ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A Phase Control Strategy for the Grid Connected PV System in Unbalanced Conditions

T.Deepika
M.Tech-Power Electronics,
Department of EEE,
SRTIST Nalgonda,Telangana.

B.Ravi Kumar
Associate Professor,
Department of EEE,
SRTIST Nalgonda,Telangana.

ABSTRACT

Independent current control of each phase of a three phase voltage source inverter under unbalanced voltage sags is proposed to effectively meet grid code requirements for grid connected photovoltaic power plants (GCPPPs). Under current grid codes, GCPPPs should support grid voltages by injecting reactive currents during voltage sags. Such injection must not allow the grid voltages of the no faulty phases to exceed 110% of their nominal value. However, grid over voltages can occur in the no-fault phases, especially if the currents injected into the grid by the GCPPP are balanced.

Based on a new requirement of the European network of transmission system operators published in 2012, a transmission system operator is allowed to introduce a requirement for unbalanced current injection. In this letter, this grid code is addressed by controlling individual phases and injecting unbalanced currents into the grid during voltage sags. Experimental results from a 2.8-kV·an inverter are presented, confirming the effectiveness of the proposed control method.

Keywords—***Photovoltaic System, power system faults, reactive current control.***

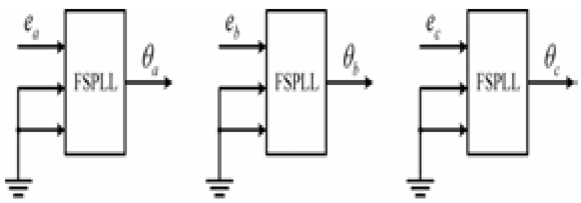
INTRODUCTION

The control of grid-connected voltage source inverters (VSIs) under unbalanced voltage sags has been widely addressed in the technical literature. Some research has focused on active power control strategies, and two methods have been presented to provide the current references for the VSIs .As in the case of synchronous generators in conventional power plants, VSIs should remain connected during voltage sags and support the grid voltages with the injection of reactive currents. This is necessary to ride-through any type of fault. The injection of balanced reactive currents to support unbalanced voltage sags may lead to overvoltage's in the no-fault phases. To prevent this, new grid codes (GCs) require the injectionof unbalanced reactive currents during unbalanced voltagesags, and for this purpose different control methods havebeen proposed. In and, a flexible voltage support methodwas introduced based on the type and severity of the voltagesags. For this purpose, the amount of reactive power injectedvia positive- and negative-sequences is controlled with an offlinecontrol parameter.Another study in proposeda method to set the positive- and negative-sequence reactivepower references based on an equivalent impedance grid modelto avoid over- and undervoltages in the phases. In that paper,the new current references were updated based on the previousreactive power references. A decoupled double synchronous reference frame current controller was introduced in, with the capability of controlling the active and reactive power of the positive- and negative-sequences independently. However, the current references were regulated offline. Regarding the individual control of currents and voltages of the

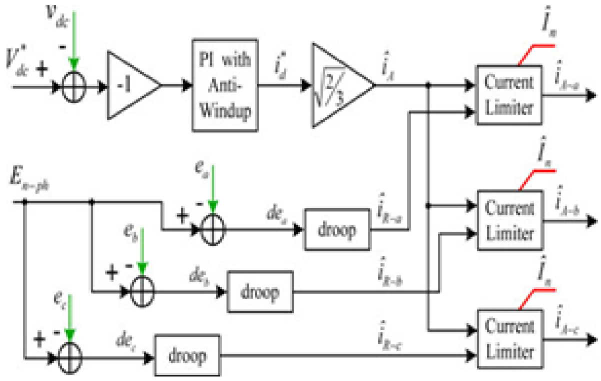
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

three phases, the new requirement of the European network of transmission system operators (TSOs) implies that TSOs are allowed to introduce requirement for unbalanced current injection. Few papers have studied or reported this concept to date. Some research was reported in to support the phases with unbalanced reactive power. However, the method used in that paper was not universal for all types of voltage sags.

The objective of this letter is to propose a control method based on individual control of the phase currents under unbalanced voltage sags. The amount of reactive current in each phase is determined based on the amount of voltage drop in that phase, which implies no reactive current injection for the nonfaultyphases. Implementation of this method requires knowledge of the grid-voltage angle of each phase. For this purpose, the phase-locked loop (PLL) proposed in is used. Moreover, the grid currents, including both active and reactive currents, are limited in order to protect the grid-connected photovoltaic power plants (GCPPPs) from ac over currents, addressing the fault-ride-through requirement. Since the grid currents are defined independently for each phase, two methods are proposed to prevent the controllers from trying to inject a zero-sequence into the grid. In this study, the proposed control technique was tested experimentally in a scaled-down GCPPP connected to allow-voltage (LV) programmable ac power supply. The remainder of this letter is organized as follows: Sectional introduces the synchronization method used to extract the Phase angles of the grid voltages individually. Generation of the current references is described in Section III, whereby a twostagecurrent limiter and two methods for eliminating the zero sequence.



From the current references are proposed. The grid currents are regulated using proportional-resonant (PR) controllers and presented in Section IV. Experimental results from scaled-down laboratory prototype with the proposed control method are presented in Section V. Finally, Section VI summarizes the main conclusions of this letter.



CIRCUIT DIAGRAM

Space Vector PWM

The Space Vector PWM generation module accepts modulation index commands and generates the appropriate gate drive waveforms for each PWM cycle. This section describes the operation and configuration of the SVPWM module.

A three-phase 2-level inverter with dc link configuration can have eight possible switching states, which generates output voltage of the inverter. Each inverter switching state generates a voltage Space Vector (V1 to V6 active vectors, V7 and V8 zero voltage vectors) in the Space Vector plane (Figure: space vector diagram). The magnitude of each active vector (V1to V6) is 2/3 Vic (dc bus voltage).

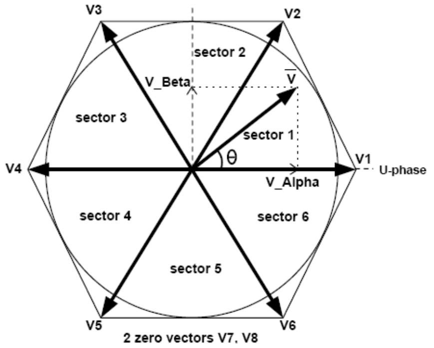
The Space Vector PWM (SVPWM) module inputs modulation index commands (U_Alpha and Upbeat) which are orthogonal signals (Alpha and Beta) as shown in Figure. The gain characteristic of the SVPWM module is given in Figure. The vertical axis of Figure represents the normalized peak motor phase voltage (V/Vic) and the horizontal axis represents the normalized modulation index (M).

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The inverter fundamental line-to-line Rams output voltage (Vine) can be approximated (linear range) by the following equation:

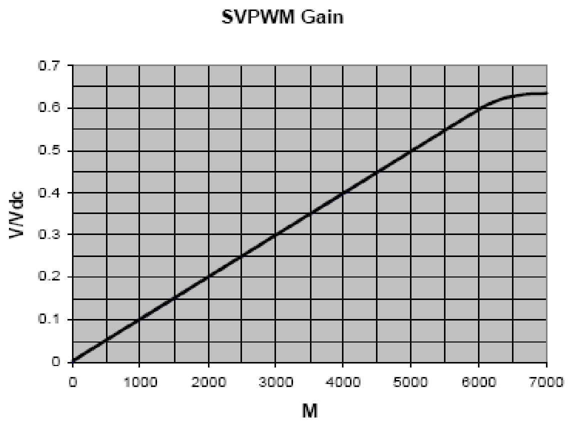
$$Vline = Umag * Mod\_Scl * Vdc / \sqrt{6} / 2^{25}$$

Where dc bus voltage (Vic) is in volts



Space Vector Diagram

This document is the property of International Rectifier and may not be copied or distributed without expressed consent



Transfer Characteristics

The maximum achievable modulation (Umag_L) in the linear operating range is given by:

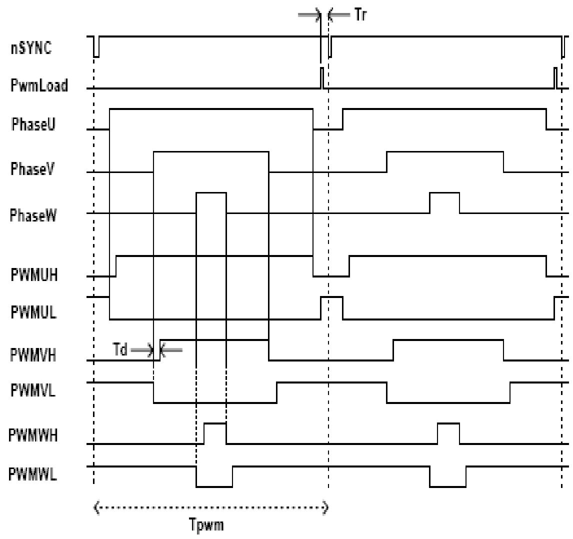
$$Umag\_L = 2^{25} * \sqrt{3} / Mod\_Scl$$

Over modulation occurs when modulation Mug>Umag_L. This corresponds to the condition where the voltage vector in (Figure: voltage vector rescaling) increases beyond the hexagon boundary. The magnitude of the voltage vector is restricted within the Hexagon; however, the phase angle (θ) is always preserved. The transfer gain (Figure: transfer characteristics) of the PWM modulator reduces and becomes non-linear in the over modulation region

PWM Operation

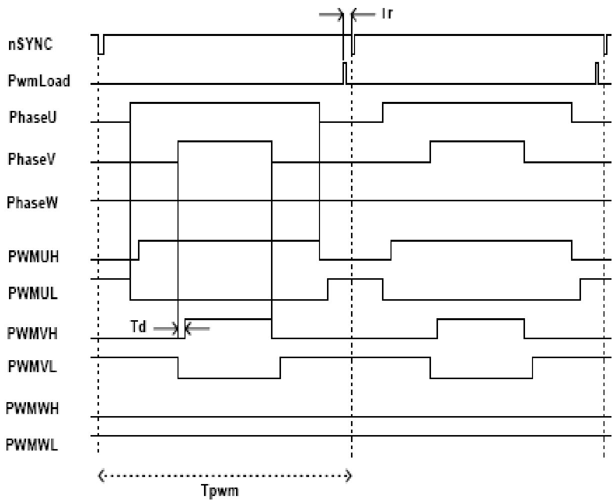
Upon receiving the modulation index commands (Alpha and Beta) the sub-module SVPWM_Tm starts its calculations at the rising edge of the PWM Load signal. The SVPWM_Tm module implements an algorithm that selects (based on sector determination) the active space vectors (V1 to V6) being used and calculates the appropriate time duration (wart. one PWM cycle) for each active vector. The appropriated zero vectors are also being selected. The SVPWM_Tm module consumes 11 clock cycles typically and 35 clock cycles (worst case Tr) in over modulation cases. At the falling edge of nSYNC, a new set of Space Vector times and vectors are readily available for actual PWM generation (PhaseU, PhaseV, PhaseW) by sub module PwmGeneration. It is crucial to trigger PwmLoad at least 35 clock cycles prior to the falling edge of nSYNC signal; otherwise new modulation commands will not be implemented at the earliest PWM cycle.

The above Figures voltage vector rescaling illustrates the PWM waveforms for a voltage vector locates in sector I of the Space Vector plane (shown in Figure). The gating pattern outputs (PWMUH … PWMWL) include dead time insertion



3-phase Space Vector PWM

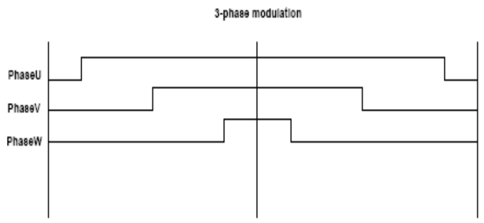
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

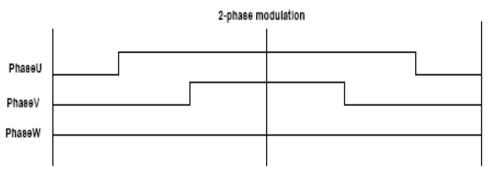


2-phase (6-step PWM) Space Vector PWM

Three-Phase and Two-Phase Modulation

Three-phase and two-phase Space Vector PWM modulation options are provided for the IRMCx203. The Volt-sec generated by the two PWM strategies are identical; however with 2-phase modulation the switching losses can be reduced significantly, especially when high switching frequency (>10 KHz) is employed. Figure: three-phase and two phase modulation shows the switching pattern for one PWM cycle when the voltage vector is inside sector 1



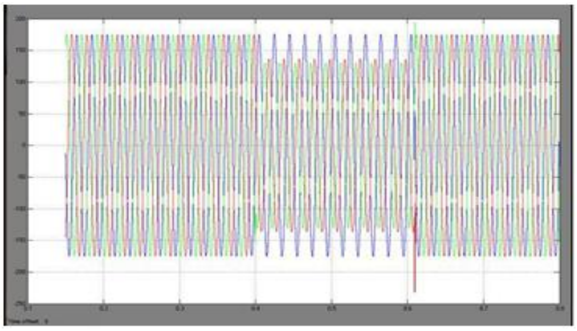


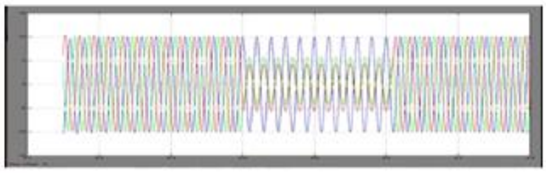
CONCLUSION

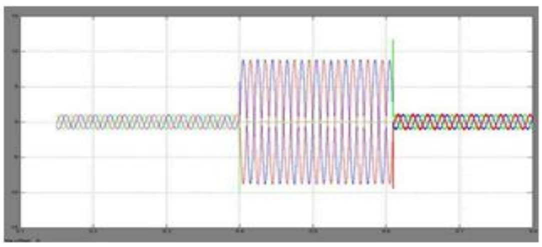
In this letter, a new control method based on individual control of the three phases of a GCPPP has been proposed. The independent control of the reactive currents injected into the grid protects the non faulty phases from overvoltage. The reactive currents are determined separately based on the amount of voltage drop in each phase. The active current references of each phase need to be limited based on the required amount of reactive currents. Furthermore, in a three-phase system, it is necessary to eliminate the zero-sequence from the current references generated. In this letter, two solutions for removing the zero-sequence component have been proposed. Finally, a method for rescaling the instantaneous current references to avoid producing over voltages in the non faulty phases, while preventing the GCPPP from over currents has also been proposed. This proposed control method has been tested experimentally on a scaled-down laboratory prototype operating with a “weak” grid.

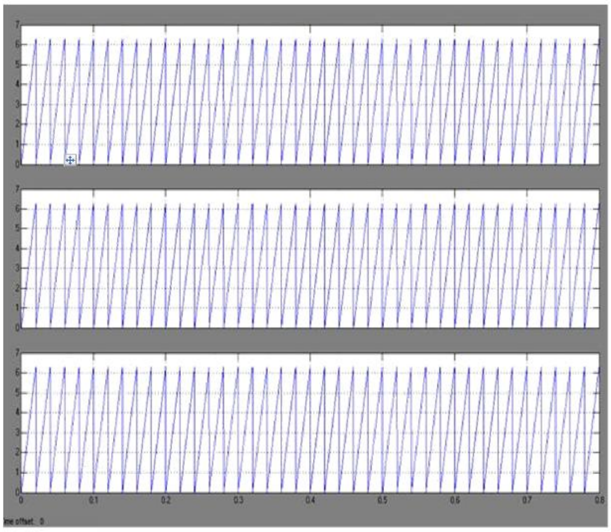
SCREENS

Performance of the proposed con trol method under 100% LG voltage sag at the grid side of the transformer. From top to bottom: grid voltages at the LV side of the transformer, detected angles of phases a, b and c, Generated re active current references, and output currents at the LV side.

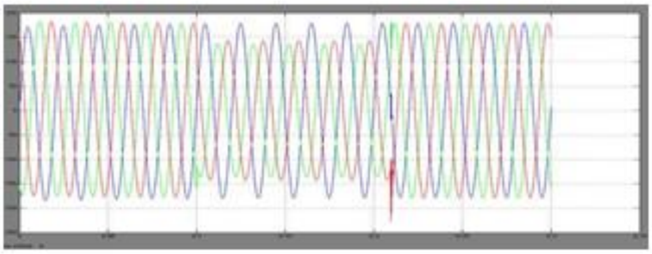








Performance of the balanced control method for the GCPPP fewer than 100% LG voltage sag at the grid side of the transformer. From top to bottom: grid voltages at the LV side of the transformer, output currents at the LV side, and reactive current reference.



REFERENCES

1. P. Rodriguez, A. Timbus, R. Teodorescu, M. Liserre, and F. Blaabjerg, "Flexible active power control of distributed power generation systems during grid faults," IEEE Trans. Ind. Electron., vol. 54, no. 5, pp. 2583–2592, Oct. 2007.

2. F. Wang, J. Duarte, and M. Hendrix, "Design and analysis of active power control strategies for distributed generation inverters under unbalanced grid faults," IET Gener., Trans. Distrib., vol. 4, no. 8, pp. 905–916, Aug. 2010.

3. BDEW. (2008, Jun.). Technical guideline-generating plants connected to the medium-voltage network-guideline for generating plants connection to and parallel operation with the medium-voltage network [Online]. Available: https://www.bdew.de

4. E. Troester, "New german grid codes for connecting PV systems to the medium voltage power grid," in Proc. 2nd Int. Workshop Concentrating Photovoltaic Power Plants, Opt. Des., Prod. Grid Connection, Mar. 2009, pp. 1–4.

5. M. Mirhosseini, J. Pou, and V. G. Agelidis, "Single-stage inverter-based grid-connected photovoltaic power plant with ride-through capability over different types of grid faults," in Proc. IEEE 39th Ann. Conf. Ind. Electron. Soc., Nov. 2013, pp. 8008–8013.

6. A. Camacho, M. Castilla, J. Miret, J. Vasquez, and E. Alarcon-Gallo, "Flexible voltage support control for three-phase distributed generation inverters under grid fault," IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1429–1441, Apr. 2013.

7. M. Castilla, J. Miret, A. Camacho, J. Matas, E. Alarcon-Gallo, and L. de Vicuna, "Coordinated reactive power control for static synchronous compensators under unbalanced voltage sags," in Proc. IEEE Int. Symp. Ind. Electron., May, 2012, pp. 987–992.

8. J. Miret, A. Camacho, M. Castilla, L. de Vicuna, and J. Matas, "Control scheme with voltage support capability for distributed generation inverters under voltage sags," IEEE Trans. Power Electron., vol. 28, no. 11 , pp. 5252–5262, Nov. 2013.

9. A. Camacho, M. Castilla, J. Miret, R. Guzman, and A. Borrell, "Reactive power control for distributed generation power plants to comply with voltage limits during grid faults," IEEE Trans. Power Electron., vol. 29 , no. 11, pp. 6224–6234, Nov. 2014.

10.M. Reyes, P. Rodriguez, S. Vazquez, A. Luna, R. Teodorescu, and J. Carrasco, "Enhanced decoupled double synchronous reference frame current controller for unbalanced grid-voltage conditions," IEEE Trans.

Power Electron., vol. 27, no. 9, pp. 3934–3943, Sep. 2012.

11. European Network of Transmission System Operator (ENTSO). (2012 , Jan.). Entso-e draft network code for requirements for grid connection applicable to all generators [Online]. Available: https://www.entsoe.eu/ major-projects/network-code-development/requirements-for-generators/ Pages/default.aspx

12. A. Uphues, K. Notzold, R. Wegener, S. Soter, and R. Griessel, "Support of grid voltages with asymmetrical reactive currents in case of grid errors," in Proc. IEEE Int. Conf. Ind. Technol., Feb. 2013, pp. 1781–1786.

13. M. Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions. New York, NY, USA: Wiley-IEEE, 2000.

14. M. Mirhosseini, J. Pou, V. G. Agelidis, E. Robles, and S. Ceballos, "A three-phase frequency-adaptive phase-locked loop for independent single-phase operation," IEEE Trans. Power Electron., vol. 29, no. 12 , pp. 6255–6259, Dec. 2014.

15. E. Robles, S. Ceballos, J. Pou, J. Martin, J. Zaragoza, and P. Ibanez, "Variable-frequency grid-sequence detector based on a quasi-ideal lowpass filter stage and a phase-locked loop," IEEE Trans. Power Electron., vol. 25, no. 10, pp. 2552–2563, Oct. 2010.

16. M.Mirhosseini,J.Pou,andV.G.Agelidis,"Single-andtwo-stageinverterbased grid-connected photovoltaic power plants with ride-through capability under grid faults," to appear in IEEE Trans. Sustain. Energy.