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

# Smart Power Grids Using Bidirectional Synchronous-VSC Comprehensive Controlling Framework for Incorporating VSCs

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***ABSTRACT:***

***This paper presents a new control strategy for voltage-source converters (VSCs) in the frequency-angle domain which enables dc-link voltage regulation via frequency and load angle adjustment. A major advantage of the proposed controller is emulating the behavior of synchronous machines (SMs) with proper regulation of dc-link voltage which eases integration of VSCs interfacing distributed and renewable generation units into ac systems in the presence of conventional SMs. A cascaded frequency, angle and virtual torque control topology is developed to emulate the mechanical behavior of an SM which offers synchronization power to eliminate the need for a phase-locked-loop after initial converter synchronization, and damping power dynamics to damp power oscillations; and presents frequency dynamics similar to SMs, thus it introduces some inertia to the grid. The controller presents high stability margin and fast dc-link voltage regulation, whereas it can provide frequency support in the ac-side during contingencies. Frequency and voltage amplitude are adjusted by two separate loops. Two different variants are proposed for dc-link voltage control; namely direct dc-link voltage control and indirect dc-link voltage control via a dc-link voltage controller. Small-signal dynamics, analysis, and design process are presented. Both simulation and experimental results are provided to validate the controller effectiveness.***

**Index Terms—Control topology, dc-link voltage regulation, power control, voltage-source converters (VSCs).**

## INTRODUCTION:

NOWADAYS, because of high penetration levels of renewable energy resources, the paradigms of microgrids (MGs) and distribution generation (DG) are gaining vital role in power and distribution systems. MGs are categorized as ac MGs, dc MGs, and hybrid ac–dcMGs. Since a considerable portion of renewable energy resources, such as wind turbines, photovoltaic (PV), fuel cells and energy storage systems, and many modern loads such as communication technology facilities, data centers, and motor drives is dc-type, dynamics and controls of rectifiers and dc MGs are gaining high interest . However, in dc grids, many generation units such as wind turbines must be interfaced to the utility grid via electronically interfaced (EI) rectifiers. In addition, several modern ac loads are coupled to ac grids through back-to-back rectifier-inverter to provide variable frequency operation. Based on predictions given in [2], the resistive load share will be significantly reduced whereas the EI loads share will increase to of the total load by 2015. The conventional control topologies for three-phase converters are the voltage-oriented vector control and direct power control . The *dq* components of the current vector are regulated by a controller generating appropriate values for the converter *dq* voltage components. A phase locked-loop (PLL) is required to transform current and voltage variables from the *abc* frame to the *dq* frame. It is also feasible to implement the controller in the stationary frame or the *abc* frame using a proportional-resonant (PR) controller . An alternative control strategy is to use direct power control in which voltage components are adjusted based on active and reactive power errors.

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None of these methods, however, can directly control the frequency and the load angle.

**Existing System:**

In this paper, a control topology is proposed in which the frequency, load angle, and dc-link voltage are control variables rather than conventional vector controls which employ current components for dc-link voltage regulation and reactive power control. Thus, direct control of frequency, angle, and dc-link power and voltage is available which in turn provides easier controllability and system analysis. In the following, the control topology is described in detail. One of the main goals in VSC control is to maintain the dc-link voltage constant. Assuming a lossless VSC, the input ac power is equal to the dc power ; and the reactive power does not correspond to any real power exchange with the converter dc-side. The power-circuit part involves the VSC and the connecting impedance between VSC and the grid and is similar to conventional grid-connected VSC systems. Usually in high power VSCs used in power systems, which are the main scope of this paper, a pure inductor without capacitor is used as output filter. If the VSC is employed to regulate frequency variations during contingencies, an energy storage system can be installed at the dc-link to transfer power from the energy storage device to the grid to damp frequency and angleoscillations. However, for rectifier applications in which no energy storage is used, the active load can be used for power exchange with the grid.

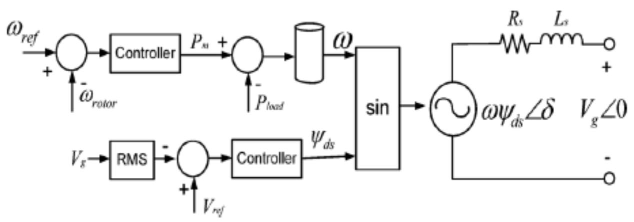


Fig. 1. SM principal operation and control concept.

**Proposed System:**

To investigate the dynamic performance and transient response of the system, a small-signal model is developed. The small-signal analysis gives insights on how controller variables variation affects the stability and convergence characteristics of the controlled variables. It also helps in optimum tuning of controller parameters to reach the best tradeoff among design objectives. In the following, the small-signal analysis of the frequency controller shown in Fig. 2(b) is presented. The voltage control loop used for reactive power regulation, shown in Fig. 3(a), is analyzed. The small-signal model of other topologies can be obtained in a similar way.

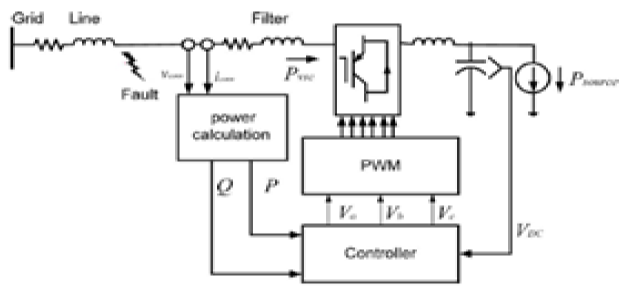


Fig Schematic view of the simulated system.

**CONTROLLER DESIGN GUIDELINES**

The transfer function of the controller can be obtained. The controller natural frequency should be chosen much smaller than the switching frequency Another concern related to is the system rise time. Usually, the most inner controller bandwidth is selected to be less than 20% of the switching frequency. Unlike real SMs, the rotational momentum and friction factor can be selected equal to values that are not possible for physical electrical machines. The larger means the higher stored energy; however, to provide this energy, more short-term energy storage or equivalently In summary, a two-step design process is proposed. In the first step, the approximate values of the design parameters are determined using and, in the second step, small signal analysis is used for accurate tuning of control parameters.

**SIMULATION RESULTS**

This section presents detailed simulation results of the proposed control system. The simulated system is shown in Fig. 7. Simulation studies are carried out in the MATLAB/SIMULINK environment. Different conditions in both generative and rectification modes

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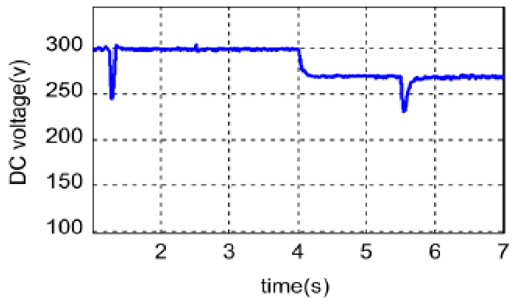
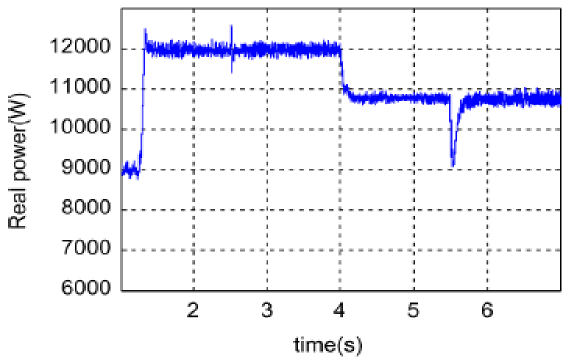
are considered to show effectiveness and generality of the controller in all cases. The system parameters are given in Table I. The controller parameters are chosen based on the design process given in Section III and the small-signal analysis to offer satisfactory performance. The system is simulated under various scenarios of VSC operating conditions. Three scenarios are taken into account; load/generation power change, dc-link voltage reference change, and grid voltage change in both rectifying and inverting modes.




(a)




(b)

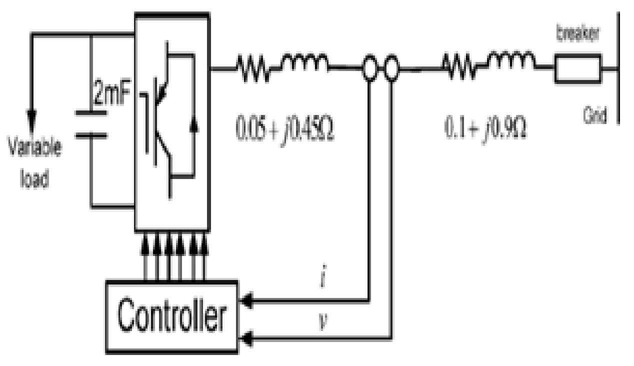



Fig. Experimental setup parameters.

## CONCLUSIONS

In this paper, a novel control topology for VSCs has been developed in the frequency-angle domain to regulate the dc-link voltage while providing

1) synchronizing and damping power components and

2) emulated inertia function to the VSC. These features are highly desirable in VSCs interfacing renewable energy resources, dcMGs and active converter-interfaced loads to weak ac systems. The proposed synchronous control topology.

3) Since the controller presents damping and synchronizing power dynamics, similar to SMs, it can automatically synchronize itself with the grid and tracks its variations, thus there is no need for a PLL after initial synchronization.

4) In the modeling and design process, the dc-link voltage dynamics are taken into account which provides a more general and accurate control framework.

5) The controller offers fault-ride-through capability which enhances the overall system reliability. Both simulation and experimental results have been provided to validate controller performance under a wide range of typical operating conditions

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