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Battery or Ultra-Capacitor Energy Storage System for Implementing the Power Management of Virtual Synchronous Generator

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***Abstract*: This paper presents implementation of battery or ultra-capacitor energy storage system for implementing the power management of virtual synchronous generator.**

***Keywords*: Ultra-Capacitor, Virtual Synchronous Generator**

1. Introduction

The growing access of renewable energy sources (RESs) has redefined the operation of modern power systems. In traditional power systems, synchronous generators are responsible for frequency regulation. During frequency events, they show inertial response, which can slow down the frequency dynamics by absorbing or providing the kinetic energy stored in the rotating part of synchronous generators and turbines. In future power systems, frequency regulation will be taken over by grid-connected power converters. However, conventional power converter operates as current sources to extract the maximum power from Renewable energy systems without providing any frequency regulation capability. An implementation of frequency regulation is known as virtual synchronous generator (VSG) or virtual synchronous machine (VSM). The fundamental idea behind this concept lies in the emulation of synchronous generators through the control of power converters. All the control loops in the VSG, e.g. inertia and speed governor, are realized by the ideal DC voltage source.

2. Selection of ESS (Energy Storage Systems)

An energy storage unit in an ESS is highly desirable that high energy density units can be used together with high power density units to increase the system operating efficiency, lifetime as well as reduce system costs. One such example is the battery/ultra-capacitor hybrid energy storage system (HESS), where the battery is used for compensation of low frequency power fluctuations and the ultra-capacitor is used for compensation of high frequency power fluctuations to show the advantages of different energy storage units. Low/high pass filters are normally in use to extract low/high frequency power fluctuations in the system. This paper proposes a battery/ultra-capacitor HESS to achieve the power management of VSGs. HESS is used to emulate the inertia coefficient, droop control, speed governor, and turbine of a VSG. The control parameters for the HESS can easily be designed based on the VSG model.

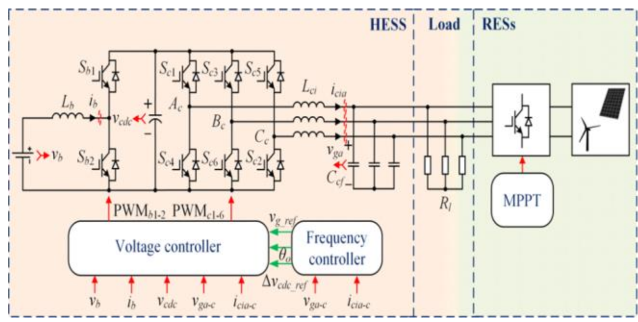

Fig. 1. Outline of the VSG model

3. Existing system

The existing power systems make use of the synchronous generators for the power fluctuations in the power grid. This method slows down the inertial response of the system since it absorbs and delivers the power to the system. Thus, it is proved to be not effective in its working. Thus the power converters are being brought into the action with the inclusion of the energy storage systems.

Disadvantages:

- Less efficiency
- High conversion time

4. Proposed system

This system makes use of virtual synchronous generator to provide fast compensation to the fluctuating power with the use of ultra-capacitor in the process and we also use battery connected hybrid circuit to provide long time power fluctuation. It also makes of PWM method of voltage control and frequency control

Advantages:

- Improved efficiency
- Less compensation time

5. Virtual inertia

A method to stabilize the frequency of the synchronous generators is to add virtual inertia to the distributed electricity generators (DEG). A virtual inertia can be obtained for any distributed electricity generator by adding short-term energy storage, combined with a suitable control mechanism for the power electronics converter, to the distributed generator. In this way distributed electricity generators can behave like "Virtual Synchronous Generators during short time intervals, and they contribute to the stabilization of the grid frequency during large fluctuations in the net loads of the synchronous generators in the grid.

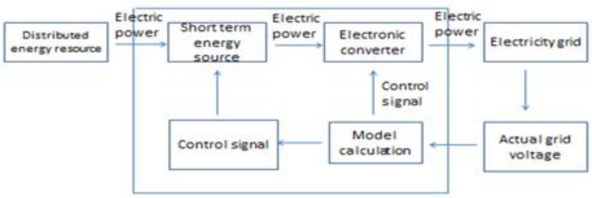

Fig. 2. VSG model based control

6. Virtual synchronous systems

The VSG principle is based on integrating the advantages of dynamic converter technology with those of the static and dynamic operating characteristics of electromechanical synchronous machines. The three distinct components of VSG are:

- PEC (which comprises of two power conversion stages, namely a DC to DC stage and a DC to AC stage)
- An energy storage device (battery, supercapacitor, flywheel, etc.)
- The control scheme that control the power exchange between energy storage and power system. This power exchange supports power system by preventing frequency fluctuations similar to SG rotational inertia.
- The VSG is commonly placed in-between a DG (or DC source) and the grid The DC source that goes to the VSG algorithm performs the function of SG by providing inertia and damping supports to the grid system.

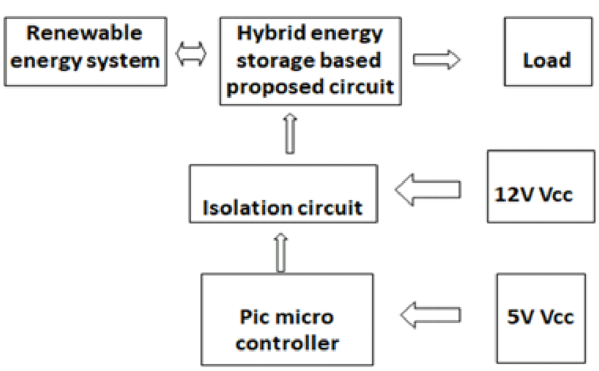

Fig. 3. Block diagram of Virtual synchronous systems

7. VSG characteristics

The following characteristics can be implemented:

- Prevent electricity grid instability and blackouts due to large frequency variations caused by decentralized generation, and the subsequent social chaos
- Retain safety in fault situations of an electricity grid with any given share of decentralized generation.
- Laydown a basis for intentionally islanding of low voltage area's with decentralized generation, in order to keep functioning the social structures in these areas.
- This gives low voltage areas with large amounts of DER the ability to operate inherently safe and maintain power quality.

8. Structure of PV system with VSG model control

A small energy storage device and an inverter are attached to the ordinary PV system. A conventional SG can absorb small disturbances in a power system by changing its rotational energy. However, PV generates electrical power not from mechanical rotational energy (no rotating mass). Therefore, in order to make the PV emulate the characteristics of the SG with a rotational inertia, it is required to equip the PV with an energy storage device. When the input power from the PV panel is higher than the output power, the energy storage device is in charging mode and in the reverse situation, it is in discharging mode. These behaviors enable PVs to emulate the change of the rotational energy of the SG. The control strategy of each converter/inverter is as follows.

DC/AC inverter connected to the power system:

- This inverter is controlled in order to make the PV copy the characteristics of the SG with the rotational inertia.
- DC/DC converter connected to the PV panel: This converter is controlled in order to keep the output from the Photo Voltaic panel constant. The difference between the output from the PV panel and the output to the power system is compensated by the energy storage device (battery and the ultra-capacitor).

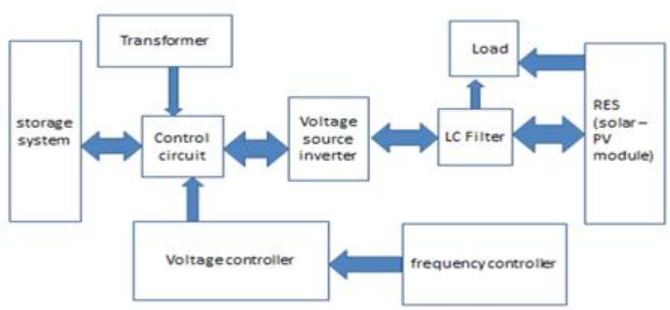

Fig. 4. VSG system integrated with solar module and energy system

9. Hard ware implementation

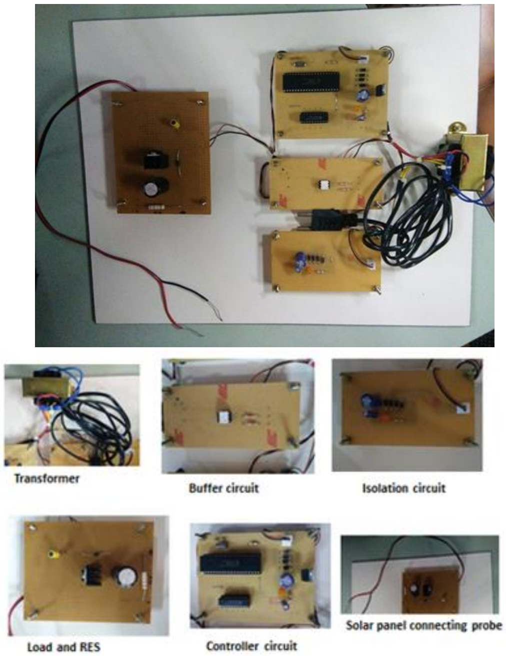

Fig. 5. Hardware setup

10. Simulation output

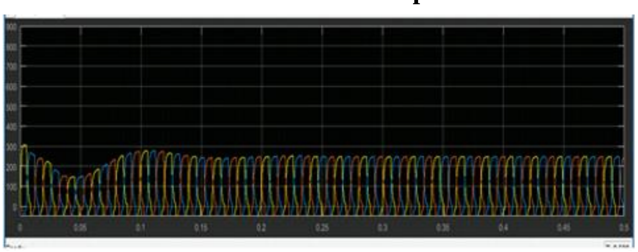

Fig. 6. Simulation output

11. VSG application

- Grid synchronization
- Power quality

12. Future scope

Researchers have begun to focus on the alternate source of energy for virtual inertia. The main attention is given towards the “Thermal Inertia" of heating, ventilation and air conditioning systems of commercial building. In data center, HVAC are installed to tap for inertial response in the future grid with large integration of renewable energy systems. Inertia is being deployed as the future service for power quality. While operating micro grid, one provides inertia services based on certain rules such as frequency deviation. The quality of services metrics which are proposed for cloud computing can be gathered for power systems to measure the power quality in terms of inertial response.

13. Conclusion

The continuous growth in the integration of DGs in the power system network, for the reason of stability and sustainability, has contributed to the imbalance in traditional power system structure. The DGs systems have little or no inertia and damping problem as found in the conventional SGs, thereby causing a total decrease in the entire system inertia. This paper has presented an overview of the crucial issues regarding the influence of the DGs in power system network, the VSG control schemes and their applications, the challenges that are needed to be addressed and the necessary improvement in the existing control scheme.

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References

[1] Vu Van T., Van Dommelen D. M., Belmans R, "Penetration level of distributed energy resources with anti-islanding criteria and secure operation of power system", 2006 IEEE Power Engineering Society Meeting, Montreal, Canada, June 2006.
[2] Sakimoto K, Sugimoto K, Shindo Y, “Behavior of virtual synchronous generator at disconnection from grid,” in 2014 National convention record Japan: IEEE, pp. 437–438, 2014.
[3] Pepermans G., Driesen J., Haeseldonckx D., Belmans R., D'Haeseleer W., "Distributed generation: definition, benefits and issues," Energy Policy, vol. 33, no. 6, pp. 787-798, April, 2005.
[4] B. Lindgren, “Topology for Decentralized Solar Energy Inverters with a Low Voltage AC-Bus,” Proceedings 8thEuropean Conference on Power Electronics and Applications (EPE-99), Lausanne, Switzerland 1999.