Current Controlled Charging Scheme for off Board Electric vehicle Batteries from Solar PV Array

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***Abstract*—In this paper, we are proposing current-controlled hill-climbing strategy used in Maximum power point tracking (MPPT) of the solar photovoltaic array to Charge OFF Board Electric vehicle lithium-ion batteries within the safety limits and supported rating of batteries so that EV battery does not get damaged and can also increase the life of the battery. Here, a current sensor and potential difference sensor-based electric vehicle off-board battery charging by hill-climbing strategy is tested on MATLAB simulation. The satisfactory steady-state battery is charging within the rated charging limit, under variable solar irradiance.**

Keywords—Electric Vehicle, Charging Current, Supported rating, PV array.

I. Introduction

The transportation sector has seen a major shift towards electric vehicles as it not only stops our dependence on fossil fuels and stop pollution from these vehicles that vehicles release. Hence, we are moving towards cleaner sources of energy. Also, photovoltaic resources are increasing in demand as they are the source of clean energy and don't emit carbon dioxide

Two types of charging method are there ON Board charging and OFF Board charging.

ON Board charging is when Battery is kept in the Electric vehicle and charging circuit is not on the vehicle itself but near the charging station. And the battery is charged directly through the DC supply.

OFF Board charging is when the charging circuit is kept in the vehicle itself, and it can be charged using AC supply as there is rectifier circuit kept on the vehicle which converts the AC into DC which then charges the battery. But charging batteries using solar photovoltaic has problems of its own as if a high output solar PV array is operating on MPPT conditions output of the solar PV is kept at the maximum power possible and when one EV battery is kept for charging it can damage the battery with very high charging current.

The MPPT is used to operate the solar PV array so that maximum power can be extracted while it is in operation for these different algorithms such as NHS, Monkey king etc. are used [1][2] or using modified PSO algorithm for MPPT [3]. Based on different sensors setup which monitors the potential difference and current across the solar PV i.e. multi-sensors MPPT operation [4]. Moreover, in some cases, single sensors were used to either check current or potential difference from the solar PV and was given as input to the algorithm to run MPPT operations [5][6]. Nowadays MPPT algorithms are used with solar PV to charge batteries with maximum current from the solar PV array[6]. Other than MPPT, the universal current mode for Li-ion batteries [7] and L3C resonant convertor are used to charge batteries from PV [8]. Moreover, solar chargers are being developed to charge EV batteries with few constant parameters such as power, current and voltage with power supply on 1-phase to 3-phase based systems. [7]-[9][10]. However, problem is this maximum charging current can cause problems, this is due to the fact large solar PV array can produce large current when operating on MPPT operation which can be greater than the rated charging current of that battery. Moreover, when more than one EV is being charged, there is no method to protect them from damage and reduce the life of the EV batteries.

In this paper, we have used a reference current as limit such that its value is 10% of the maximum current discharge rate of the lithium-ion battery. This limit is the maximum charging current so that the batteries do not get damaged. Now by using the hill-climbing strategy for Maximum power point tracking with the help of the DC-DC boost converter and reference current as the limit the power output from the solar PV array is being controlled such that when charging current is under the limit that is below the reference current, solar PV can operate on maximum power and DC-DC boost converter can operate the solar PV array on Maximum power point tracking operation and when charging current is over the limit that

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is above the reference current solar PV power output is brought down and DC-DC boost converter can operate the solar PV array on De-rating operation until the charging current is below reference current. Further, when there are multiple numbers of Electric vehicle to be charged we use total numbers of OFF board electric vehicle as input data and it will be used to calculate the Charging current which is required to charge multiple EV in parallel, this is done by multiplying the reference current by number of Electric vehicles to get the new Charging current. And as the battery is charged charging current is reduced again.

II. System Layout

A. Solar PV Setup-

Fig.1 shows current-controlled hill climbing MPPT Off-board EV charging using two sensors scheme which is a current and potential difference of the solar PV array. this proposed setup is for two batteries charging in parallel with switch and protection diodes with each battery.

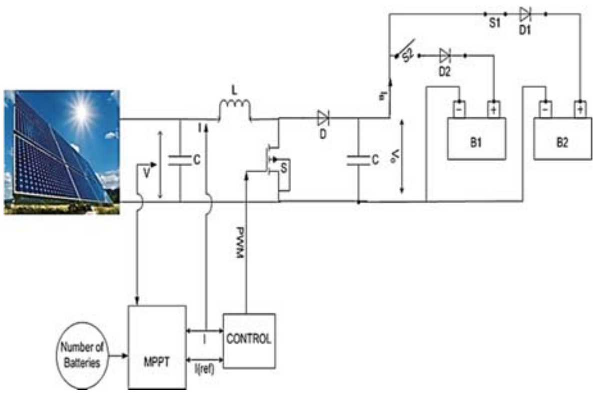

Fig 1. Proposed model for two batteries connected in parallel.

Where the number of batteries connected to the charging unit is an input to calculate the charging current.

B. E.V Battery Arrangement-

"N" numbers of EV Batteries charging in parallel with protection diode for each charging line to stop the reverse current from flowing back in the charging system and switches(S) to cut off the connection from the charging unit when charging is complete.

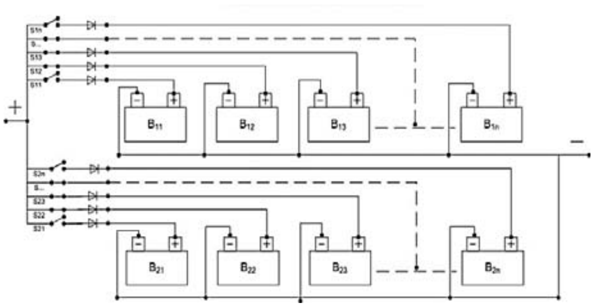

Fig 2 (N) numbers of electric vehicle batteries in parallel connection.

We have

$$I_{(Battery)} = n * I_{(B\ Charging)} \tag{1}$$

Where, $I_{(B\ Charging)}$ is rated charging current, and $I_{(\ Battery)}$ is charging current from PV

C. Current vs. Number of Batteries graph-

The Fig. 3 shows how $I_{(\ Battery)}$and number EV Batteries connected are linearly related to each other. When the number of batteries to be charged increases $I_{Battery}$ increases so that all the EV batteries can get optimally charge similarly as the batteries get fully charged the $I_{Battery}$ decreases so that the battery does get damaged.

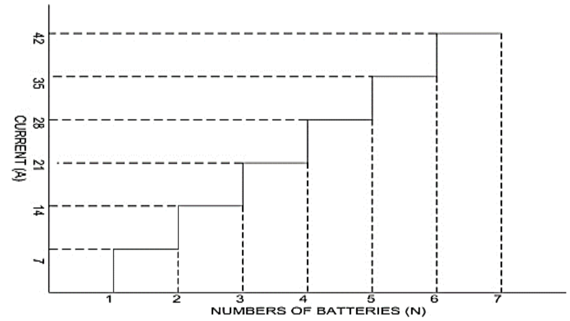

Fig 3. Linear relation between $I_{(\ Battery)}$ and (N) number of batteries.

D. Solar PV Cell-

Solar PV Cell is used to convert solar energy into electrical energy.

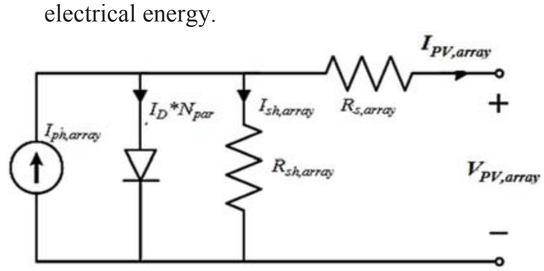

Fig 4 Solar PV cell electrical model

$$V_{OC} = \frac{nkT}{q} * Log \frac{I_L}{I_O\ +1} \tag{2}$$

$$I_{SC} = qG(L_N + L_G) \tag{3}$$

Where, V_{OC} is Open Circuit Voltage, and I_{SC} is Short circuit Current

E. DC-DC boost converter-

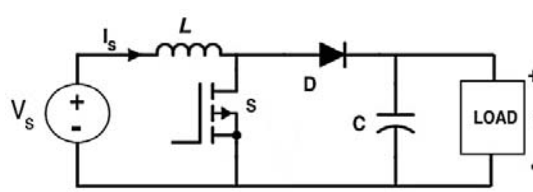

Fig 5 DC-DC Boost converter electrical model

The DC-DC boost converter is used to control the voltage by controlling the Input duty cycle given to the converter.

$$V_0 = \frac{V_{in}}{(1-D)} \quad (4)$$

Where, V_0 is Voltage output, V_{in} is Voltage input, and D is the Duty cycle.

According to the Fig.1 output voltage from DC to DC boost converter is connected the battery to charge it hence

$$V_0 = V_{Battery} \quad (5)$$

Moreover, the voltage generated by solar PV is fed to the converter as input voltage, hence;

$$V_{in} = V_{PV} \quad (6)$$

Therefore, we can rewrite (4) as,

$$V_{Battery} = \frac{V_{PV}}{(1-D)} \quad (7)$$

F. Electric Vehicle Battery used-

Now in most electric vehicles, Lithium-ion batteries are used due to their high-power density, lightweight and fast charging speed.

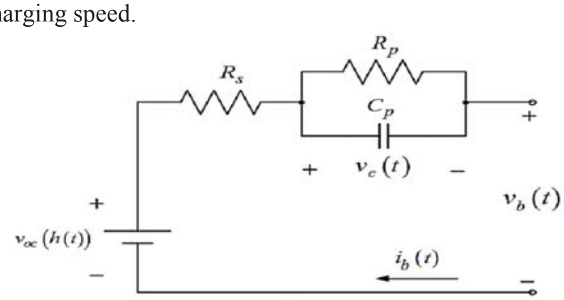

Fig 6. Lithium-ion electrical model

Fig.6 shows the Electrical representation of Lithium-ion battery, where Each battery is made with some standard specifications such as capacity (AH), rated charging current, rated voltage.

III. Control Scheme

The objective is Battery charging current must be below safety limit and rated charging current, Therefore MPPT algorithm [11]-[31] will run according to using controlled hill-climbing MPPT technique.

$$I_{charging}(t) > I_{Battery} \Rightarrow \text{(De-rating operation)} \quad (8)$$

$$I_{charging}(t) < I_{Battery} \Rightarrow \text{(MPPT operation)} \quad (9)$$

$$I_{Battery} = n * I_{B\ Charging} \quad (10)$$

Where, n is Number of batteries, $I_{B\ Charging}$ is Maximum Allowed Charging Current, $I_{Charging}$ is Charging current from PV to the battery.

A. MPPT Operation

In MPPT operation, the objective is to maximize the power generation($P\_generation$). In this case, the system varies the Duty cycle for achieving this objective. The variation of duty cycle depends upon increment or decrement of power(ΔP) Since the characteristics of Solar PV is non-linear in nature So we also check the information that is linear in nature for this we monitor change in voltage(ΔV)to decide the optimal duty cycle.

The Variation in duty cycle is calculated as:

$$\Delta P > 0 \,\&\, \Delta V > 0 \Rightarrow Decrement\ in\ duty\ cycle \quad (11)$$

if-else

$$\Delta P > 0 \,\&\, \Delta V < 0 \Rightarrow Increment\ in\ duty\ cycle \quad (12)$$

if-else

$$\Delta P < 0 \,\&\, \Delta V > 0 \Rightarrow Increment\ in\ duty\ cycle \quad (13)$$

if-else

$$\Delta P < 0 \,\&\, \Delta V < 0 \Rightarrow Decrement\ in\ duty\ cycle \quad (14)$$

Then Eqn. (11)-(14) can be concluded as:

if

$$\Delta P > 0 \,\&\, \Delta V > 0\ or\ \Delta P < 0 \,\&\, \Delta V < 0 \quad (15)$$
$$\Rightarrow Decrement\ in\ duty\ cycle$$

Else

$$\Delta P > 0 \,\&\, \Delta V < 0\ or\ \Delta P < 0 \,\&\, \Delta V > 0 \quad (16)$$
$$\Rightarrow Decrement\ in\ duty\ cycle$$

Then Eqn. (15)-(16) can be rewritten as:

if

$$(\Delta P > 0 \,\&\, \Delta V > 0) or\ (\Delta P < 0 \,\&\, \Delta V < 0)$$
$$\Rightarrow D(t) = D(t-1) - \delta_i \quad (17)$$

Else

$$\Rightarrow D(t) = D(t-1) + \delta_i \quad (18)$$

Where δ_i is the step change of the duty cycle & $D(t-1)$ is a previous duty cycle.

B. De-rating Operation

In De-rating operation the objective is to bring down the $P\_generated$ below the safety limit. In this case, In De-rating operation the objective is to bring down the power generation($P_{generation}$) below the safety limit. In this case, the system varies the Duty cycle for achieving this objective. The variation of duty cycle depends upon increment or decrement of power(ΔP) Since the current characteristic of Solar PV is non-linear in nature, We check the information that is linear in nature for this we monitor change in voltage(ΔV) to decide the optimal duty cycle.

The Variation in duty cycle is calculated as:

$$\Delta P > 0 \,\&\, \Delta V > 0 \Rightarrow Increment\ in\ duty\ cycle \quad (19)$$

If-else

$$\Delta P > 0 \,\&\, \Delta V < 0 \Rightarrow Decrement\ in\ duty\ cycle \quad (20)$$

If-else

$$\Delta P < 0 \,\&\, \Delta V > 0 \Rightarrow Decrement\ in\ duty\ cycle \quad (21)$$

If-else

$$\Delta P < 0 \,\&\, \Delta V < 0 \Rightarrow Increment\ in\ duty\ cycle \quad (22)$$

Then Eqn. (19)-(22) can be conclude as:

if

$$\Delta P > 0 \,\&\, \Delta V > 0\ or\ \Delta P < 0 \,\&\, \Delta V < 0 \quad (23)$$

$$\Rightarrow Increment\ in\ duty\ cycle$$

Else

$$\Delta P > 0 \,\&\, \Delta V < 0\ or\ \Delta P < 0 \,\&\, \Delta V > 0 \quad (24)$$

$$\Rightarrow Decrement\ in\ duty\ cycle$$

Then Eqn. (23)-(24) can be rewritten as:

if

$$(\Delta P > 0 \,\&\, \Delta V > 0)\ or\ (\Delta P < 0 \,\&\, \Delta V < 0)$$

$$\Rightarrow D(t) = D(t-1) + \delta_i \quad (25)$$

Else

$$\Rightarrow D(t) = D(t-1) - \delta_i \quad (26)$$

Where δ_i is the step change of the duty cycle & $D(t-1)$ is the previous duty cycle.

C. Flow Chart

Complete flow chart of current-controlled hill climbing MPPT strategy is shown in Fig.7. Here (Si=δ_i) and reference current taken to be 7A for one battery.
Here,

$$I_B(t) = n * I(B) \quad (27)$$

Where, $I_B(t)$ is controlled current from the DC-DC boost converter. $I(B)$ is Rated charging limit of the battery.

IV. Results and Discussion

In this section, results and discussion are shown in three sections, 1) Output of solar PV array, 2) Output of DC-DC converter and 3) charging output of the battery.

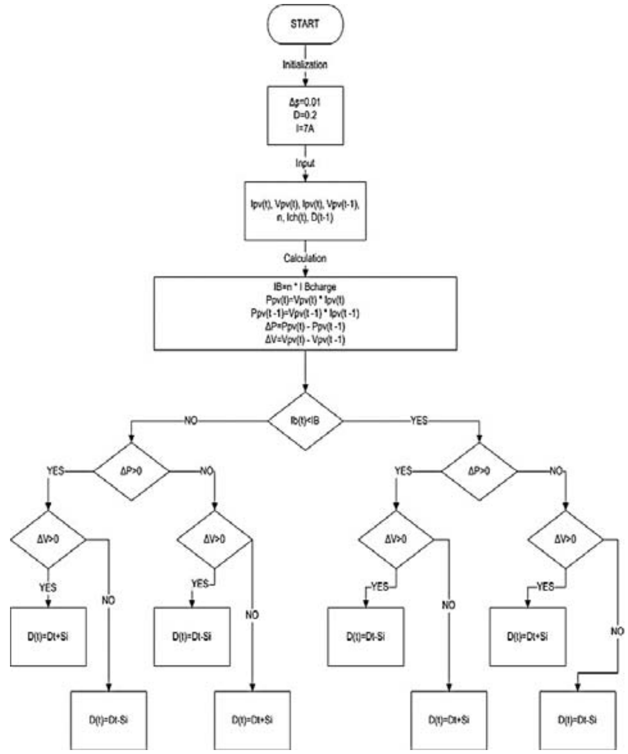

Fig 7. Flowchart representation of hill-climbing strategy

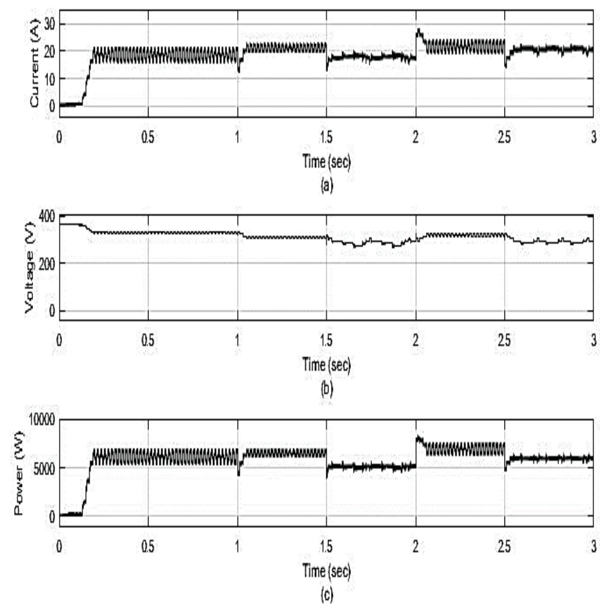

Fig 8. Output waveforms of the solar PV array, a) I_{PV} b) V_{PV} and c) P_{PV}.

A. The measurement power output of the Solar PV array

In Fig.8, the waveform of I_{PV} , V_{PV} and P_{PV} are shown, where I_{PV} is the current generated from the Solar PV array, V_{PV} is the Voltage generated from the solar PV array, and P_{PV} is power generated from the solar PV array, which is the Product of I_{PV} and V_{PV}. These readings are under the changing solar irradiance condition, where an ambient temperature of 25 degrees is constant.

Here output current and voltage are varied according to the varied solar irradiance, which is falling on the solar PV array. Resulting in variable voltage as well as variable current output as shown below.

- T= 0 - 1 sec. current just below 20A, where solar irradiance is 800 W/m^2.
- T=1 – 1.5 sec. current is increased and equal to the 20A because solar irradiance is increased to the 900 W/m^2.
- T=1.5 – 2 sec. current is suddenly decreased because solar irradiance is decreased from 900 W/m^2 to the 600 W/m^2.
- T= 2 - 2.5 sec. due to solar irradiance of 1000 W/m^2, current may be more than 20A, but using de-rating MPPT, it is forced to stop on 20A.
- T=2.5 – 3 sec current is suddenly decreased below to the 20A because solar irradiance is decreased from 1000 W/m^2 to the 700 W/m^2.

Here corresponding battery charging current is more than the rated charging current i.e. 14A. Therefore, this current needs to be under the required range before it can be used to charge the batteries.

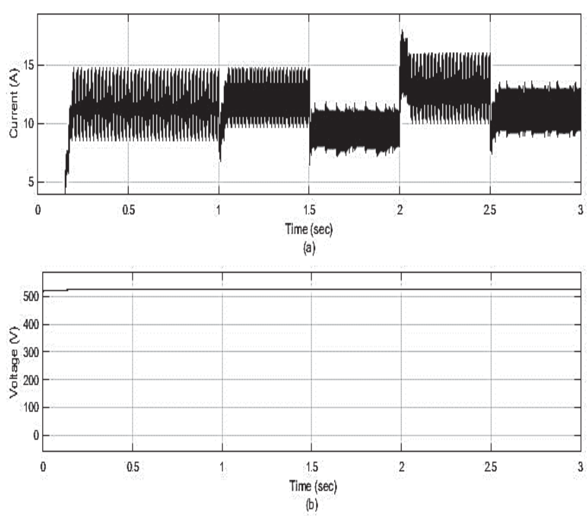

Fig 9. Waveforms of DC-DC converter a) Controlled current output and b) Controlled Voltage output.

B. *Measurement Power output after the DC to DC Boost circuit*

The output of the Solar PV array is not optimal as per our requirements therefore $V_{PV}$is fed into the DC-DC converter. Here, due to Controlled hill-climbing technique, the solar PV array is forced by the DC to DC Boost converter to work at MPPT operation and De-rating operation during the charging cycle of the EV battery due to varied solar irradiance. Which by controlling the output voltage also controls the output current and get it in a suitable range for the battery, that is controlled current output. Here, the DC-DC Boost converter is operating from:

T= 0 to 1.5 sec —> Normal operation
T= 1.5 to 2 sec —> MPPT operation
T= 2 to 2.5 sec —> de-rating operation.
T=2.5 to 3 sec —> MPPT operation

This is done to get controlled current output i.e. $I_{Battery}$ in the range below rated charging current that is 14 A.

C. *Measurement while Battery charging -*

Fig.10 shows Charging condition while Battery is being charged with $I_{Battery}$during MPPT and during De-rating operations. These conditions are mainly the State of Charge, charging current and charging voltage.

- Increase in state of charge shows that battery is being charged.
- The negative value of charging current shows current is going in the battery and it is not being discharged Charging voltage is constant.

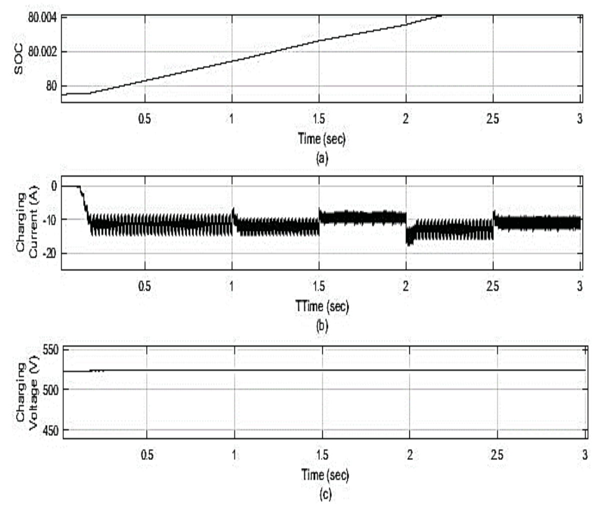

Fig 10 waveform of battery charging, a) State of charge b) Charging current and c) Charging Voltage

V. CONCLUSION

The proposed method of current-controlled hill-climbing Maximum power point tracking of the solar photovoltaic array for charging off-board electric vehicles using two sensors has been tested and simulated using MATLAB Simulink and steady charging current under the specified limit was maintained by proposed strategy during the simulation of the system.

REFERENCES

[1] N. Kumar, I. Hussain, B. Singh and B. K. Panigrahi, "Normal harmonic search algorithm based MPPT of solar PV system," *2016 7th India International Conference on Power Electronics (IICPE)*, Patiala, 2016, pp. 1-6.

[2] N. Kumar, I. Hussain, B. Singh and B. K. Panigrahi, "Maximum Power Peak Detection of Partially Shaded PV Panel by Using Intelligent Monkey King Evolution Algorithm," in *IEEE Transactions on Industry Applications*, vol. 53, no. 6, pp. 5734-5743, Nov.-Dec. 2017.

[3] M. Alshareef and Z. Lin, "A Modified Particle Swarm Optimization based Maximum Power Point Tracking for PV Systems," *2018 53rd International Universities Power Engineering Conference (UPEC)*, Glasgow, 2018, pp. 1-6.

[4] N. Kumar, I. Hussain, B. Singh and B. K. Panigrahi, "Normal Harmonic Search Algorithm-Based MPPT for Solar PV System and Integrated With Grid Using Reduced Sensor Approach and PNKLMS Algorithm," in *IEEE Transactions on Industry Applications*, vol. 54, no. 6, pp. 6343-6352, Nov.-Dec. 2018.

[5] N. Kumar, I. Hussain, B. Singh and B. K. Panigrahi, "Single Sensor-Based MPPT of Partially Shaded PV System for Battery Charging by Using Cauchy and Gaussian Sine Cosine Optimization," in *IEEE Transactions on Energy Conversion*, vol. 32, no. 3, pp. 983-992, Sept. 2017.

[6] N. Kumar, I. Hussain, B. Singh and B. K. Panigrahi, "Single sensor based MPPT for partially shaded solar photovoltaic by using human psychology optimisation algorithm," *IET Generation, Transmission & Distribution*, vol. 11, no. 10, pp. 2562-2574, 2017.

[7] N. Shafiei, M. Ordonez, M. A. Saket Tokaldani and S. A. Arefifar, "PV Battery Charger Using an $L3C$ Resonant Converter for Electric Vehicle Applications," *IEEE Transactions Transportation Electrification*, vol. 4, no. 1, pp. 108-121, March 2018.

[8] S. Biswas, L. Huang, V. Vaidya, K. Ravichandran, N. Mohan and S. V. Dhople, "Universal Current-Mode Control Schemes to Charge Li-Ion Batteries Under DC/PV Source," in *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 63, no. 9, pp. 1531-1542, Sept. 2016.

[9] A. Verma and B. Singh, "Multi-Objective Reconfigurable Three-Phase Off-Board Charger for EV," in *IEEE Transactions Industry Applications*, vol. 55, no. 4, pp. 4192-4203, July-Aug. 2019.

[10] C. Duan *et al*., "A Solar Power-Assisted Battery Balancing System for Electric Vehicles," in *IEEE Transactions on Transportation Electrification*, vol. 4, no. 2, pp. 432-443, June 2018.

[11] N. Kumar, B. Singh and B. K. Panigrahi, "LLMLF-Based Control Approach and LPO MPPT Technique for Improving Performance of a Multifunctional Three-Phase Two-Stage Grid Integrated PV System," in *IEEE Transactions on Sustainable Energy*, vol. 11, no. 1, pp. 371-380, Jan. 2020.

[12] N. Kumar, B. Singh and B. K. Panigrahi, "Grid synchronisation framework for partially shaded solar PV-based microgrid using intelligent control strategy," in *IET Generation, Transmission & Distribution*, vol. 13, no. 6, pp. 829-837, 26 3 2019.

[13] S. K. Saha, R. Kar, T. I. Mandai, N. Kumar and S. P. Ghoshal, "Optimal linear phase fir high pass filter design using PSOCFIWA-WM," *2012 World Congress on Information and Communication Technologies*, Trivandrum, 2012, pp. 768-773.

[14] N. Kumar, B. Singh and B. K. Panigrahi, "PNKLMF-Based Neural Network Control and Learning-Based HC MPPT Technique for Multiobjective Grid Integrated Solar PV Based Distributed Generating System," in *IEEE Transactions on Industrial Informatics*, vol. 15, no. 6, pp. 3732-3742, June 2019.

[15] N. Kumar, B. Singh, B. K. Panigrahi, C. Chakraborty, H. M. Suryawanshi and V. Verma, "Integration of Solar PV With Low-Voltage Weak Grid System: Using Normalized Laplacian Kernel Adaptive Kalman Filter and Learning Based InC Algorithm," in *IEEE Transactions on Power Electronics*, vol. 34, no. 11, pp. 10746-10758, Nov. 2019.

[16] S. S. Satapathy and N. Kumar, "Derated MPPT Scheme for Grid Integrated Solar PV Energy Conversion System," *2019 International Conference on Computing, Power and Communication Technologies (GUCON)*, NCR New Delhi, India, 2019, pp. 975-980.

[17] N. Kumar, B. Singh and B. K. Panigrahi, "Framework of Gradient Descent Least Squares Regression-Based NN Structure for Power Quality Improvement in PV-Integrated Low-Voltage Weak Grid System," in *IEEE Transactions on Industrial Electronics*, vol. 66, no. 12, pp. 9724-9733, Dec. 2019.

[18] N. Kumar, B. Singh, B. K. Panigrahi and L. Xu, "Leaky-Least-Logarithmic-Absolute-Difference-Based Control Algorithm and Learning-Based InC MPPT Technique for Grid-Integrated PV System," in *IEEE Transactions on Industrial Electronics*, vol. 66, no. 11, pp. 9003-9012, Nov. 2019.

[19] N. Kumar, B. Singh and B. K. Panigrahi, "Integration of Solar PV With Low-Voltage Weak Grid System: Using Maximize-M Kalman Filter and Self-Tuned P&O Algorithm," in *IEEE Transactions on Industrial Electronics*, vol. 66, no. 11, pp. 9013-9022, Nov. 2019.

[20] N. Kumar, B. Singh and B. K. Panigrahi, "Integration of Solar PV Generation with Distribution Grid: Using Novel Adaptive Filter Based Control Technique," *2018 4th International Conference on Universal Village (UV)*, Boston, MA, USA, 2018, pp. 1-6.

[21] N. Kumar, B. Singh and B. K. Panigrahi, "Discrete noise-eliminating second order generalized integrator based control strategy applied to grid-integrated solar PV synchronization converter," *2018 IEEMA Engineer Infinite Conference (eTechNxT)*, New Delhi, 2018, pp. 1-6.

[22] N. Kumar, B. Singh and B. K. Panigrahi, "Takagi-Sugeno-Kang fuzzy model-based self-adaptive maximum power harvesting technique for PV array: Tested on European standard EN50530," *2017 7th International Conference on Power Systems (ICPS)*, Pune, 2017, pp. 640-645.

[23] N. Kumar, B. Singh and B. K. Panigrahi, "Harmony Search with Wavelet Mutation evolutionary approach for ramp rate constrained unit commitment," *2015 Annual IEEE India Conference (INDICON)*, New Delhi, 2015, pp. 1-6.

[24] N. Kumar, I. Hussain, B. Singh and B. K. Panigrahi, "Implementation of Multilayer Fifth-Order Generalized Integrator-Based Adaptive Control for Grid-Tied Solar PV Energy Conversion System," in *IEEE Transactions on Industrial Informatics*, vol. 14, no. 7, pp. 2857-2868, July 2018.

[25] N. Kumar, T. Mulo and V. P. Verma, "Application of computer and modern automation system for protection and optimum use of High voltage power transformer," *2013 International Conference on Computer Comm. and Informatics*, Coimbatore, 2013, pp. 1-5.

[26] N. Kumar, S. Majumdar and G. M. Babu, "Automatic control of tidal power plant," *2012 International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM)*, Chennai, 2012, pp. 24-28.

[27] N. Kumar, B. singh and B. Panigrahi, "Intuitive Control Technique for Grid Connected Partially Shaded Solar PV Based Distributed Generating System," *IET Renewable Power Generation*, 2020.

[28] N. Kumar, B. Singh and B. K. Panigrahi, "ANOVA Kernel Kalman Filter for Multi-Objective Grid Integrated Solar Photovoltaic-Distribution Static Compensator," *IEEE Trans. Circuits and Systems I: Regular Papers*, 2019.

[29] B. Singh, N. Kumar, and B. K. Panigrahi, " Steepest Descent Laplacian Regression Based Neural Network Approach for Optimal Operation of Grid Supportive Solar PV Generation," *IEEE Transactions on Circuits and Systems II: Express Briefs*.

[30] S. S. Satapathy and N. Kumar, "Modulated Perturb and Observe Maximum Power Point Tracking Algorithm for Solar PV Energy Conversion System," *2019 3rd International Conference on Recent Developments in Control, Automation & Power Engineering (RDCAPE)*, NOIDA, India, 2019, pp. 345-350.

[31] S. S. Satapathy and N. Kumar, "Wavelet Mutation based JAYA Optimization Algorithm for Global Maximum Power Peak Searching for Partially Shaded Solar PV Panel Condition," *2019 3rd International Conference on Recent Developments in Control, Automation & Power Engineering (RDCAPE)*, NOIDA, India, 2019, pp. 351-356.