GRID CONNECTED CROSS TIED CONFIGURATION OF INTEGRATED CONVERTERS WITH MPP TRACKING UNDER VARIOUS CLIMATIC CONDITIONS

Harshini Vellanki¹, M. Srikanth², S. Palanikumar³, B. Jyothi⁴

Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswarm, AP, India

Received: 11.11.2019 Revised: 16.12.2019 Accepted: 29.01.2020

Abstract
The central inverter design of integrated photovoltaic cells consists of different configurations of PV modules. These configurations of PV modules are exposed to shading effects and cause power losses. To reduce to effect of shading and to extract the maximum power a MPP controller is used along with the developed architecture. In this paper all the string integrated converters are total cross tied and a MPPT controller is integrated to it. For the maximum power extraction perturb and observe and incremental conduction MPPT techniques are used. The performance of both the techniques are compared and examined under different shading conditions.

Keywords: Maximum power point (MPP), perturb and observe (P&O), shading conditions, incremental conduction (IC).

INTRODUCTION
Photo voltaic (PV) are the finest resources since the solar energy is limitless and free. PV systems can accompany with other sources very easily as they do not have any mobile parts and can last longer than 20 years. As the renewable sources are the environmental friendly those are the most commonly used resources. Among the different sustainable power sources, the force produced by sunlight based (photovoltaic) PV frameworks have been raised 25% per year in the course of the most recent 20 years. PV deployment systems have power ratings in different ranges ranging from kilowatts to few megawatts.

To extract the PV arrays maximum energy a control strategy has to developed for finding the operating, such control strategy is known as maximum power point tracking. The most commonly used techniques are perturb and observe (P&O) technique and incremental conductance (IC). The position of the MPP depends on the variation of temperature and irradiances.

PV module is a main PV system unit consists of PV cells which are connected in series. The design of PV systems depends on PV module arrangement and converter stages used and the form of MPPT techniques used [2]. The integrated PV systems are generally associated with the central inverter design and this architecture consists of different configurations of PV modules such as parallel, series, cross-tied, bridge-linked, honeycomb [3],[4]. Due to the partial shading and mismatching the power output from the PV modules decreases. Besides the power losses as the configurations of PV modules exhibits many connections it brings complicity in the system. The problems caused by inconsistent power losses were solved by attaching an anti-parallel bypass diode to each PV module[5].

The series and parallel connection of MICs exhibit several drawbacks such as voltage stress, high duty ratios, low conversion efficiency. Cross tied configuration of integrated converters is proposed to overcome these drawbacks. In this MPPT converter along boost converter is integrated to PV modules connected in series and is named as string integrated converters (SIC). In this proposed system 16 SICs were used.

Modeling of proposed system
PV system characteristics
In this proposed architecture 16 strings are used. A single PV string generate 310.03 W of power at MPP voltage (43 V) and current (7.21 A) at STC conditions. The P-V and I-V characteristics of a PV string at different isolation levels.

Fig 1. I-V characteristics with temperature and irradiance variation
From Fig 1(a) it is observed that the irradiance increases the current magnitude increases but there small variation in voltage from Fig 1(b) increase in the temperature the voltage increases.

**Fig 2. P-V characteristics**

**Proposed block diagram**

The PV array is connected to the DC-DC converter through a DC link capacitor. The array (voltage) $V_{pv}$, (current)$I_{pv}$ are fed to controller to generate a PWM signal and the signal is given to the DC-DC converter. In this proposed block diagram the MPPT is integrated with the DC-DC converter and then the output of the converter is given to the load. The converter generates the voltage according to the pulse given by MPPT and final output is given to the load.

**Proposed system**

In this configuration all the 16 PV strings were cross tied and connected in series and parallel and distinguished as row and columns separately. For this PV strings shading effect is created such as column shading, row shading, diagonal shading, row and column shading. In the row shading the first row is shaded unevenly and in column shading the first column of strings are shaded unevenly and in diagonal shading the shading is done diagonally and in row and column shading the first two columns are shaded unevenly.

**DC-DC converter with MPPT**

A boost converter is used which boost the PV string output voltage. The output current ($I_{pv}$) and voltage ($V_{pv}$) of the PV string are given as input parameters to the converter. The main components are MOSFET switch, inductor, output capacitor, diode and a input capacitor. The parameters of the converter are given as

### a) Inductor selection:

The inductance of inductor is calculated as

$$L_b = \frac{V_{pv}D}{2 \ast \delta I_L \ast F_{SW}}$$

Where $D$ is duty ratio of switch, $V_{pv}$ is PV string output voltage, $F_{SW}$ is switching frequency of switch, $\delta I_L$ is inductor current ripple

### b) Input capacitor:

The capacitance of input capacitor is calculated as

$$C_{pv} = \frac{\delta I_L}{8 \ast \delta V_{PV} \ast F_{SW}}$$

Where $\delta V_{PV}$ is PV string output voltage ripple

### c) Output capacitor:

The capacitance of output capacitor is calculated as

$$C_b = \frac{V_b \ast D}{2 \ast \delta V_{is} \ast R_b \ast F_{SW}}$$

Where $R_b$ is load resistance, $V_b$ is output voltage, $\delta V_{is}$ is output voltage ripple

The output voltage ($V_b$) and input voltage ($V_{pv}$) are related as

$$V_b = \frac{V_{pv}}{1 - D}$$

The output current ($I_b$) and input current ($I_{pv}$) are related as

$$I_b = I_{pv}(1 - D)$$

### d) Selection of switch:

Based on the current rating and output voltage of the string the switch has to be chosen.

**Fig 3. Proposed system with T-C-T configuration**

**Fig 4. Boost converter**
GRID CONNECTED CROSS TIED CONFIGURATION OF INTEGRATED CONVERTERS WITH MPP TRACKING UNDER VARIOUS CLIMATIC CONDITIONS

Implementation of MPPT:

The PV voltage and current are provided as input parameters to the controller to generate the output control signal. A PWM signal is generated by comparing the signal with the sawtooth signal of frequency 10KHz. To obtain the maximum power, the signal is applied to SIC.

Algorithm of P&O MPPT:

In this method, the voltage increased by the controller taken in small amount from the set and checks the output. The power is calculated by taking the values of current and voltage. The change in power is calculated by subtracting the previous power value and present power value. If the change in power is greater than zero the change in the values of voltage are taken by decreasing or increasing the duty ratios.

Algorithm of IC MPPT:

The controller tests incremental changes in PV array current and voltage within the incremental conductance system to predict the effect of a voltage shift. The incremental conductance test measures the maximum power point. If these two are similar then the MPP voltage is the output voltage. This voltage is regulated by controller until the irradiation switches and cycle is repeated. The incremental conductance model is based on $\frac{dp}{dv} = 0$ and $P = IV$ at maximum power level.

Simulation results

The simulation results of the proposed configuration under various shading patterns using P&O and IC MPPT are described in this section.

| Specifications                | Values      |
|------------------------------|-------------|
| $P_{mp}$, maximum power      | 62.006 W    |
| $V_{oc}$, open circuit voltage| 10.9 V      |
| $I_{sc}$, short circuit current| 7.32 A   |
| $V_{mpp}$                    | 8.6 V       |
| $I_{mpp}$                    | 7.21 A      |
| $I_{ph}$, photo generated current| 7.3503 A |
| Ideality factor              | 0.89864     |
| $R_s$, series resistance     | 0.14761Ω    |
| $R_{sh}$, shunt resistance   | 38.1127Ω    |
| $n_c$, no. of cells          | 18          |

Table 1 Specifications of PV module (sharp-nd-62RU2)
Based on the different irradiiances the shading effect is created as row, column, diagonal, long and narrow shading unevenly. The shading pattern contains various insolation levels such as 300, 500, 800, 1000 W/m².

**Table 2** Comparision of P&O and IC output power (KW) under different shading patterns

| Shading patterns      | Perturb and observe (KW) | Incremental (KW) |
|-----------------------|--------------------------|------------------|
| Uneven row            | 7.1                      | 8.8              |
| Uneven column         | 5.02                     | 6.6              |
| Diagonal              | 6.5                      | 7.1              |
| Long and narrow       | 6.7                      | 7.5              |

**CONCLUSION:**
This paper explains about PV characteristics and design of DC-DC converter and implementation of MPPT techniques. In this paper T-C-T configuration of SiCs is used to extract the maximum power. Both P&O and IC results are compared in this paper for extraction of maximum power. The results are compared taking different shading effects such as column.
shading, row shading and long and narrow shading unevenly taking different irradiances. IC method tracks more power rapidly than the P&O method.

REFERENCES
1. Sameel Raju pendem, Suresh Mikili, "PV Distributed-MPP Tracking: Total-Cross-tied Configuration of String-Integrated-Converter to Extract the Maximum Power Under Various PSSs", IEEE SYSTEMS JOURNAL, May 25 2019.
2. B. L. Rani, G. S. Ilango, and C. Nagamani, “Enhanced power generation from PV array under partial shading conditions by shade dispersion using Su Do Ku configuration,” IEEE Trans. Sustain. Energy, vol. 4, no. 3, pp. 594–601, Jul. 2013.
3. J. M. Carrasco et al., “Power-electronic systems for the grid integra- tion of renewable energy sources: A survey,” IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1016, Jun. 2006.
4. J. D. Bartidas-Rodriguez, E. Franco, G. Petrone, C. A. Ramos-Paja, and G. Spagnuolo, “Maximum power point tracking architectures for photo- voltaic systems in mismatching conditions: A review,” IET Power Electron., vol. 7, no. 6, pp. 1396–1413, Jan. 2014.
5. S.Sai Keerthi, J. Somal, “Role of PI/Fuzzy Logic Controlled Transformerless Shunt Hybrid Power Filter using 6-Switch 2-Leg Inverter to Ease Harmonics in Distribution System”, Indian Journal of Science and Technology, Vol.9,Issue.23,pp.1-7,June 2016.
6. Y.-C. Kuo, T.-J. Liang, and J.-F. Chen, “Novel maximum-power point tracking controller for photovoltaic energy conversion system,” IEEE Trans. Ind. Electron., vol. 48, no. 3, pp. 594–601, Jun. 2001.
7. C. Lin, A. Amriahmadi, Q. Zhang, N. Kutkut, and L. Batarseh, “Design and implementation of three-phase two-stage grid-connected mod-ule integrated converter,” IEEE Trans. Power Electron., vol. 29, no. 8, pp. 3881-3892, Aug. 2014.
8. A.S.Yadav,Y. K.Pachauri,Y.K.Chauhan,S.Choudhury, and A. R. Singh, "Performance enhancement of partially shaded PV array using novel shade dispersion effect on magic-square puzzle configuration," Solar Energy, vol. 144, pp. 780–797, Feb. 2017.
9. C Manickam, G. P. Raman, G. R. Raman, G. Saravana Ilango, and C. Nagamani, “Fireworks enriched P&O algorithm for GMPPPT and detection of partial shading in PV systems,” IEEE Trans. Power Electron., vol. 32, no. 6, pp. 4432–4443, Jun. 2017.
10. J. Prasanth Ram and N. Rajasekar, “A novel flower pollination based global maximum power point method for solar maximum power point tracking.” IEEE Trans. Power Electron., vol. 32, no. 11, pp. 8486–8499, Nov. 2017.
11. Suresh Palla, Jarupula Somlal, Comprehensive Examination on Solar-Wind Energy Systems Grid Integration and Emerging Power Quality challenges, International Journal of Engineering and Advanced Technology (IJEAT), Vol.8, Issue 653, September 2019
12. Buchibabu P., Somlal J, An examination on advanced MPPT methods for PV systems under normal & partial shading conditions, International Journal of Engineering and Advanced Technology (IJEAT), Vol.8, Issue-653, September 2019.
13. T Vijay Muni, S V N L Lalitha, "Fast Acting MPPT Controller for Solar PV with Energy Management for DC Microgrid", International Journal of Engineering and Advanced Technology, Volume 8, Issue 5, pp-1539-1544.
14. Ravi Teja, S., Mouli, S., Nikhil, M., Ventaka Srinivas, B. "A dual wireless power transfer-based battery charging system for electric vehicles", International Journal of Engineering and Advanced Technology 8 (4) ,pp.1211, 2019.
15. D. Ravi Kishore, and T. Vijay Muni, "Efficient energy management control strategy by model predictive control for standalone dc micro grids", AIP Conference Proceedings 1992, 030012 (2018); doi:10.1063/1.5047963
16. K Venkata Kishore, T Vijay Muni, P Balra Krishna, “Fuzzy Control Based UPFQ Controller to Improve the Network of a Grid Organization”, Int. J. Modern Trends Sci. Technol. 2019,3(11), 40-44.
17. T Vijay Muni; Kishore, K.V. Experimental Setup of Solar–Wind Hybrid Power System Interface to Grid System. Int. J. Modern Trends Sci. Technol. 2016, 2, 1–6.
18. Sathishwar Reddy, K., Sai Priyanka, A., Dusarlapudi, K., Vijay Muni, T., “Fuzzy logic based UPFQ for grid voltage regulation at critical load bus”, International Journal of Innovative Technology and Exploring Engineering,8(5), pp.721-725.
19. Swapna Sai, P., Rajasekhar, G.G., Vijay Muni, T., Sai Chand, M., “Power quality and custom power improvement using UPFQ”, International Journal of Engineering and Technology(UAE) 7(2), pp. 41-43.
20. T. Vijay Muni, S V N L Lalitha, B Rajasekhar Reddy, T Shiva Prasad, K Sai Mahesh, “Power Management System in PV Systems with Dual Battery”, International Journal of Applied Engineering Research ISSN 0973–4562 Volume 12, Number 1 (2017), pp.523-529.
21. T. Vijay Muni, G Sai Sri Vidy, N Rini Susan, “Dynamic Modeling of Hybrid Power System with MPPT under Fast Varying of Solar Radiation”, International Journal of Applied Engineering Research ISSN 0973–4562 Volume 12, Number 1 (2017), pp.523-529.
22. T Vijay Muni, A Satya Pranav, A Amara Srinivas, "IoT Based Smart Battery Station using Wireless Power Transfer Technology", International Journal of Scientific and Technology Research, volume 9, issue 01, January 2020, pp:2876-2881.
23. Vo, Nam Xuan, Trung Quang Vo, Ha Thi Song Nguyen, and Thuy Van Ha. "The Economic Evaluation in Vaccines - A Systematic Review in Vietnam Situation." Systematic Reviews in Pharmacy 9.1 (2018): 1-5. Print. doi:10.5530/srp.2018.1.1.