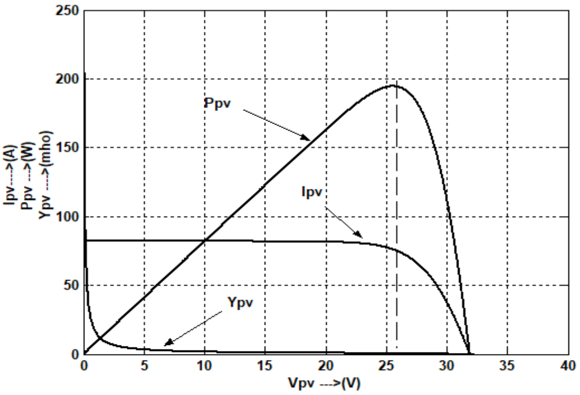

Figure 2. Curves of current, power and conductance with respect to voltage of PV unit at irradiation (G=1000W/m^2) and temperature (T=30 ^{o}C), Scale: Ipv(1:10), Vpv (1:1), and Y(1:10)

Out of two regions of Y, one is between Y=0 and Y=Y_{mp} and it is regarded as more or less constant current region, where the fall in current in this zone is quite small. Similarly, between region of Y (i.e., Y_{mp} to zero), it is regarded as constant voltage region, as the difference between V_{mp} to V_{oc} is significantly small (i.e., fall of voltage is comparatively small). Now there arises question that how dc-dc converter deals with such complex I~V characteristic of PV source (i.e. partly constant current source and rest close to constant voltage source) to maximize power to load.

The MPPT concept has been popular among the researchers since more than a decade in order to explore the possibility of maximizing power at different load. The researchers have evolved various techniques for tracking maximum power [4] and the review paper pertaining to this concept is illustrated. Though the various techniques have been evolved for MPPT, the most popular technique is P&OMPPT, which is being implemented by a few manufacturers of solar technologies. The findings from this method are quite interesting. So. a comparative approach between MPPT and without MPPT is narrated as follows. The data available with MPPT and without MPPT are presented in tabular form (Tables 1 and 2) respectively. Under without MPPT, the load conductance (Y_{mp}) corresponding to maximum power is 0.294 mho.

It is observed with MPPT that at different load, the voltage level across the load is increased beyond V_{mp} to raise the power. This raise of power in case of MPPT is more than that of without MPPT beyond V_{mp} for same load. On other hand, the power available with MPPT is lesser than that of without MPPT when the

V_{pv} is less than V_{mp}. The magnification of power in case of MPPT to without MPPT is presented in Table 1. On investigation, it is found that during constant current region (i.e., when $V_{pv}<V_{mp}$), the shunt inductor gets saturated and unable to boost up the input voltage. Not only that the power delivered under MPPT is less than those without MPPT. So, in order to explore maximization of power during this region, a new control strategy needs to be developed so that maximization of power is to be achieved under all load conditions (i.e., from V_{pv}=0 to $V_{pv}=V_{oc}$).

In Table 1the data pertaining to MPPT and without MPPT are combined together for comparison under different load conductances. The magnification of power in case of MPPT with respect to without MPPT is approximately equal to 1, when the load conductance 'Y' is 0.2 ℧. This value of Y at which the ratio of power without too with MPPT is unity is treated as Y_{cr} (i.e., known as critical conductance and value 0.2 ℧ approx. The value of Y_{cr} is less than Y_{mp} (i.e., 0.294 ℧) which corresponds to maximum power under without MPPT. So, when load conductance 'Y' is greater than Y_{cr}, the power amplification (i.e., ratio of power with MPPT to without MPPT) is less than unity. This happens mostly during constant current region of I~V characteristic. For $Y<=Y_{cr}$, the power amplification is either equal to or greater than unity.

Table 1.Comparison between with and without MPPT

Sl No.	Load conductanceY(℧)	Power with MPPTPo1(W)	Power without MPPTPo2(W)	Magnification=Po1/Po2
1	0.001	6.78	1.02	6.64
2	0.010	46.38	10.07	4.60
3	0.020	83.72	19.98	4.18
4	0.040	144	39.30	3.66
5	0.083	150	78.47	1.91
6	0.200	158	163.1	0.97
7	0.294	174	194.4	0.89
8	0.333	172	189.6	0.91
9	0.400	143	165.8	0.86
10	0.500	128	133.8	0.96
11	0.667	84.35	100.6	0.84

3. CONTROL STRATEGY

In order to overcome the problem arising out of constant current region of PV module, it is planned to avoid MPPT technique during constant current region (i.e., V=0 to V_{mp}) so that maximization power can be achieved during entire region of V_{pv}=0 to V_{oc}, conductance under MPPT and without MPPT. These graphs are shown in Figures 3 and 4 respectively, where Y_{mp}=0.294℧ that corresponds to maximum power without MPPT. But on comparison, it is observed that at certain load conductance, the power delivered is equal under both MPPT and without MPPT and this value of load conductance is known as critical conductance as discussed in previous section. So, in order to maximize the power delivered to load under both MPPT and without MPPT, the flexibility in control strategy is to be maintained in such a way that MPPT technique is modified so that it would extract positive aspects under both with and without MPPT at different load conductance's. Figure 5 (see Appendix) represents the flow chart of modified MPPT. Based upon this figure, the simulation model work is developed.

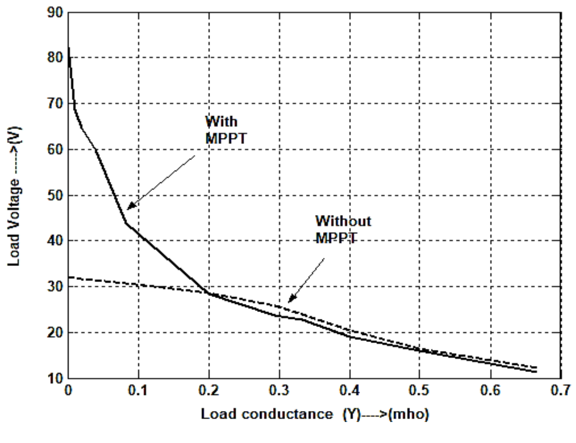

Figure 3.Variation of load voltage with load conductance under with and without MPPT

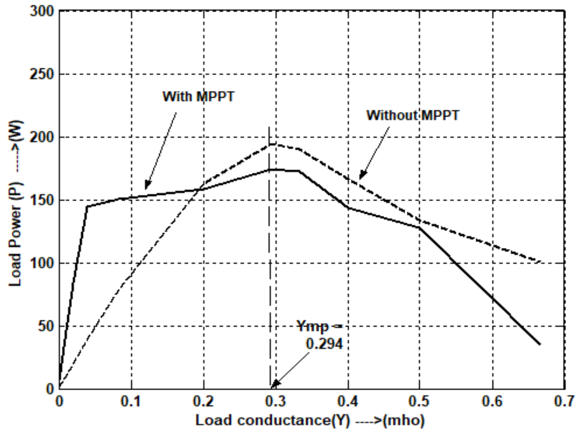

Figure 4.Variation of power with load conductance under with and without MPPT

4. SIMULINK MODEL

For implementation of control strategy, the complex logical thinking of modified MPPT is put into state flow block of Simulink. The complete scheme along with whole control strategy is shown in Figure 6. The modified MPPT is based upon P&O method.

4.1. Simulation result

For this Modified MPPT is based upon P&O scheme, load conductance (Y)) is considered for implementation. The load conductance is compared with its critical value (Y_{cr}) and its logical output is utilized to decide the operation of MPPT or not. From Figure 4, the critical load conductance Y_{cr} is found to be 0.2 mho (i.e., where power is equal with and without MPPT shown in Figure 4). When the load conductance 'Y' is less than 'Y_{cr}', the MPPT is activated, whereas for $Y>Y_{cr}$, the MPPT is disabled to extract maximum power. So,for different load conductance's (i.e., for $Y <Y_{cr}$ and $Y>=Y_{cr}$), the simulation is carried out and the result is given in Table 2. The values of load voltage, current and power at different load conductance's are presented in Table 2.

The data from Table 2 are represented in graphical forms shown in Figure 6. This shows the waveforms of load voltage, current and power across load with respect to variation in load conductance under Modified MPPT. Figure 7 represents output power variation with various load conductances under the concept of modified MPPT.

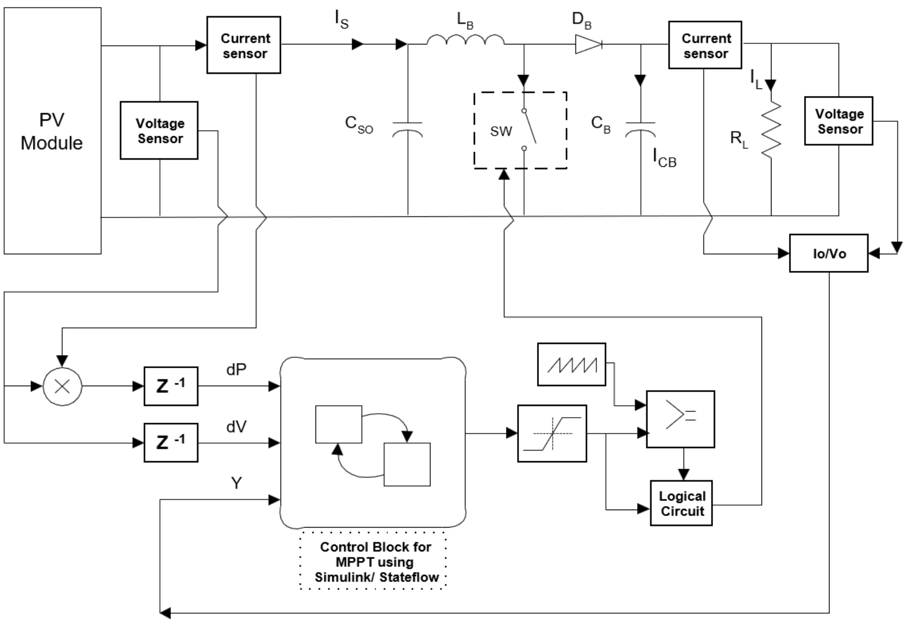

Figure 6. Modified MPPT for PV module for maximization of power using MATLAB

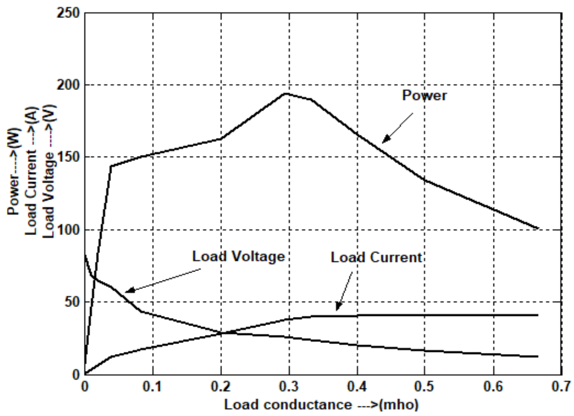

Figure 7. Variation of output power with respect to different load conductance's under modified MPPT

Table 2. Results from with modified MPPT

Sl No.	Load conductance Y (℧)	Vo(V)	Io(A)	Po(W)
1	0.001	82.43	0.082	6.78
2	0.010	68.47	0.677	46.38
3	0.020	64.7	1.294	83.72
4	0.040	60	2.400	144
5	0.083	43.8	3.425	150
6	0.200	28.56	5.712	163.1
7	0.294	25.71	7.563	194.4
8	0.333	23.85	7.951	189.6
9	0.400	20.36	8.144	165.8
10	0.500	16.36	8.179	133.8
11	0.667	12.29	8.192	100.6

5. CONCLUSION

A new concept of optimizing power from PV module is formulated and successfully implemented using MATLAB/ Simulink. Since the PV module possesses a complex I~V characteristic, so it is developed a special strategy to deal the situation based upon the requirement. The control strategy is modified in P&O-based MPPT so as to explore the maximization of power at different load conductance's by compromising between MPPT and without MPPT. In this modified P&O MPPT, it is required two pairs of voltage and current sensors. One pair of voltage and current sensor is to determine the parameter of load conductance, whereas other pair of voltage and current sensor is engaged in implementing MPPT. The proposed scheme does not need to determine the voltage corresponding to maximum power point, V_{mp} or conductance corresponding to maximum power point, Y_{mp}. Rather it needs determination of critical conductance (Y_{cr}), which is determined by correlating power vs load conductance from both with and without MPPT method. With determination of Y_{cr}, it is considered as boundary between activation of MPPT and deactivation of MPPT. Though the variation in irradiation is considered here between 300 to 1000 W/m^2 and temperature variation between 30 to 25 degrees centigrade, but significant effect on I~V characteristics is observed during change in irradiation. Such a scheme is only applicable where the stabilizing the output voltage is not a matter of is concern. The application of such scheme can be extended to water heater, battery charger, dc light load and for inhabitants in islanded area. The prevailing scheme provides simple solution whose control strategy can be implemented and made compact using internet of things or IOT based technology.

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APPENDIX

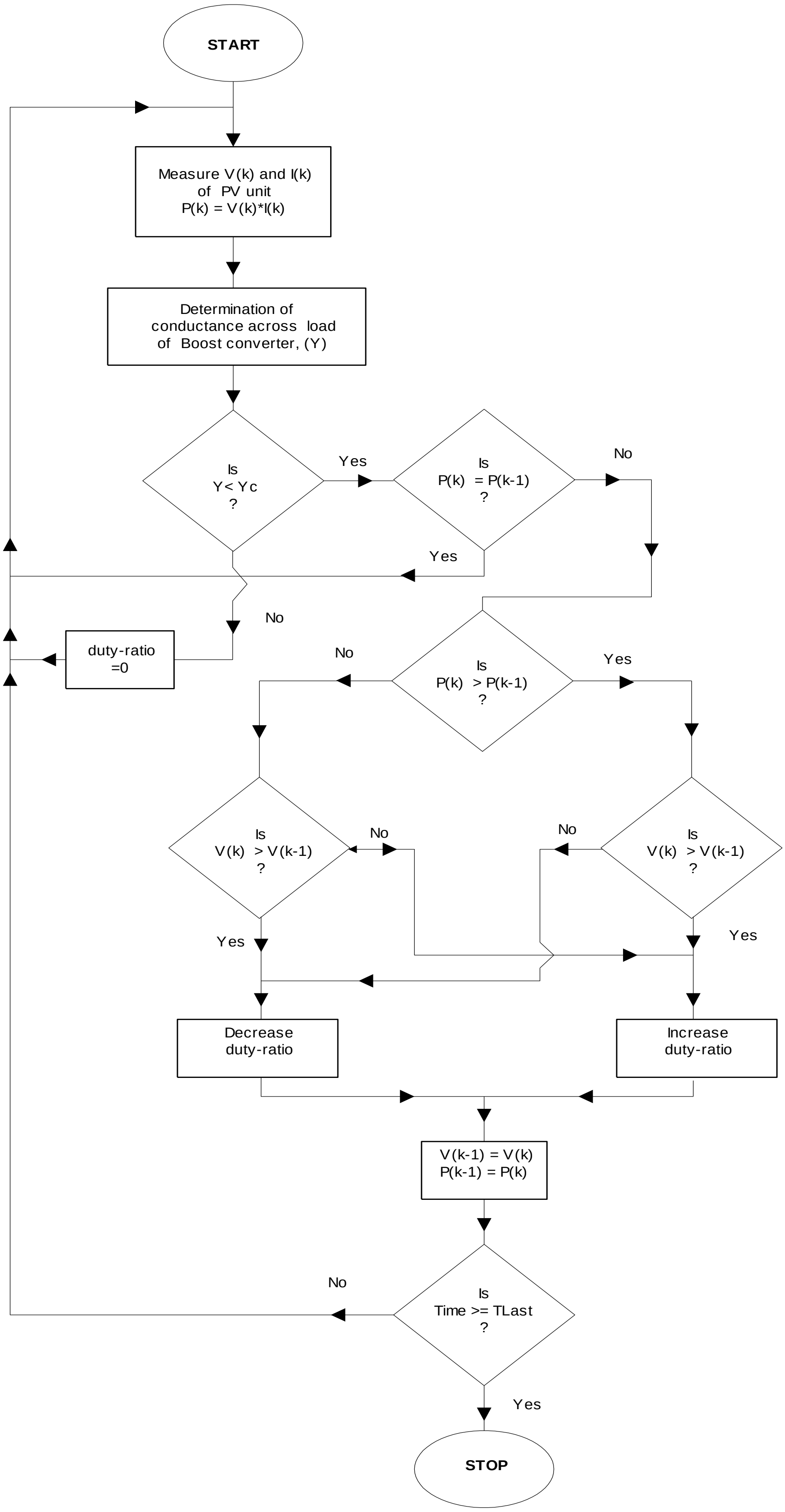

Figure 5. Flow-chart of modified MPPT

REFERENCES

[1] M. Forouzesh, Y. P. Siwakoti, S. A. Gorji, F. Blaabjerg, and B. Lehman, "Step-Up DC-DC converters: A comprehensive review of voltage-boosting techniques, topologies, and applications," *IEEE Transactions on Power Electronics*, vol. 32, no. 12, pp. 9143–9178, Dec. 2017, doi: 10.1109/TPEL.2017.2652318.

[2] S. G. Malla *et al.*, "Whale optimization algorithm for PV based water pumping system driven by BLDC motor using sliding mode controller," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 10, no. 4, pp. 4832–4844, 2022, doi: 10.1109/JESTPE.2022.3150008.

[3] S. Behera *et al.*, "Computation of maximum power point tracking of PV module using modified Newton Raphson technique," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 4, pp. 2478–2487, 2022, doi: 10.11591/ijpeds.v13.i4.pp2478-2487.

[4] J. Priolkar and A. Anvekar, "Design, simulation and implementation of solar PV based micro inverter," in *2016 - Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy, PESTSE 2016*, Jan. 2016, pp. 1–5, doi: 10.1109/PESTSE.2016.7516435.

[5] W. J. Praiselin and J. Belwin Edward, "Improvement of power quality with integration of solar PV and battery storage system based micro grid operation," in *2017 Innovations in Power and Advanced Computing Technologies, i-PACT 2017*, Apr. 2017, vol. 2017-January, pp. 1–5, doi: 10.1109/IPACT.2017.8245082.

[6] P. Vtas and Y. Pal, "Solar PV array buck-boost converter fed single phase induction motor drives for water pumping," in *IEEE International Conference on Information, Communication, Instrumentation and Control, ICICIC 2017*, Aug. 2018, vol. 2018-January, pp. 1–5, doi: 10.1109/ICOMICON.2017.8279090.

[7] M. Ghosh Majumder, P. Ranjan Kasari, B. Das, and A. Chakraborti, "Solar photovoltaic array based multilevel inverter for power conditioning in four-wire distribution system," in *Proceedings of the 3rd IEEE International Conference on Advances in Electrical and Electronics, Information, Communication and Bio-Informatics, AEEICB 2017*, Feb. 2017, pp. 193–197, doi: 10.1109/AEEICB.2017.7972410.

[8] S. S. Nag, S. Mandal, and S. Mishra, "Solar PV based DC power supply for rural homes with analog, multiplier-less MPPT controller," in *Proceedings IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society*, Oct. 2017, vol. 2017-January, pp. 2689–2694, doi: 10.1109/IECON.2017.8216452.

[9] A. Dash *et al.*, "Grid-tied distribution static synchronous compensator for power quality enhancement using combined-step-size real-coefficient improved proportionate affine projection sign algorithm," *Energies*, vol. 15, no. 1, p. 197, Dec. 2022, doi: 10.3390/en15010197.

[10] S. G. Malla *et al.*, "Coordinated power management and control of renewable energy sources based smart grid," *International Journal of Emerging Electric Power Systems*, vol. 23, no. 2, pp. 261–276, Apr. 2022, doi: 10.1515/ijeeps-2021-0113.

[11] B. N. Alajmi, K. H. Ahmed, S. J. Finney, and B. W. Williams, "Fuzzy-logic-control approach of a modified hill-climbing method for maximum power point in microgrid standalone photovoltaic system," *IEEE Transactions on Power Electronics*, vol. 26, no. 4, pp. 1022–1030, Apr. 2011, doi: 10.1109/TPEL.2010.2090903.

[12] M. Kumar Sahu, M. Biswal, and J. Mohana Rao Malla, "THD analysis of a seven, nine, and eleven level cascaded H-bridge multilevel inverter for different loads," *Tehnički glasnik*, vol. 14, no. 4, pp. 514–523, Dec. 2020, doi: 10.31803/tg-20180206150332.

[13] M. Nasir, H. A. Khan, A. Hussain, L. Mateen, and N. A. Zaffar, "Solar PV-based scalable DC microgrid for rural electrification in developing regions," *IEEE Transactions on Sustainable Energy*, vol. 9, no. 1, pp. 390–399, Jan. 2018, doi: 10.1109/TSTE.2017.2736160.

[14] B. Subudhi and R. Pradhan, "A new adaptive maximum power point controller for a photovoltaic system," *IEEE Transactions on Sustainable Energy*, vol. 10, no. 4, pp. 1625–1632, Oct. 2019, doi: 10.1109/TSTE.2018.2865753.

[15] Y. Shan, J. Hu, K. W. Chan, Q. Fu, and J. M. Guerrero, "Model predictive control of bidirectional DC-DC converters and AC/DC interlinking converters-a new control method for PV-wind-battery microgrids," *IEEE Transactions on Sustainable Energy*, vol. 10, no. 4, pp. 1823–1833, Oct. 2019, doi: 10.1109/TSTE.2018.2873390.

[16] S. Tang, Y. Sun, Y. Chen, Y. Zhao, Y. Yang, and W. Szeto, "An enhanced MPPT method combining fractional-order and fuzzy logic control," *IEEE Journal of Photovoltaics*, vol. 7, no. 2, pp. 640–650, Mar. 2017, doi: 10.1109/JPHOTOV.2017.2649600.

[17] F. J. Lin, K. C. Lu, and B. H. Yang, "Recurrent fuzzy cerebellar model articulation neural network based power control of a single-stage three-phase grid-connected photovoltaic system during grid faults," *IEEE Transactions on Industrial Electronics*, vol. 64, no. 2, pp. 1258–1268, Feb. 2017, doi: 10.1109/TIE.2016.2618882.

[18] A. Bidram, A. Davoudi, and R. S. Balog, "Control and circuit techniques to mitigate partial shading effects in photovoltaic arrays," *IEEE Journal of Photovoltaics*, vol. 2, no. 4, pp. 532–546, Oct. 2012, doi: 10.1109/JPHOTOV.2012.2202879.

[19] M. Dhimish, "Assessing MPPT techniques on hot-spotted and partially shaded photovoltaic modules: Comprehensive review based on experimental data," *IEEE Transactions on Electron Devices*, vol. 66, no. 3, pp. 1132–1144, Mar. 2019, doi: 10.1109/TED.2019.2894009.

[20] S. Hanafiah, A. Ayad, A. Hehn, and R. Kennel, "A hybrid MPPT for quasi-Z-source inverters in PV applications under partial shading condition," in *2017 11th IEEE International Conference on Compatibility, Power Electronics and Power Engineering, CPE-POWERENG 2017*, 2017, pp. 418–423, doi: 10.1109/CPE.2017.7915208.

[21] E. P. Sarika, J. Jacob, S. Mohammed, and S. Paul, "A novel hybrid maximum power point tracking technique with zero oscillation based on P&O algorithm," *International Journal of Renewable Energy Research*, vol. 10, no. v10i4, pp. 1962–1973, 2020, doi: 10.20508/ijrer.v10i4.11502.g8096.

[22] E. Kandemir, N. S. Cetin, and S. Borekci, "Single-stage photovoltaic system design based on energy recovery and fuzzy logic control for partial shading condition," *International Journal of Circuit Theory and Applications*, vol. 50, no. 5, pp. 1770–1792, 2022, doi: 10.1002/cta.3223.

[23] Eltamaly Ali M. and Farh Hassan M., "Dynamic global maximum power point tracking of the PV systems under variant partial shading using hybrid GWO-FLC," *Solar Energy*, vol. 177, pp. 306–316, 2019.

[24] J. A. Nemours and S. Chowdhury, "Performance analysis of fuzzy logic maximum power point tracking scheme for solar PV system under varying load and atmospheric conditions," in *2019 IEEE PES/IAS PowerAfrica*, Aug. 2019, pp. 134–139, doi: 10.1109/PowerAfrica.2019.8928895.

[25] S. K. R. Moosavi, M. Mansoor, M. H. Zafar, N. M. Khan, A. F. Mirza, and N. Akhtar, "Highly efficient maximum power point tracking control technique for PV system under dynamic operating conditions," *Energy Reports*, vol. 8, pp. 13529–13543, Nov. 2022, doi: 10.1016/j.egyr.2022.10.011.

[26] S. S. Mohammed and D. Devaraj, "Simulation and analysis of stand-alone photovoltaic system with boost converter using

MATLAB/Simulink,” in *2014 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2014]*, Mar. 2014, pp. 814–821, doi: 10.1109/ICCPCT.2014.7054991.

[27] I. Kaaya, M. Koehl, A. P. Mehilli, S. De Cardona Mariano, and K. A. Weiss, “Modeling outdoor service lifetime prediction of PV modules: Effects of combined climatic stressors on PV module power degradation,” *IEEE Journal of Photovoltaics*, vol. 9, no. 4, pp. 1105–1112, Jul. 2019, doi: 10.1109/JPHOTOV.2019.2916197.

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