ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 6, April 2017

Reactive Power Control for a Grid Interactive Cascaded Photovoltaic Systems

Aneesh S.L
PG scholar,
MCET,Thiruvanathapuram
aneeshslkarthika@gmail.com

***Abstract*—Renewable energy is a critical part of reducing global carbon emissions .Among many renewable energies the penetration of photovoltaic (PV) solar power generation in distributed generation (DG) systems is growing rapidly because of its stability and cleanliness. Especially when high penetration levels are achieved ,it imposes new requirements to the operation and management of the distribution grid. Based on the requirements power electronics technology(eg: cascaded modular multilevel converters) is used to properly integrate PV system to the grid .However, power distribution and control in the cascaded PV system faces tough challenge on output voltage over modulation when considering the varied and non uniform solar energy on segmented pv arrays .This paper solves the issue and proposes improved PV system with cascaded modular multilevel converters using FLC in DC-DC converter controller. A newly derived vector diagram is used to find the relation between output voltage component of each module and power generation which illustrates the proposed power distribution principle.**

***Index Terms*—Cascaded photovoltaic (PV) system, power–voltage distribution, reactive power compensation, unsymmetrical active power.**

I. INTRODUCTION

Renewable energy is generally defined as the energy the is collected from resources which are naturally replenished on a human time scale such as sunlight ,wind ,rain ,tides ,waves and geothermal heat. Among of these renewable energy, solar energy is much easier to be harvested, converted, and delivered to grid by a variety of power converters [1]–[5]. In particular, large-scale grid-connected photovoltaic (PV) systems play a major role to achieve PV grid parity and have been put forward in high penetration renewable energy systems [6]. Numerous industrial applications have begun to require high power apparatus in recent years. Some medium voltage motor drives and utility applications requires medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources.

Renewable energy sources such as photovoltaic, wind, and fuel ... multilevel conv... application. As ... converters, casc... many merits o... Lower electromagnetic interference modularity, etc., but also is very promising for the large-scale PV system due to its unique advantages such as independent maximum power point tracking (MPPT) for segmented PV arrays, high ac voltage capability, etc. [4]–[5].PV systems with cascaded multilevel converters have to face tough challenges considering solar power variability and mismatch of maximum power point from each converter module due to manufacturing tolerances, partial shading, dirt, thermal gradients, etc. In a cascaded PV system, the total ac output voltage is the sum of output voltages from each converter module in one phase leg, which must fulfill grid codes or requirements. Because same grid current flows through ac side of each converter module, active power mismatch will result in unsymmetrical ac output voltage of these modules [5]. The converter module with higher active power generation will carry more portion of the whole ac output voltage, which may cause over modulation and degrade power quality if proper control system is not embedded into the cascaded PV system. Several control strategies have been proposed for the cascaded PV system with direct connection between individual inverter module and segmented PV arrays. But they did not consider the fact that PV arrays cannot be directly connected to the individual inverter module in high-voltage large-scale PV system application due to the PV insulation and leakage current issues. Even if there are low-frequency medium-voltage transformers between the PV converters and grid, there are still complicated ground leakage current loops among the PV converter module. Therefore, those methods in are not qualified for a practical large-scale grid-connected cascaded PV system. Moreover, reactive power compensation was not achieved, which

Sibin H.S
Asst.professor,
MCET,Thiruvanathapuram
Sibinhs87@gmail.com

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

largely limits the functions of the cascaded PV system to provide ancillary services. Proper reactive power compensation can significantly improve the system reliability, and in the meantime help the MPPT implementation for the cascaded module under unsymmetrical condition as well as comply with the system voltage requirement simultaneously. A reactive and active power control strategy has been applied in cascaded PV system with isolated dc–dc converter. If symmetrical active power comes from each module, active and reactive power can be equally distributed into these modules under traditional power control. However, if unsymmetrical active power is generated from these modules, this control strategy will not be able to achieve decoupled active and reactive power control. Reactive power change is along with the active power change at the same direction, which may aggravate output voltage over modulation during unsymmetrical active power outputs from segmented PV arrays. In order to solve the aforementioned issues, this paper proposes a large-scale grid-connected cascaded PV system including current-fed dual-active-bridge (CF-DAB) dc–dc converters and cascaded multilevel inverters. A decouple active and reactive power control system is developed to improve the system operation performance. Reactive power from each PV converter module is synchronously controlled to reduce the over modulation of PV converter output voltage caused by unsymmetrical active power from PV arrays. In particular, the proposed PV system allows a large low-frequency dc voltage ripple for each PV converter module, which will not affect MPPT achieved by CF-DAB dc–dc converters. As a result, film capacitors can be applied to replace the conventional electrolytic capacitors, thereby enhancing system lifetime. Christo Ananth et al.[8] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes.

II. SYSTEM CONFIGURATION AND POWER–VOLTAGE DISTRIBUTION

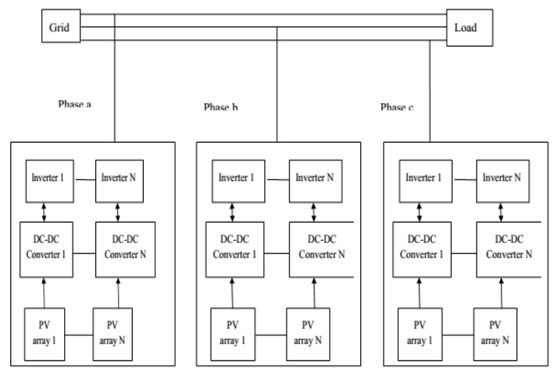

Fig 1 ; Block diagram of Grid-connected PV system with Cascaded PV inverter

A. System configuration

Fig. 1 describes the system configuration of one two-stage grid-interactive PV system with n cascaded converter modules for each phase, which is very suitable for the medium/high voltage application. It can be immune to the leakage current and PV potential induced degradation issues. In this paper, threephase PV converters are connected in “wye” configuration. They also can be connected in “delta” configuration. In the two-stage PV system, the first-stage dc/dc converters with high voltage insulation can achieve the voltage boost and MPPT for the segmented PV arrays. The second stage three-level H-bridge converter modules are cascaded to augment the output voltage, deliver active power to grid, and provide reactive power compensation. The dc-link voltage can be controlled to be constant and the same in each converter module. The single-stage PV system features simple configuration and fewer devices integration in each module. However, additional methods need be developed to solve the leakage current issues. In addition, the system may need to be oversized to accommodate the wide input voltage variation. In these configurations, unsymmetrical active power may be harvested from the cascaded modules due to PV module mismatch, orientation mismatch, partial shading, etc. In this case, improper power distribution and control are prone to an intrinsic instability problem if MPPT is still desired, which results in a limited operation range for the system. Moreover, it may also seriously deteriorate the system reliability and power quality. Particularly, appropriate reactive power compensation is very

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 6, April 2017

helpful to improve the operation of the cascaded PV system. Considering active power is produced by PV arrays and reactive power injection or absorption is regardless of PV arrays, one expects an independent active and reactive power control for each module. By this way, effect of reactive power compensation on system reliability and power quality can be investigated. In this paper, efforts are focused on the intelligent reactive power compensation method and optimized reactive power distribution from each module.

B. Power and Voltage Distribution Analysis

In the cascaded PV system, the same ac grid current flows through the ac side of each converter module. Therefore, the output voltage distribution of each module will determine the active and reactive power distribution. In order to clarify the power distribution, four modules are selected in the cascaded

Vector diagrams are derived in Fig. 2 to demonstrate the principle of power distribution between the cascaded converter modules in phase a.he same analysis can be extended to phase's b and c. It means that active and reactive power will be independently controlled in each phase. Therefore, a discrete Fourier transform phase locked Loop (PLL) method is adopted in this project, which is only based on single-phase grid voltage orientation and can extract fundamental phase, frequency, and amplitude information from any signal. Considering that the PCC voltage is relatively stable,V_{ga} is first used as the PLL synchronous signal of the cascaded PV system as shown in Fig.2(a).$V_{ga}$is transformed in to αβ stationary reference frame quantities $V_{ga\alpha}$and $V_{ga\beta}$which is the virtual voltage with $\pi/2$ phase shift to $V_{ga\alpha}$.

Fig. 2(b) illustrates voltage distribution of four cascaded converter modules under unsymmetrical active power generation in phase a. The output voltage of the total converter $V_{sa}$is synthesized by the four-converter module output voltage with different amplitude and angles.

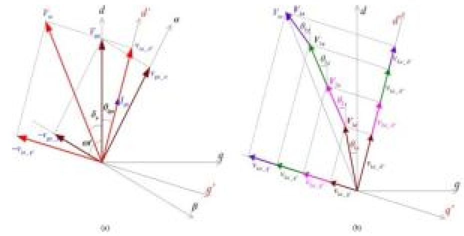

Fig 2 Vector diagrams showing relation between αβ frame,dq frame.(a)Relationship between grid current, grid voltage, and converter output voltage in phase a.(b) Voltagedistribution of the PV converter in phase a.

The average active and reactive power to grid in phase a$P_{ga}$and Q_{ga}, can be derived

$$P_{ga} - jQ_{ga} = V_{ga}\left(\frac{V_{sa}-V_{ga}}{jX_L}\right)\text{……….(1)}$$

$$P_{ga} = \left(\frac{1}{2}\right)V_{ga}I_{gad}\text{ …….......(2)}$$

$$Q_{ga} = (1/2)V_{ga}I_{gaq}\text{……….(3)}$$

III CONTROL SYTEM DESIGN

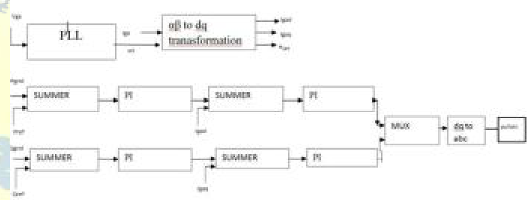

Fig 3;block diagram of the proposed control system

The active and reactive power is regulated in the dq reference frame. PLL is used to synchronize the output voltage of the cascaded PV converters grid current I_{ga} with V_{ga} so that the desired power control can be achieved. The maximum active power harvesting from each module can be implemented by MPPT control and dc-link voltage control.In this the active power and reactive power can be controlled in separate axis.In the d-axis real power is controlling and in the q-axis reactive power is controlling.Fig 3 shows the block diagram representation of the proposed control systems.

IV SIMULATION RESULTS

In order to explore the performance of grid interactive cascaded PV system with the proposed reactive power compensation approach, simulations were first conducted in a cosimulation platform of MATLAB/Simulink . A 1500W/415V three-phase two-stage cascaded PV system as shown in Fig. 1 is applied in this paper.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 6, April 2017

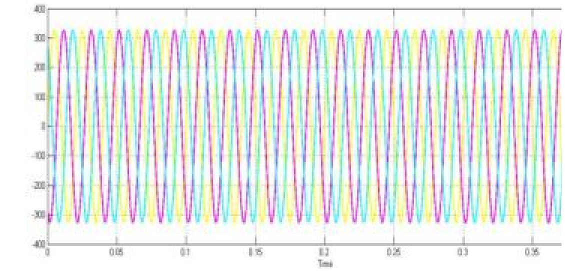

Fig 4 ;Three phase voltage at the grid.

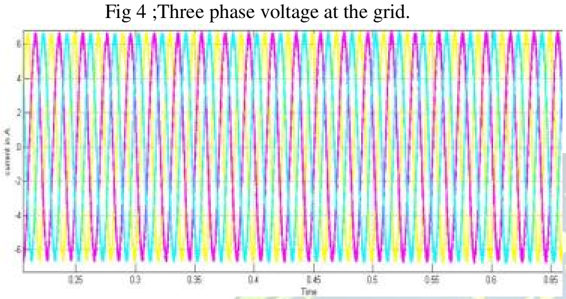

Fig 5;Three phase current at the grid

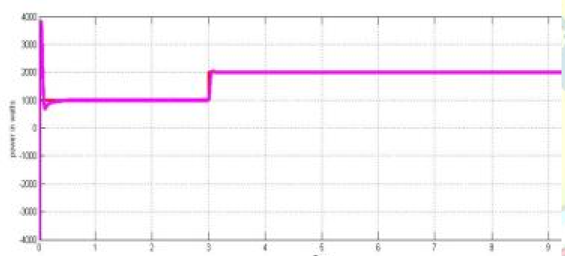

Fig 6 ;Active power at the grid

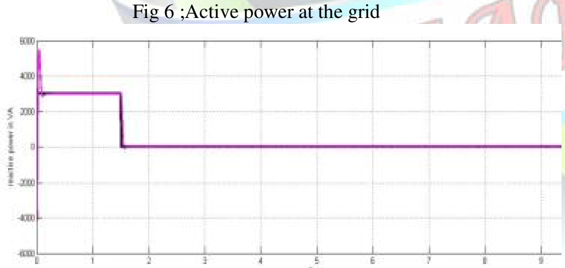

Fig 7 ;Reactive power at the grid

V CONCLUSION

This paper addressed the effect of reactive power compensation on system operation performance in grid-interactive cascaded PV systems.The system stability and reliability issue caused by unsymmetrical active power was specifically analyzed. Reactive power compensation and distribution was introduced to mitigate this issue.The output voltage of each module was verified to directly determine the power distribution.The relationship between voltage distribution and power distribution was illustrated with a wide power change range.

REFERENCES

[1] D. Meneses, F. Blaabjery, O. Garcia, and J. A. Cobos, “Review and comparison of step-up transformerless topologies for photovoltaic AC-module application,” IEEE Trans. Power Electron., vol. 28, no. 6, pp. 2649–2663, Jun. 2013..

[2] Y. Zhou, L. Liu, and H. Li, “A high performance photovoltaic module integrated converter (MIC) based on cascaded quasi-Z-source Inverters (qZSI) using eGaN FETs,” IEEE Trans. Power Electron., vol. 28, no. 6, pp. 2727–2738, Jun. 2013.

[3] L. Liu, H. Li, and Y. Zhou, “A cascaded photovoltaic system integrating segmented energy storages with self regulating power distribution control and wide range reactive power compensation,” IEEE Trans. PowerElectron., vol. 26, no. 12, pp. 3545–3559, Dec. 2011

[4] L. M. Tolbert and F. Z. Peng, “Multilevel converters as a utility interface for renewable energy systems,” in Proc. IEEE Power Eng. Soc. Summer Meet., Seattle, Washington, USA, Jul. 2000, pp. 1271–1274.

[5] L. Liu, H. Li, and Y. Xue, “A coordinated active and reactive power control strategy for grid-connected cascaded photovoltaic (PV) system in high voltage high power applications,” in Proc. IEEE 28th Appl. Power Electron.Conf. Expo., Long Beach, CA, USA, Mar. 17–21, 2013, pp. 1301–1308.

[6] Y. Bo, L. Wuhua, Z. Yi, and H. Xiangning, “Design and analysis of a grid connected photovoltaic power system,” IEEE Trans. Power Electron., vol. 25, no. 4, pp. 992–1000, Apr. 2010.

[7] J. Ebrahimi, E. Babaei, and G. B. Gharehpetian,“A new topology of cascaded multilevel converters with reduced number of components for high-voltage applications,” IEEE Trans. Power Electron., vol. 26, no. 11, pp.3109–3118, Nov. 2011.

[8] Christo Ananth, W.Stalin Jacob, P.Jenifer Darling Rosita. "A Brief Outline On ELECTRONIC DEVICES & CIRCUITS.", ACES Publishers, Tirunelveli, India, ISBN: 978-81-910-747-7-2, Volume 3,April 2016, pp:1-300.

[9] D. Meneses, F. Blaabjery, O. Garcia, and J. A. Cobos, “Review and comparison of step-up transformerless topologies for photovoltaic ac- module application,” IEEE Trans. Power Electron.,vol. 28, no. 6, pp. 2649–2663, Jun. 2013.

[10] Y. Shi, L. Liu, H. Li, and Y. Xue, “A single -phase grid-connected PV converter with minimal DC-link capacitor and low-frequency ripple-free maximum power point tracking,” in Proc. IEEE 5th Energy Convers.Congr. Expo., Denver, Colorado, USA, Sep. 15–19, 2013, pp. 2385–2390.

[11] M. J. Ryan, R. W. D. Doncker, and R. D. Lorenz, “Decoupled control ofa four-leg inverter via a new 4*4 transformation matrix,” IEEE Trans.Power Electron., vol. 16, no. 5, pp. 694–701, Sep. 2001.

[12] P. C. Loh and D. G. Holmes, “Analysis of multiloop control strategies for LC/CL/LCL-filtered voltage-source and current-source inverters,” IEEETrans. Ind. Appl., vol. 41, no. 2, pp. 644–654, Mar./Apr. 2005.

[13] A. Lindberg,“PWM and control of two and three level high power voltage source converters,” Licentiate thesis, Royal Inst. of Technology, Stockholm, Sweden, 1995.

[14] Y. Shi, L. Liu, H. Li, and Y. Xue, “A single-phase grid-connected PV converter with minimal DC-link capacitor and low -frequency ripple-free maximum power point tracking,” in Proc. IEEE 5th Energy Convers. Congr.Expo., Denver, Colorado, USA, Sep. 15–19, 2013, pp. 2385–2390.

[15] L. Liu, H. Li, and Y. Zhou, “A cascaded photovoltaic system integratingsegmented energy storages with self-

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 6, April 2017

regulating power distribution control and wide range reactive power compensation," IEEE Trans. Power Electron., vol. 26, no. 12, pp.3545–3559, Dec. 2011.

[16] W. Zhao, H. Choi, G. Konstantinou, M. Ciobotaru, and V. G. Agelidis,"Cascaded H-bridge multilevel converter for large-scale PV gridintegration with isolated dc–dc stage," in Proc. 3rd Int. Symp. Power Electron.Distrib. Generation Syst., Aalborg, Denmark, Jun. 25–28, 2012, pp. 849–856.

[17] H. Choi, W. Zhao, M. Ciobotaru, and V. G. Agelidis, "Large-scale PVsystem based on the multiphase isolated DC/DCconverter," in Proc. 3rd Int. Symp. Power Electron.Distrib.Generation Syst., Aalborg, Denmark, Jun. 25–28, 2012, pp. 801–807.

[18] L. Liu, H. Li, Y. Xue, and W. Liu, "Reactive power compensation andoptimization strategy for grid-interactive cascaded photovoltaic systems," accepted by IEEE Trans. Power Electron., 2014.

[19] O. Alonso, P. Sanchis, E. Gubia, and L. Marroyo, "Cascaded H-bridge multilevel converter for grid connected photovoltaicgenerators with independent maximum power point tracking of each solar array," in Proc. IEEE 34th Annu. Power Electron. Spec. Conf., Jun. 2003, vol. 2, pp. 731–735.

[20] Y. Zhou, L. Liu, and H. Li, "A high performance photovoltaic moduleintegrated converter (MIC) based on cascaded quasi-Z-source inverters (qZSI) using eGaN FETs," IEEE Trans. Power Electron., vol. 28, no. 6,pp. 2727–2738, Jun. 2013.

[21] H. Jin, "Behavior-mode simulation of power electronic circuits," IEEETrans. Power Electron., vol. 12, no. 3, pp. 443–452, May 1997.