A VOLTAGE REGULATOR FOR POWER QUALITY IMPROVEMENT IN LOW VOLTAGE DISTRIBUTION GRIDS

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Abstract— This paper presents a voltage-controlled distribution static synchronous compensator (DSTATCOM)-based voltage regulator for low voltage distribution grids. The voltage regulator is designed to temporarily meet the grid code, postponing unplanned investments while a definitive solution could be planned to solve regulation issues. The power stage is composed of a three-phase four wire voltage-source inverter and a second-order lowpass filter. The control strategy has three output voltage loops with active damping and two dc bus voltage loops. In addition, two loops are included to the proposed control strategy: the concept of minimum power point tracking (MPPT) and the frequency loop.

Keywords: DSTATCOM, frequency compensation, minimum power point (MPP) tracker, power quality, static VAR compensators, voltage control, voltage regulation.

I. INTRODUCTION

Costumers connected at the end of low-voltage distribution grids may experience poor voltage regulation. According to Brazilian grid code [1], power companies have constrained deadlines (15 to 90 days) to restore the voltage levels at the point-of common coupling (PCC) if the voltages are outside the admissible levels. The time needed for permanent solutions, like grid restructuring or capacitor banks installation, to be operational may exceed the deadlines. In the case of failure to meet the deadlines, the power company has to refund every customer in the distribution grid during the time that the poor voltage regulation persisted [1].

Aiming to prevent refunds, a voltage regulator can be utilized as a temporary solution. The voltage regulator must have fast voltage regulation, reduced weight, and easy installation [2], [3]. Using the proposed solution, the grid power quality is reestablished and the PCC voltage is restored in a short period of time. In the meantime, the permanent solution can be planned and installed in an appropriate time frame. Once the definite solution is implemented, the voltage regulator can be disconnected from the grid and connected to another grid with similar problems.

In real applications, poor voltage regulation occurs when the PCC is far from the main grid transformer and the distance between the PCC and the transformer can easily be further than 100 m. Access to grid voltage information can be difficult to obtain. To meet the voltage regulation requirement, a voltage controlled DSTATCOM-based voltage regulator is proposed with shunt connection to PCC [2]–[9], as shown in Fig. 1. The shunt connection avoids power supply interruption while the voltage regulator is installed or disconnected. The proposed DSTATCOM allows the power company to postpone investments and enhances the flexibility of grid management.

2. PROPOSED SYSTEM

Voltage-controlled DSTATCOM can maintain the PCC voltages balanced even under grid or load unbalances. The PCC voltage is directly controlled by the DSTATCOM and sudden load changes have no significant impact in the PCC voltage waveforms. Moreover, the voltage-controlled DSTATCOM decouples the grid and the loads, serving as a low impedance path for harmonic distortions due the voltage-source behavior. Current harmonic distortions from the loads have small impact in the grid and vice versa. The grid current quality, therefore, is exclusively given by the grid voltage quality.

According to [3], angular position reference is required for the voltage-controlled DSTATCOM to work properly. Before the DSTATCOM starts its operation, synchronization circuits generate the angular position to the voltage regulator [8]–[10]. Once the operation begins, the voltage-controlled voltage regulator replaces the PCC voltage and the grid voltage frequency and angle are no longer available. PCC voltage frequency and angle are then determined by the voltage regulator. For a real application, due to the distance between the transformer and the PCC, only the PCC voltage should be measured to compose the voltage reference of the DSTATCOM.

In past years, the PCC voltage amplitude (VPCC) for reactive compensation methods was usually adopted as the nominal grid voltage [2], [5], i.e., 1.00 p.u. However, Brazilian grid code determines a maximum (1.05 p.u.) and a minimum (0.92 p.u.) voltage amplitude for low-voltage distribution grids [1]. The PCC amplitude can be

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viewed as a degree of freedom and the processed power can be reduced with a suitable control loop.

In this effort, Kumar and Mishra [8] propose a new method to determine the suitable PCC terminal voltage for reduction of the DSTATCOM power rating. The method is formulated according to the desired source current, aiming to achieve the unity power factor at the grid. However, this method requires information about the source current, grid resistance, and reactance.

3. SYSTEM CONFIGURATION

Kumar and Mishra propose another method to determine suitable VPCC using the positive-sequence components of the load current to compute the PCC voltage. In both cases, additional information is required, increasing the process complexity, number of sensors, and the cost of the solution. To maintain the easy installation feature and reasonable costs, it is convenient to set the PCC voltage, in which the processed power is minimal, without monitoring any load or grid information and using only internal signals of the DSTATCOM, such as the PCC voltages and DSTATCOM output currents.

This paper presents a voltage-controlled DSTATCOM-based voltage regulator for low voltage distribution grids, using a three-phase four wire voltage-source inverter (VSI) with an LC lowpass output filter, as shown in Fig. 2. Operation principles of the voltage-controlled DSTATCOM and the control strategy are presented. Additionally, two loops are included to the proposed control strategy: the concept of minimum power point tracking (MPPT) [6] and the frequency loop [11]. The MPPT avoids unnecessary reactive compensation, increasing the compensation capability. The frequency loop overcomes the practical difficulty of synchronization by correcting the frequency of the voltage reference.

This paper proposes the combination of both loops, providing to the power company a solution for the poor voltage regulation in real distribution grids with superior PCC voltage quality. Experimental results confirm the effectiveness of the voltage regulator and the features of both loops, separately and simultaneously.

4. SIMULATION ANALYSIS

The MPPT allows the voltage regulator to operate at the minimum power point, avoiding the circulation of unnecessary reactive compensation. The frequency loop allows the voltage regulator to be independent of the grid voltage information, especially the grid angle, using only the information available at the point-of-common coupling. Simulation results show the regulation capacity, the features of the MPPT algorithm for linear and nonlinear loads, and the frequency stability.

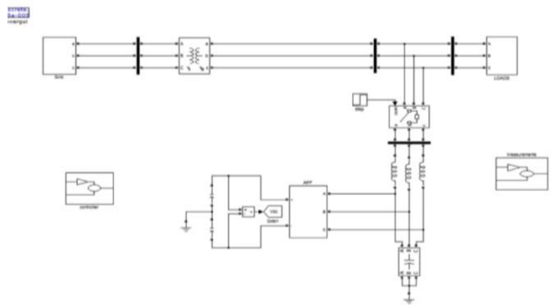
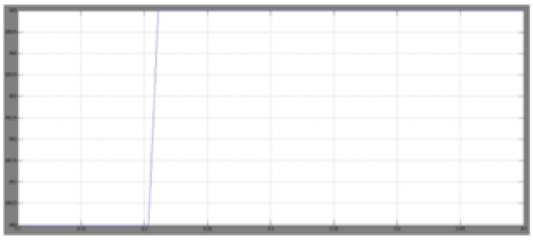
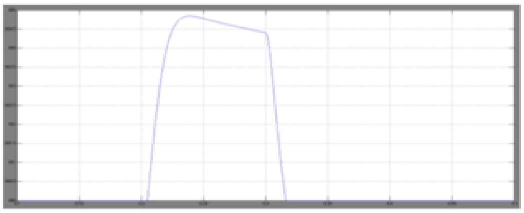


Fig.1. Simulation Implementation of proposed system



(a)



(b)

Fig.2. Total dc bus voltage during the grid frequency variation: (a) without and (b) with the frequency compensation

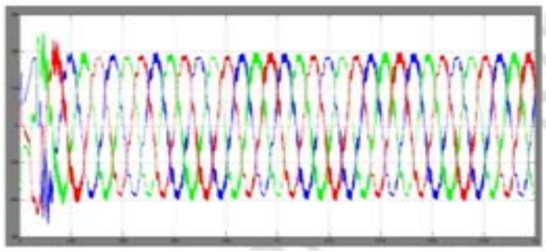


Fig.3. PCC voltages without compensation for nonlinear loads

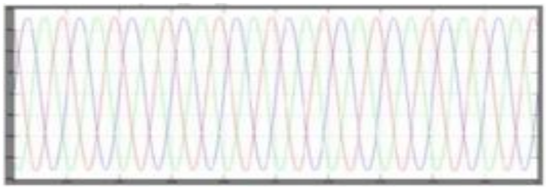


Fig.4. PCC voltages with compensation for nonlinear loads

The effect of the grid frequency step on the total dc bus voltage can be seen in Fig. 2 (a).

The dc bus voltage has low steady state error (around 6 V) because of a large total dc bus voltage controller bandwidth. With the fref update, Fig. 2 (b), the total voltage returns to nominal voltage. After the frequency step, the total voltage controller has a slope output. Without fref update, Fig. 3, the compensation angle decreases indefinitely, whereas with the frequency loop the compensation angle is constant, as shown in Fig. 3. However, the compensation angle does not return to the previous value. Errors between fref and fPCC are accumulated in the compensation angle and the controller output may reach its limits. If imminent, a protective routine is activated, which adds a constant factor to fref, bringing the compensation angle back to 0 radians. After that, the frequency loop returns to normal operation.

The MPPT can also be implemented in current-controlled DSTATCOMs, achieving similar results. The frequency loop kept the compensation angle within the analog limits, increasing the autonomy of the voltage regulator, and the dc bus voltage regulated at nominal value, thus minimizing the dc bus voltage steady state error. Simultaneous operation of the MPPT and the frequency loop was verified. The proposed voltage regulator is a shunt connected solution, which is tied to low voltage distribution grids without any power interruption to the loads, without any grid voltage and impedance information, and provides balanced and low-THD voltages to the customers.

5. CONCLUSION

A three phase DSTATCOM as a voltage regulator and its control strategy, composed of the conventional loops, output voltage and dc bus regulation loops, including the voltage amplitude andthe frequency loops. Simulation results demonstrate the voltage regulation capability, supplying three balanced voltages at the PCC, even under nonlinear loads. The proposed amplitude loop was able to reduce the voltage regulator processed apparent power about 51 % with nonlinear load and even more with linear load (80%). The mPPT algorithm tracked the minimum power point within the allowable voltage range when reactive power compensation is not necessary. With grid voltage sag and swell, the amplitude loop meets the grid code.

REFERENCES

1. ANEEL National Electric Power Distribution System Procedures— PRODIST, Module 8: Energy Quality. Revision 07, 2014.
2. M. Mishra, A. Ghosh, and A. Joshi, ―Operation of a DSTATCOM in voltage control mode, IEEE Trans. Power Del., vol. 18, no. 1, pp. 258– 264, Jan. 2003.
3. G. Ledwich and A. Ghosh, ―A flexible DSTATCOM operating in voltage or current control mode, IEE Proc., Gener., Transm. Distrib., vol. 149, no. 2, pp. 215–224, Mar. 2002.
4. T. P. Enderle et al., ―D-STATCOM applied to single-phase distribution networks: Modeling and control, in Proc. IEEE Ind. Electron. Soc. Annu. Conf., Oct. 2012, pp. 321–326.
5. C. Kumar and M. Mishra, ―Energy conservation and power quality improvement with voltage controlled DSTATCOM, in Proc. Annu. IEEE India Conf., Dec. 2013, pp. 1–6.
6. R. T. Hock, Y. R. De Novaes, and A. L. Batschauer, ―A voltage regulator based in a voltage-controlled DSTATCOM with minimum power point tracker, in Proc. IEEE Energy Convers. Congr. Expo., Sep. 2014, pp. 3694– 3701.
7. B. Singh, R. Saha, A. Chandra, and K. AlHaddad, ―Static synchronous compensators (STATCOM): A review, IET Power Electron., vol. 2, no. 4, pp. 297–324, Jul. 2009.
8. C. Kumar and M. Mishra, ―A multifunctional DSTATCOM operating under stiff source, IEEE Trans. Ind. Electron., vol. 61, no. 7, pp. 3131–3136, Jul. 2014.
9. C. Kumar and M. Mishra, ―A voltage-controlled DSTATCOM for powerquality improvement, IEEE Trans. Power Del., vol. 29, no. 3, pp. 1499– 1507, Jun. 2014.
10. S.-H. Ko, S. Lee, H. Dehbonei, and C. Nayar, ―Application of voltageand current-controlled voltage source inverters for distributed generation systems, IEEE Trans. Energy Convers., vol. 21, no. 3, pp. 782–792, Sep. 2006.
11. R. T. Hock, Y. R. De Novaes, and A. L. Batschauer, ―Frequency compensation for stand alone voltage-controlled DSTATCOM, in Proc. Brazilian Power Electron. Conf. Southern Power Electron. Conf., Dec. 2015, pp. 1– 6.
12. T. Esram and P. Chapman, ―Comparison of photovoltaic array maximum power point tracking techniques, IEEE Trans. Energy Convers., vol. 22, no. 2, pp. 439–449, Jun. 2007.
13. A. Al-Diab and E. C. Sourkounis, ―Multitracking single-fed PV inverter, in Proc. 15th IEEE Med. Electrotech. Conf., Apr. 2010, pp. 1117–1122.
14. M. de Brito, L. Galotto, L. Sampaio, G. De Azevedo, E. Melo, and C. Canesin, ―Evaluation of the main MPPT Techniques for photovoltaic applications, IEEE Trans. Ind. Electron., vol. 60, no. 3, pp. 1156–1167, Mar. 2013.
15. F. Ansari, A. Iqbal, S. Chatterji, and A. Afzal, ―Control of MPPT for photovoltaic systems using advanced algorithm EPP,‖ in Proc. 3rd Int. Conf. Power Syst., Dec. 2009, pp. 1–6.
16. S. Jain and V. Agarwal, ―Comparison of the performance of maximum power point tracking schemes applied to single-stage grid-connected photovoltaic systems, IET Electr. Power Appl., vol. 1, no. 5, pp. 753–762, Sep. 2007.

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ISSN NO:0377-9254

17. Y. Jiang, J. Qahouq, and T. Haskew, ―Adaptive step size with adaptiveperturbation-frequency digital MPPT controller for a single-sensor photovoltaic solar system, IEEE Trans. Power Electron., vol. 28, no. 7, pp. 3195–3205, Jul. 2013.

18. D. Sera, L. Mathe, T. Kerekes, S. V. Spataru, and R. Teodorescu, ―On the perturb-and-observe and incremental conductance MPPT methods for PV systems, IEEE J. Photovoltaics, vol. 3, no. 3, pp. 1070–1078, Jul. 2013.

19. N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, ―Optimization of perturb and observe maximum power point tracking method, IEEE Trans. Power Electron., vol.
20, no. 4, pp. 963– 973, Jul. 2005. 20. 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., to be published.

21. C. Manickam, G. P. Raman, G. R. Raman, S. I. Ganesan, and N. Chilakapati, ―Fireworks enriched P&O algorithm for GMPPT and detection of partial shading in PV systems, IEEE Trans. Power Electron., vol. 32, no. 6, pp. 4432–4443, Jul. 2017.

22. T. P. Enderle, ―Analise, projeto e implementac ´ ¸ao de um D-STATCOM ˜ para redes de distribuic¸ao monof ˜ asica, M.S. thesis, Dept. Electr. Energy ´ Process., Federal Univ. Santa Maria, Santa Maria, Brazil, 2012.