International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 04 | Apr-2018 www.irjet.net p-ISSN: 2395-0072

Coordinate Control of voltage support scheme and Active Power Flow Control with ACO in GCC under Unbalanced Conditions

Supriya. V. N[1], **Jisha .K.V**[2]

[1,2] *Department of Electrical and Electronics Jawaharlal College of Engineering &Technology Palakkad, Kerala, India.*

***

Abstract — Under grid fault conditions the accuracy of voltage support scheme is affected due to the zero sequence voltage. An advanced voltage support scheme in the converter units which is called zero sequence compensated voltage support schemes (ZCVS) used to regulate the voltage of grid. The maximum power from the solar panel is generated using maximum power point tracking (MPPT) controller. Controller converts the duty cycle of the DC DC converter .An inverter is connected at the output of the converter. Inverter is controlled by using the PI-ANT colony.ANT colony helps in assisting the controller and also helps the power injection with greater accuracy. A prototype of the hardware is also developed.

Keywords— Maximum Power Point Tracking, Proportional Integral, Positive and Negative Sequence Control, Unbalanced Grid Voltages.

I. INTRODUCTION

Power converters are critical components for interfacing distributed energy resources to power grids. The safe and proper operation of the grid-connected converters (GCCs) has thus been a substantial challenge for network operators. This becomes more challenging under various fault conditions. The blend of rising distributed energy resources with large applications of modern loads causes in a grid more vulnerable to voltage sags, swells, and unbalanced conditions. However, a GCC can be smartly controlled for not only withstanding these distant faults, but also rendering local ancillary services. Different control strategies, which are mainly based on symmetric sequences, were studied to ride through grid faults by a GCC .References studied two control techniques for the static synchronous compensators (STATCOMs) to regulate the positive and negative sequences of the point of common coupling (PCC) voltage, where the active power delivery is considered zero. In the existing literature, little work has been carried out on the phase voltage regulation of a GCC under unbalanced conditions. The methods presented in have three drawbacks. First, they do not consider the zero-sequence voltage component whereas it exists in most unbalanced faults. Their accuracy is thus severely affected by the zero sequence component of the PCC voltage. Second, these methods have been only applied in inductive grids, i.e. assuming very high X/R ratio. Third, all of the existing strategies are formulated assuming zero active power delivery. Solar energy is gaining popularity in the field of electricity generation. The advantages of solar power such as no air pollution, no fuel costs, noiseless and low maintenance have boosted the demand on this type of energy. However, the high expense in acquiring the Photo Voltaic (PV) module has slowed down the adoption of PV system in electricity generation. Maximum power point tracking (MPPT) controller is introduced to ensure the DG system always provides high efficiency despite the variation in active power injection and the load.

II. PROPOSED SYSTEM

The basic requirement in the voltage support is to avoid the over-voltage and under-voltage at the PCC whenever possible. If the rated power of the GCC and the connecting line impedance are not small, the three-phase voltages can be regulated at the pre-set safety limits, that is V^{set}_{min} and V^{set}_{max} .In the proposed scheme was only applied to the STATCOM application where the reference current only consists of the reactive components. However, the effect of the active power in regulating the voltage should not be ignored at the distribution level since:(1) the resistance of the lines in the distribution system is not negligible; and, (2) DGs inherently generate and inject the active power to the system.

The positive and negative sequences of the reactive current component were obtained for regulating the phase voltages in an inductive grid. In this section, two complementary strategies are proposed to be applied to the active components of the current. The first strategy, that is LAPO, aims to limit the oscillations on the active power which is critical to improve the dc-bus voltage stabilization. Furthermore, the second strategy, i.e. MAPD, intends to deliver the maximum active power with respect to the rating current while simultaneously supporting the voltage with ZCVS. These strategies can be also obtained for the resistive grids and grids with any X/R value if the active and reactive components are replaced are satisfied.

A. ZCVS with LAPO Strategy

In severe unbalanced conditions, the required negative reactive component of the current obtained by ZCVS may. become high. Negative sequence current and voltage components give rise to large oscillations in the active power. Therefore, the LAPO strategy is proposed to obtain the a limit for the negative reactive current component which does not cause exceeding the pre-set maximum allowable active power oscillation P^{set}_{max} Considering the symmetric-sequence-based instantaneous power theory, the output active and reactive powers of the GCC as calculated as follows:

$$p = v.i = (v^+ + v^-).(i^+ + i^-) \\ = \underbrace{v^+.i^+ + v^-.i^-}_{P} + \underbrace{v^+.i^- + v^-.i^+}_{\tilde{P}}$$

Using the corresponding equivalents of the positive/negative voltage and current vectors from above gives the magnitude of the oscillations on the active power as

$$\tilde{P} = \sqrt{\left(V^- I_p^+ + V^+ I_p^-\right)^2 + \left(V^- I_q^+ - V^+ I_q^-\right)^2}$$

The equation of the maximum negative reactive current will be obtained which limits the oscillation magnitude of the active power to $P^{`set}_{max}$:

$$I^-_{q,\,LAPO} = \frac{\sqrt{\tilde{P}^{set\,2}_{max} - \left(V^- I_p^+ + V^+ I_p^-\right)^2} + V^- I_q^+}{V^+}$$

This analytical expression limits the active power oscillations and enhances the dc-bus voltage stabilization. Fig 1 shows the control diagram of the ZCVS scheme with LAPO strategy. LAPO may slightly affect the operation of the ZCVS.

However, the GCC operator can flexibly compromise between the full ZCVS and the limited active power oscillation (LAPO) capability, by using these analytical expressions.

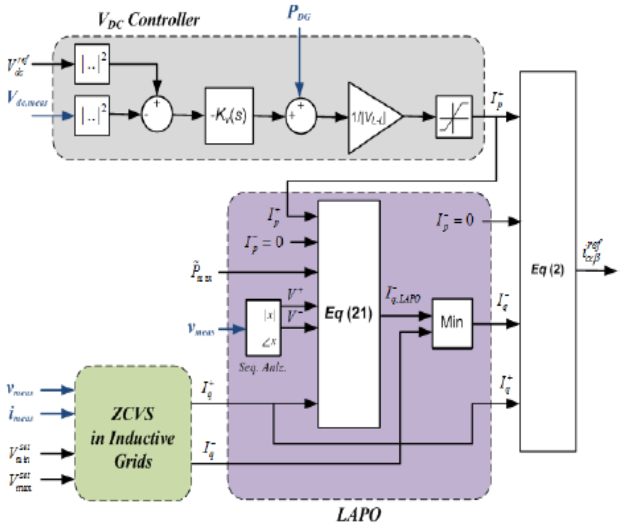

Fig.1 Proposed control diagram to limit the active power oscillations

B. ZCVS with MAPD Strategy

Applying the MAPD technique ensures *i*) delivering the maximum allowable active power to the grid and *ii*) simultaneously respecting the current limitations while *iii*) riding through abnormal conditions, and simultaneously *iv*) regulating the phase voltages. Therefore, this section finds the equation of $I\,p$, *MAPD.* To achieve the a for mentioned goals. $I\,p$, *MAPD* is the term determining the maximum allowable value for $I\,p$ to provide the maximum allowable active power injection such that none of the phase currents passes $I^{set}{}_{max}$. .This strategy, I_{q-} and I_{q+} are already obtained by the proposed voltage support. The value of $I_{\ p}$ is also set to zero to allocate all the available current capacity to $I_{\ p+}$. Then the equation can be rewritten as

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} I_p^+ \cos(\omega t + \delta^+) + I_q^+ \sin(\omega t + \delta^+) - I_q^- \sin(\omega t + \delta^-) \\ I_p^+ \sin(\omega t + \delta^+) - I_q^+ \cos(\omega t + \delta^+) - I_q^- \cos(\omega t + \delta^-) \end{bmatrix}$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \left(I_p^+ + I_q^- \sin\gamma\right)\cos(\omega t + \delta^+) + \left(I_q^+ - I_q^- \cos\gamma\right)\sin(\omega t + \delta^+) \\ \left(I_p^+ - I_q^- \sin\gamma\right)\sin(\omega t + \delta^+) - \left(I_q^+ + I_q^- \cos\gamma\right)\cos(\omega t + \delta^+) \end{bmatrix}$$

The $\alpha\ \beta$ currents are transformed into the *abc* currents, and the magnitude of the phase currents will be obtained as

$$\begin{bmatrix} I_a^2 \\ I_b^2 \\ I_c^2 \end{bmatrix} = \begin{bmatrix} (I_{\alpha c})^2 + (I_{\alpha s})^2 \\ (-\frac{1}{2} I_{\alpha c} + \frac{\sqrt{3}}{2} I_{\beta c})^2 + (\frac{1}{2} I_{\alpha s} + \frac{\sqrt{3}}{2} I_{\beta s})^2 \\ (-\frac{1}{2} I_{\alpha c} - \frac{\sqrt{3}}{2} I_{\beta c})^2 + (\frac{1}{2} I_{\alpha s} - \frac{\sqrt{3}}{2} I_{\beta s})^2 \end{bmatrix}$$

Where

$$\begin{cases} I_{\alpha c} = I_p^+ + I_q^- \sin\gamma \\ I_{\alpha s} = I_q^+ - I_q^- \cos\gamma \\ I_{\beta s} = I_p^+ - I_q^- \sin\gamma \\ I_{\beta c} = -\left(I_q^+ + I_q^- \cos\gamma\right) \end{cases}$$

Then, the phase current magnitudes under the fault can be found by

$$I_a^2 = \left(I_p^+ + I_q^- \sin\gamma\right)^2 + \left(I_q^+ - I_q^- \cos\gamma\right)^2$$

$$I_b^2 = \left(-\tfrac{1}{2}\left(I_p^+ + I_q^- \sin\gamma\right) - \tfrac{\sqrt{3}}{2}\left(I_q^+ + I_q^- \cos\gamma\right)\right)^2 \\ + \left(-\tfrac{1}{2}\left(I_q^+ - I_q^- \cos\gamma\right) + \tfrac{\sqrt{3}}{2}\left(I_p^+ - I_q^- \sin\gamma\right)\right)^2 \\ = \left(\tfrac{1}{2} I_p^+ + I_{Q1}\right)^2 + \left(\tfrac{\sqrt{3}}{2} I_p^+ + I_{Q2}\right)^2$$

$$\begin{aligned} I_c^2 &= \left(-\tfrac{1}{2}\left(I_p^+ + I_q^- \sin\gamma\right) + \tfrac{\sqrt{3}}{2}\left(I_q^+ + I_q^- \cos\gamma\right)\right)^2 \\ &\quad + \left(-\tfrac{1}{2}\left(I_q^+ - I_q^- \cos\gamma\right) - \tfrac{\sqrt{3}}{2}\left(I_p^+ - I_q^- \sin\gamma\right)\right)^2 \\ &= \left(\tfrac{1}{2} I_p^+ + I_{Q3}\right)^2 + \left(-\tfrac{\sqrt{3}}{2} I_p^+ + I_{Q4}\right)^2 \end{aligned}$$

Where

$$I_{Q1} = \tfrac{1}{2} I_q^- \sin\gamma + \tfrac{\sqrt{3}}{2} I_q^+ + \tfrac{\sqrt{3}}{2} I_q^- \cos\gamma$$

$$I_{Q2} = -\tfrac{1}{2} I_q^+ + \tfrac{1}{2} I_q^- \cos\gamma - \tfrac{\sqrt{3}}{2} I_q^- \sin\gamma$$

$$I_{Q3} = \tfrac{1}{2} I_q^- \sin\gamma - \tfrac{\sqrt{3}}{2} I_q^+ - \tfrac{\sqrt{3}}{2} I_q^- \cos\gamma$$

$$I_{Q4} = -\tfrac{1}{2} I_q^+ + \tfrac{1}{2} I_q^- \cos\gamma + \tfrac{\sqrt{3}}{2} I_q^- \sin\gamma$$

Using the above equations, three values are respectively obtained for $I_{\mathrm{P}}{}^{+}$ ($I_{\mathrm{P}.}{}^{+}{}_{\mathrm{a}}\,.I_{\mathrm{P}}{}^{+}{}_{.\mathrm{a}.}$. and $I_{P}{}^{+}{}_{.C}$)

In three cases ,that is $I_a = I^{\mathrm{set}}{}_{\mathrm{max}}$. $I_{\mathrm{b}} = I_{\mathrm{max}}{}^{\mathrm{set.}}$. and $I_{\mathrm{c}} = I_{\mathrm{max}}{}^{\mathrm{set}}$:

$$I_{p,a}^+ = \sqrt{I_{\max}^{set\ 2} - \left(I_q^+ - I_q^- \cos\gamma\right)^2} - I_q^- \sin\gamma$$

$$I_{p,b}^+ = \frac{-I_{Q1} - \sqrt{3} I_{Q2} + \sqrt{\left(I_{Q1} + \sqrt{3} I_{Q2}\right)^2 - 4\left(I_{Q1}{}^2 + I_{Q2}{}^2 - I_{\max}^{set\ 2}\right)}}{2}$$

$$I_{p,c}^+ = \frac{-I_{Q3} + \sqrt{3} I_{Q4} + \sqrt{\left(I_{Q3} - \sqrt{3} I_{Q4}\right)^2 - 4\left(I_{Q3}{}^2 + I_{Q4}{}^2 - I_{\max}^{set\ 2}\right)}}{2}$$

$$I_{p,MAPD}^+ = \min\left(I_{p,a}^+ \,, I_{p,b}^+ \,, I_{p,c}^+\right)$$

Figure 2 shows the control diagram of the ZCVS scheme with MAPD strategy.

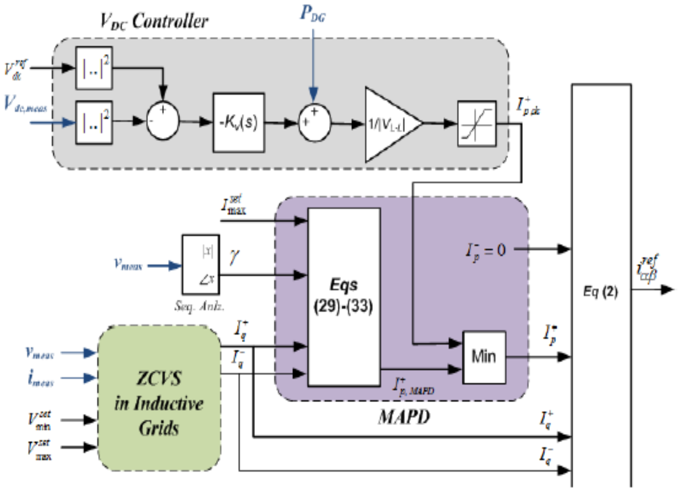

Fig.2 Proposed control diagram to maximize the active power delivery

III. RESULT & CONCLUSIONS

The proposed ZCVS scheme with LAPO and MAPD strategies, three test cases are studied. The circuit topology of a grid-connected 1.0 MVA, 690 V, 60 Hz converter-interfaced DG unit. The operation of a GCC under the unbalanced ac-side condition is usually studied by assuming a constant dc voltage source in the dc-side for simplicity. This system contains a voltage-source converter connected to an ac grid via impedances and a transformer. The switching frequency is 10 kHz. Using this transformer, the converter operating voltage is reduced to safely emulate the grid faults and disturbances. Steady-state over-voltage up to 1.32 pu (on phase *C* between *t*=1.8s and 3.4s) and under-voltage down to 0.68 pu (on phase *A* between *t*=1.8s and 4.7s) occur. It is due to neglecting the zero. sequence voltage in the traditional VSS. However, the proposed ZCVS method demonstrates successful performance and accurate phase voltage regulation. The proposed ZCVS method addresses these three problems. Moreover, two complementary objectives, related to the active power delivery, are also augmented in the proposed scheme. First, the limited active power oscillation is proposed under severe unbalanced faults to analytically obtain a limit for the injected negative reactive current. This feature provides an adjustable limited active power oscillation, and improved dc voltage while supporting the ac-side voltage. Second, the expressions of the maximum active power delivery are proposed to exploit the maximum allowable active power of a distributed energy resource even under severe unbalances and while still regulating the phase voltages. The proposed voltage support scheme and two complementary strategies bring significant advantages to emerging distributed generation units. The successful results of the proposed schemes are verified using simulation.

ACKNOWLEDGMENT

My endeavour stands incomplete without dedicating my gratitude to everyone who has contributed a lot towards successful completion of my work. First of all, I offer thanks to my parents for their blessings. I am indebted to God Almighty for blessing me with his grace and taking my endeavour to a successful culmination. I specially acknowledge Dr.K.Umesha, Vice Principal and Head of the Department and my project guide Ms.Jisha.K.V. Assistant Professor, Department of Electrical and Electronics Engineering for her technical support and guidance given to me and steering me to successful completion of this work.

REFERENCES

[1] M. K. Hossain and M. H. Ali, "Transient Stability Augmentation of PV/DFIG/SG-Based Hybrid Power System by Nonlinear Control Based Variable Resistive FCL," in IEEE Transactions on Sustainable Energy, vol. 6, no. 4, pp. 1638-1649, Oct. 2015.

[2] H. Xiao, et al. "An Improved Control Method for Multiple Bidirectional Power Converters in Hybrid AC/DC Microgrid," in IEEE Transactions on Smart Grid, vol. 7, no. 1, pp. 340-347, Jan. 2016.

[3] P. Wang, et al. "Distributed Control for Autonomous Operation of a Three-Port AC/DC/DS Hybrid Microgrid," in IEEE Transactions on Industrial Electronics, vol. 62, no. 2, pp. 1279-1290, Feb. 2015.

[4] K. A. Alobeidli, et al. "Novel Coordinated Voltage Control for Hybrid Micro-Grid With Islanding Capability," in IEEE Transactions on Smart Grid, vol. 6, no. 3, pp. 1116-1127, May 2015.

[5] A. Camacho, et al. "Reactive Power Control for Distributed Generation Power Plants to Comply With Voltage Limits During Grid Faults," in IEEE Trans. on Power Electronics, vol. 29, no. 11, Nov. 2014.

[6] S. Chaudhary, et al. "Negative sequence current control in wind power plants with VSC-HVDC connection," IEEE Trans. Sustainable Energy, vol. 3, no. 3, pp. 535–544, Jul. 2012.

[7] Y. Mohamed and E. El-Saadany, "A control scheme for PWM voltage source distributed-generation inverters for fast load-voltage regulation and effective mitigation of unbalanced voltage disturbances," IEEE Trans. Ind. Electron., vol. 55, no. 5, pp. 2072–2084, May 2008.

[8] Abdul Motin Howlader, Tomonobu Senjyu, "A comprehensive review of low voltage ride through capability strategies for the wind energy conversion systems", Renewable and Sustainable Energy Reviews, Volume 56, April 2016, Pages 643-658, ISSN 1364-0321.

[9] Mohammadalizadeh-Shabestary M., et al. "A general approach for optimal allocation of FACTS devices using equivalent impedance models of VSCs" International Transactions on Electr. Energ. Syst., 25, 1187–1203, July 2015

[10] Hamed Hashemi Dezaki, et al. "A New Method based on Sensitivity Analysis to Optimize the Placement of SSSCs", Turkish Journal of Electrical Engg and Computer Sciences, Vol. 21, Issue 1, Dec. 2013.

[11] A.K. Pathak, M.P Sharma, Mahesh Bundele, A critical review of voltage and reactive power management of wind farms, Renewable and Sustainable Energy Reviews, Volume 51, Nov. 2015, pp. 460-471.

[12] M. Nasiri, J. Milimonfared, S.H. Fathi, A review of low-voltage ridethrough enhancement methods for permanent magnet synchronous generator based wind turbines, Renewable and Sustainable Energy Reviews, Volume 47, July 2015, Pages 399-415.