A review on Virtual Inertia emulation during Integration of Renewable Energy Sources

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Abstract: *Now a days for power generation it is essential to utilize Renewable Energy Sources. Carbon emissions are polluting our environment, so conventional sources of energy are to be limited and it is suggested to go for green and clean energy. Penetration of Renewable Energy Sources into gird is increased and it is a major concern for power engineers to maintain the power quality. Due to integration of Solar and Wind energy Systems in Grid, the power quality issues may arise, and grid becomes weaker. Power grid integration of renewable energy sources is achieved through power electronic converters. These converters decouple the source from load without providing inertia. As a result, inertia of the power grid decreases, resulting in undesirable load shedding and cascading failures under power imbalances. To preserve stability during contingency events, it is important to add inertia support to the grid. In the presented work power quality issues are described. Literature review on power quality issues and its mitigation techniques has been covered. An attempt has been made to discuss about virtual inertia of Inverter during Grid Integration of Renewable Energy Sources. Inertia emulation and its control strategy has been proposed. To assure and maintain good quality of power at all the levels it is needed to develop an efficient technique to resolve the power quality issues.*

Keywords: PQ power Quality, VSI Voltage Source Inverter, PV Photovoltaic, RE Renewable Energy

1. INTRODUCTION

To assure and maintain good quality of power at generation, transmission, distribution, and utilization of AC electrical power. Typically, some power quality problems related to the voltage at the point of common coupling (PCC) where various loads are connected are the presence of voltage harmonics, surge, spikes, notches, sag/dip, swell, unbalance, fluctuations, glitches, flickers, outages, and so on. However, some power quality problems related to the current drawn from the AC mains are poor power factor, reactive power burden, harmonic currents, unbalanced currents, and an excessive neutral current in poly phase systems due to unbalancing and harmonic currents generated by some nonlinear loads. Harmonic or Unbalanced currents generated by the local loads degrades the power quality and also results in parallel or series resonance, which will create instabilities in the system, if not taken care of. Sudden switching ON/OFF of loads, voltage fluctuations also degrade the power quality. Power Quality is the main problem in Renewable energy sources. It is a major concern to develop a solution for Grid integration to deliver variable renewable energy (RE) to the grid.

2. LITERATURE REVIEW

The large inertia of a traditional power system slows down system's frequency response but also allows decent time for controlling the system. Since an autonomous renewable microgrid usually has much smaller inertia, the control system must be very fast and accurate to fight against the small inertia and uncertainties. To reduce the demanding requirements on control, this paper proposes to increase the inertia of photovoltaic (PV) system through inertia emulation. The inertia emulation is realized by controlling the charging/discharging of the direct current (DC)-link capacitor over a certain range and adjusting the PV generation when it is feasible and/or necessary. By well designing the inertia, the DC-link capacitor parameters and the control range, the negative impact of inertia emulation on energy efficiency can be reduced. The proposed algorithm can be integrated with distributed generation setting algorithms to improve dynamic performance and lower implementation requirements. Simulation studies demonstrate the effectiveness of the proposed solution. [1]

In a DC microgrid (DC-MG), the dc bus voltage is vulnerable to power fluctuation derived from the intermittent distributed energy or local loads variation. In this paper, a virtual inertia control strategy for DC-MG through bidirectional grid-connected converters (BGCs) analogized with virtual synchronous machine (VSM) is proposed to enhance the inertia of the DC-MG, and to restrain the dc bus voltage fluctuation. The small-signal model of the BGC system is established, and the small signal transfer function between the dc bus voltage and the dc output current of the BGC is deduced. The dynamic characteristic of the dc bus voltage with power fluctuation in the DC-MG is analyzed in detail. As a result, the dc output current of the BGC is equivalent to a disturbance, which affects the dynamic response of the dc bus voltage. For this reason, a dc output current feed-forward disturbance suppressing method for the BGC is introduced to smooth the dynamic response of the dc bus voltage. By analyzing the control system stability, the appropriate virtual inertia control parameters are selected. Finally, simulations and experiments verified the validity of the proposed control strategy [2]

The gradual increase in power generation from renewable energy sources (RES), results in a reduction in power system inertia. It adversely affects the stable operation of the microgrids that contains high penetration of RES. The frequency stability concerns caused by the penetration of RES in the grid-connected system is controlled by synchronous generator (SG). Whereas in the stand-alone microgrid, which entails of RES deteriorates the frequency stability under power imbalances. The emulated inertia control (EIC) technology used for the power electronic inverter mimics the inertia of SG. EIC provides an effective solution for power systems with low inertia. This paper analyses the performance of EIC applied to the stand-alone microgrid that comprises of RES only. The utilization of EIC in stand-alone microgrid successfully addresses the frequency stability issues under solar irradiation and load variations. Furthermore, the small-signal stability analysis of the EIC is performed to analyze the stability under parameter variation. The simulation analysis shows that the frequency response and DC bus voltage is regulated in sudden disturbances with EIC efficiently as compared with constant voltage constant frequency (CVCF). The proposed EIC strategy is tested and compared with CVCF using the hardware in the loop (HIL) simulation with the help of real-time simulator OP5700 to verify the feasibility. [3]

The ongoing evolution of the power system towards a “SmartGrid” implies a dominant role of power electronic converters but poses strict requirements on their control strategies to preserve stability and controllability. In this perspective, the definition of decentralized control schemes for power converters that can provide grid support and allow for seamless transition between grid-connected or islanded operation is critical. Since these features can already be provided by synchronous generators, the concept of Virtual Synchronous Machines (VSMs) can be a suitable approach for controlling power electronics converters. This paper starts with a discussion of the general features offered by the VSM concept in the context of

SmartGrids. A specific VSM implementation is then presented in detail together with its mathematical model. The intended emulation of the synchronous machine characteristics is illustrated by numerical simulations. Finally, stability is assessed by analysing the eigenvalues of a small-signal model and their parametric sensitivities. [4]

The use of renewable energy sources either as distributed generators in public AC networks or as isolated generating units supplying is one of the new trends in power-electronic technology. The main objective of this paper is to identify the problems associated with grid connected solar power system. The main objective of this work is to study of the behaviors of the solar PV systems and the power quality issues in converters and inverter. Harmonics are created by the switching system of the power electronic circuit and can cause damage to power equipment on the utility side and sensitive loads on the customer side. This paper presents studies of anti-islanding control and protection and capacitive control and focused on application of electrochemical capacitor in power quality. [5]

Traditionally, wind power and solar photovoltaic (PV) power generation is non-dispatchable, and their normal operation relies on Maximum Power Point Tracking (MPPT) control. Therefore, it can be of highly disturbance to the system dispatch in particularly context of microgrids. To effectively fulfill dispatch command or market schedule, a novel cascading power sharing control (PSC) scheme is proposed to coordinate wind and solar PV power productions in microgrids while reducing the loss of renewable energy production involved. Considering different properties of wind and solar PV power generation systems, the discrepancies between dispatch command (market schedule) and actual renewable generation is firstly counterbalanced by adjusting wind power output via temperately storing or releasing kinetic energy of turbine rotors. Only when rotors of wind generator reach their limitations, should solar PVs begin to reduce their generation. The proposed PSC scheme is fully simulated in a microgrid with wind and solar PV, and the simulation results clearly indicate it can be more energy efficient than the traditional dispatch method while fulfilling the dispatch demand. [6]

Microgrids are modern, small-scale versions of the centralized electricity system which can generate, distribute, and regulate the flow of electricity to consumers at a local level. These microgrids are an ideal way to integrate renewable resources in the community level. In this paper, a microgrid model has been shown which focuses on community harvesting of power, bi-directional power capability and energy consumption management. These objectives are achieved using two distinct components of the microgrid: a smart meter at every end user and a smart station for each locality. These two essential components of the grid are integrated into the system using a microgrid architecture governed by an efficient communication technique and control algorithms. The proposed microgrid yields higher penetration of renewable sources into the grid and facilitates energy conservation. Architecture of a microgrid with renewable sources which is integrated with the grid, having parallel AC and DC systems, has been presented. This architecture demonstrates how the microgrid can be self sufficient in case of loss of power or shortage of power. The microgrid has been simulated using ETAP 12.0. [7]

Depletion of natural resources to meet power demands has revolutionized the use of Renewable Energy Sources (RESs). The paradigm shift from the centralized to distributed control is witnessed due to the Microgrids. Different configurations using smart grids and Microgrids are expected to ensure grid stability and security. Eventually, electricity market is subjected to change due to the projected changes in the grid architecture. This paper is a review on the Microgrids, its elements and the controllability. This paper discusses the major issues in the Microgrids, the factors affecting the choice of the Microgrid type and also various generation sources and their combination for reliable power quality and control. Recent developments with future trends are also addressed in this paper. [8]

3. PROPOSED STRATEGY

Power quality suffers due to pq issues but a novel solution can be computed via which we can inject artificial inertia through inverter.

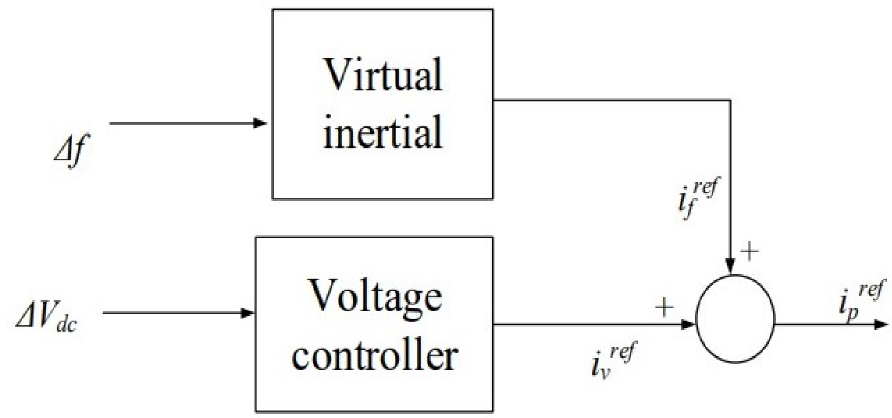

Fig. 1: Block Diagram of Control Strategy for Virtual Interia Control

To control the virtual inertia one can, design Voltage controller and can prepare proper control algorithms so that Inertia can be emulated. MATLAB software tool can be used to perform simulations and results.

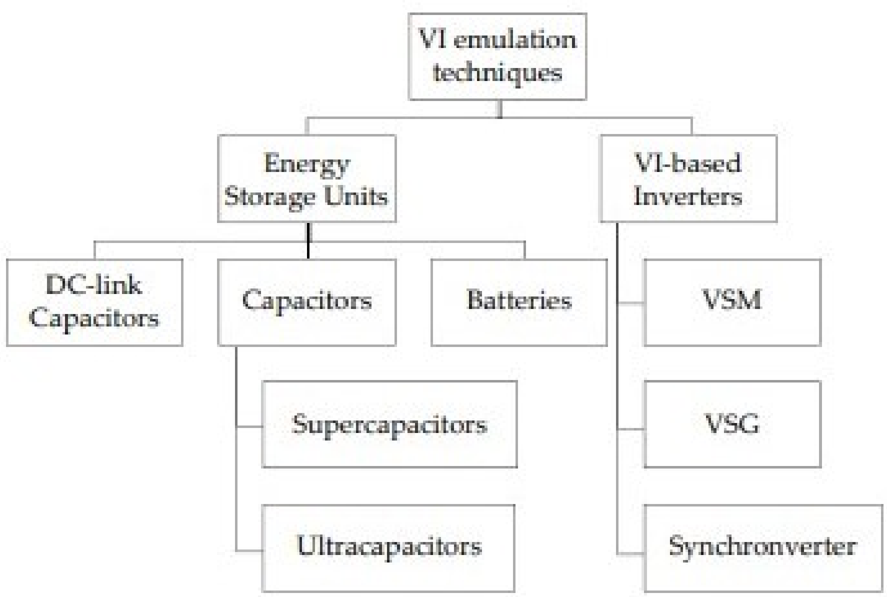

Fig. 2: Classification of Virtual Inertia Emulation Techniques

Using Energy storage Devices, VI based Inverters Inertia emulation can be performed, and smart grids can turn stable. To improve the transient response, design of inertia constant along with damping factor plays an important role. The moment of inertia based VSG control will be more fruitful if damping is added in controller. Damping helps to absorb the oscillation. VSG Controller with alternating virtual damping factor and alternating virtual inertia constant is also a novel solution to this issue. Maximum values of inertia constant and damping factor are used during acceleration period to reduce acceleration time. Minimum values are considered during deceleration period to boost the deceleration. In the case of VSG control, during sudden load change, there is a drop in the terminal voltage similar to SG due to the presence of virtual inertia. Inertia in SG and virtual inertia in VSG do not allow them to supply the power to load during a sudden change. A large amount of current flows, resulting drop in terminal voltage because of output impedance between the inverter and PCC terminal.

3. Conclusions

Power quality issues occurring due to integration of Renewable Energy Sources are discussed in the paper. Literature review is presented. A block diagram of control algorithm is proposed here. To improve power quality, virtual inertia control of inverter must be focused, and suitable inertia emulation techniques has to be implemented.

3. References

[1] *Won-Sang Im, Cheng Wang, Liming Liu, Distributed Virtual Inertia Based Control of Multiple Photovoltaic Systems in Autonomous Microgrid, IEEE/CAA JOURNAL OF AUTOMATICA SINICA, VOL. 4, NO. 3, JULY 2017*

[2] *Wu, Wenhua; Chen, Yandong; Luo, An; Zhou, Leming; Zhou, Xiaoping; Yang, Ling; Dong, Yanting; Guerrero, Josep M, A Virtual Inertia Control Strategy for DC Microgrids Analogized with Virtual Synchronous Machines, I E E E Transactions on Industrial Electronics, 2017*

[3] *Ratnam Kamala Sarojini, K. Palanisamy. Emulated Inertia Control for the Stand-Alone Microgrid with High Penetration of Renewable Energy Sources. INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH R. Kamala Sarojini and K. Palanisamy, Vol.10, No.2, June, 2020.*

[4] *Salvatore D'Arco, Jon Are Suul, Olav B. Fosso, A Virtual Synchronous Machine implementation for distributed control of power converters in SmartGrids, Electric Power Systems Research, Volume 122, 2015,*

[5] *Vikas khare, Dr. Savita Nema, Dr. Prashant baredar Power Quality Disturbances in Grid Connected Solar System & Its Prevention, International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 5, May 2012*

[6] *Yujun Li, Zhao Xu, Liansong Xiong, Guobing Song, Jianliang Zhang, Donglian Qi, Hongming Yang, A cascading power sharing control for microgrid embedded with wind and solar generation, Renewable Energy, Volume 132, 2019*

[7] *Karun Arjun Potty, Pramath Keny, Chandrasekhar Nagarajan, An Intelligent Microgrid with Distributed Generation, IEEE ISGT Asia 2013 1569814413*

[8] *Ritu Raj Shrivastwa, Ahmad Hably, Kaouthar Melizi, Seddik Bacha, Understanding Microgrids and Their Future Trends, 9781@IEEE2019*

[9] *R. K. Sarojini and P. Kaliannan, "Inertia Emulation Through Supercapacitor for a Weak Grid," in IEEE Access, vol. 9, pp. 30793-30802, 2021, doi: 10.1109/ACCESS.2021.3058951.*

[10] *H. T. Nguyen, G. Yang, A. H. Nielsen, and P. H. Jensen, ''Combination of synchronous condenser and synthetic inertia for frequency stability enhancement in low-inertia systems,'' IEEE Trans. Sustain. Energy, vol. 10, no. 3, pp. 997–1005, Jul. 2019.*

[11] *Q. Peng, J. Fang, Y. Yang, T. Liu and F. Blaabjerg, "Maximum Virtual Inertia From DC-Link Capacitors Considering System Stability at Voltage Control Timescale," in IEEE Journal on Emerging and Selected Topics in Circuits and Systems, vol. 11, no. 1, pp. 79-89, March 2021, doi: 10.1109/JETCAS.2021.3049686.*

[12] *Ratnam, Kamala & Kaliannan, Palanisamy & Sanjeevikumar, P. & Holm-Nielsen, Jens. (2019). Inertia emulation control technique-Based frequency control of grid-connected single-phase rooftop photovoltaic system with battery and super-capacitor. IET Renewable Power Generation. 14. 10.1049/iet-rpg.2019.0873.*

[13] *Sun, Dawei & Liu, Hui & Gao, Shunan & Wu, Linlin & Song, Peng & Wang, Xiaosheng. (2020). Comparison of Different Virtual Inertia Control Methods for Inverter-based Generators. Journal of Modern Power Systems and Clean Energy. 8. 768-777. 10.35833/MPCE.2019.000330.*

[14] *Q. Wu, E. Larsen, K. Heussen, H. Binder and P. Douglass, "Remote off-grid solutions for Greenland and Denmark: Using smart-grid technologies to ensure secure, reliable energy for island power systems," in IEEE Elec Magazine, vol. 5, no. 2, pp. 64-73, June 2017.*

[15] *H. Han, X. C. Hou, J. Yang, J. F. Wu, M. Su, and J. M. Guerrero, "Review of power sharing control strategies for islanding operation of ac micro-grids," IEEE Trans. Smart Grid, vol. 7, no. 1,pp: 200–215, Jan. 2016.*

[16] *L. Y. Lu and C. C. Chu, "Consensus-based secondary frequency and voltage droop control of virtual synchronous generators for isolated ac micro-grids," IEEE J. Emerg. Sel. Topics Circuits Syst., vol. 5, no. 3, pp. 443–455, Sep. 2015.*

[17] *Q. C. Zhong, and G. Weiss. "Synchronverters: Inverters That Mimic Synchronous Generators." IEEE Trans on Ind. Electron, vol. 58, no. 4 April 2011: 1259–67.*

[18] *M. Guan, W. Pan, J. Zhang, Q. Hao, J. Cheng, and X. Zheng. "Synchronous Generator Emulation Control Strategy for Voltage Source Converter (VSC) Stations." IEEE Trans on Power Systems. vol. 30, no. 6 Nov. 2015: 3093–3101.*

[19] *R. Aouini, B. Marinescu and M. Elleuch. "Synchronverter-Based Emulation and Control of HVDC Transmission." IEEE Trans on Power Systems, vol. 31, no. 1, Jan 2016: 278–86.*

[20] *L. Huang, H. Xin, Z. Wang, K. Wu, H. Wang, J. Hu, and C. Lu. "A Virtual Synchronous Control for Voltage Source Converters Utilizing Dynamics of DC-Link Capacitor to Realize Self-Synchronization." IEEE Journal of Emerging and Selected Topics in Power Elec, 2017.*