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Closed Loop Voltage Control of a Three-Phase PWM CSR for SMPS Applications

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Abstract:

Switched-mode power supplies have applications in various areas. A switched-mode supply is chosen for an application when its weight, efficiency, size, or wide input range tolerance make it preferable to linear power supplies. Initially the cost of semiconductors made switch-mode supplies a premium cost alternative, but current production switch-mode supplies are nearly always lower in cost than the equivalent linear power supply. It maintains a constant output voltage irrespective of change in load current or line voltage. Many different types of voltage regulators with a variety of control schemes are used. With the increase in circuit complexity and improved technology a more severe requirement for accurate and fast regulation is desired. This has led to need for newer and more reliable design of dc-dc converters. The dc-dc converter inputs an unregulated dc voltage input and outputs a constant or regulated voltage. The regulators can be mainly classified into linear and switching regulators. All regulators have a power transfer stage and a control circuitry to sense the output voltage and adjust the power transfer stage to maintain the constant output voltage. Since a feedback loop is necessary to maintain regulation, some type of compensation is required to maintain loop stability. In this paper, a PI controller is designed and analyzed for a buck-boost converter. Stability analysis and selection of PI gains are based on the closed-loop error dynamics. PI controller, being the most widely used controller in industrial applications, needs efficient methods to control the different parameters of the plant. The output of the conventional PID system has a quite high overshoot and settling time.

In this project, three-phase pulse width modulation (PWM) current source rectifiers (CSRs) with a closed loop voltage regulation capability that applied as dc voltage power supply include capacitors in the dc bus to obtain dc output voltage, control strategy is proposed. Here dynamic model of the three-phase PWM CSR is established in the dq-rotating frame for capacitive load applications.

Keywords:

Active damping, current source rectifier (CSR),dc voltage power supply, dynamic model, state variable feedback control.

INTRODUCTION:

The traditional three-phase PWM CSR usually employs an inductor as the dc link and serves as a current source. Their models already exhibit characteristics of high order and nonlinearity, even in the dq-rotating frame [10]–[13]. Common control strategies include PID control, nonlinear control, and predictive control. PID control has a simple structure and high robustness, though it is difficult to optimize the control parameters due to system nonlinearity. Nonlinear methods aim to linearize the system model [11], but they are not robust. Predictive control strategies rely on the accuracy of the system model [12]. Overall, to simplify the CSR model is always an effective way to achieve good performance. In [10], the CSR is considered as a controlled ac current source when viewed from the ac side and treated as a controlled dc voltage source. when viewed from the dc side. This helps to achieve separate control of the ac and dc sides.

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In [13], an effective model in the dq-rotating frame is proposed by setting the q-axis of the ac filter capacitor voltage vector to zero, which also successfully realizes separate control of the dc and ac sides. **P**hase controlled rectifiers are widely used for industrial applications largely because of their low cost; however, due to their low-power factor and high current harmonics they are being gradually replaced by pulse width modulation (PWM) rectifiers [1]–[3]. There are two main choices of PWM rectifiers: 1) voltage source rectifiers (VSRs) and 2) current source rectifiers (CSRs). VSRs are more popular and can be found in a wide range of applications, from low power to high power, while the CSRs have also been successfully applied to high-power ac motor drives when combined with current source inverters [3]–[6]. Due to the losses incurred by and the cost of the dc side inductor, CSRs have been ignored in low and medium voltage level circuits. Nonetheless, CSRs have many inherent advantages compared with VSRs. First, in terms of the amplitude of the grid and dc link voltages, CSRs exhibit a step-down conversion.

When used as dc voltage source, CSRs can output a lower dc voltage without a bulky, grid-side step-down transformer, as is usually employed in VSRs. Second, because of the inherent current regulation in CSRs, parallel operation and short-circuit protection can be easily achieved. According to [3], the effective stiffness of the generator shaft is inversely proportional to the pole pairs, which means that the larger number of pole pairs the generator has, the “softer” the driven-train shaft becomes. Hence, the torsional twist of the shaft for a multipole permanent-magnet synchronous generator (PMSG) may significantly affect the operation of the whole wind-energy conversion system (WECS) [3], [4]. Because of the torsional characteristic of the drive train, the generator speed is prone to oscillation whenever the system gets excited by mechanical or electrical load changes [5]. The oscillation leads to the fluctuation in the output power and the increase of mechanical fatigue of the drive train.

Typical frequency of the oscillation is as low as 0.1–10 Hz which tends to coincide with the frequencies associated with power system interarea oscillations (0.1–2.5 Hz). For applications such as microgrid, MMC, and UPS, CSRs are required to function as dc voltage sources [14]. A dc capacitor is, therefore, connected after the dc link inductor to convert the current source into a voltage source.

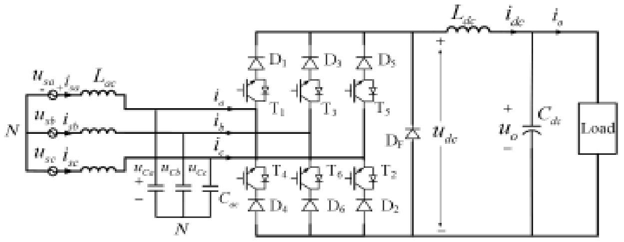

Fig. 1. Circuit of the three-phase CSR as a dc voltage source.

SMPS APPLICATIONS:

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power), to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.

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Pulse Width Modulation:

Pulse-width modulation (PWM) is the basis for control in power electronics. The theoretically zero rise and fall time of an ideal PWM waveform represents a preferred way of driving modern semiconductor power devices. With the exception of some resonant converters, the vast majority of power electronic circuits are controlled by PWM signals of various forms. The rapid rising and falling edges ensure that the semiconductor power devices are turned on or turned off as fast as practically possible to minimize the switching transition time and the associated switching losses. Although other considerations, such as parasitic ringing and electromagnetic interference (EMI) emission, may impose an upper limit on the turn-on and turn-off speed in practical situations, the resulting finite rise and fall time can be ignored in the analysis of PWM signals and processes in most cases. Hence only ideal PWM. There are number of PWM methods for variable frequency voltage-sourced inverters. A suitable PWM technique is employed in order to obtain the require In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. Inverters employing PWM principle are called PWM inverters. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is modulated to obtain inverter output voltage control and to reduce its harmonic content. The advantages possessed by PWM technique are

1. The output voltage control with this method can be obtained without any additional components.

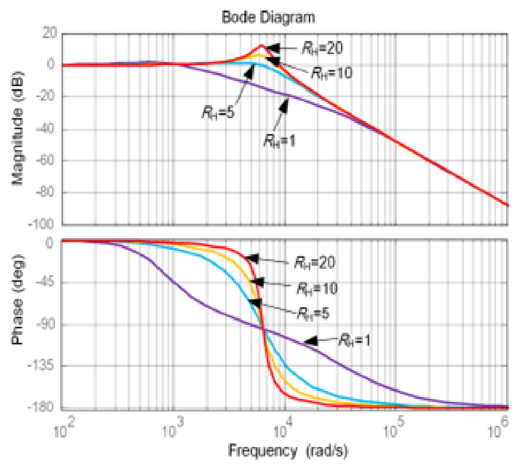
2. With this method, lower order harmonics can be eliminated or minimized along with its output voltage control. As higher order harmonics can be filtered easily, the filtering requirements are minimized.

The main disadvantage of this method is that the SCRs are expensive as they must possess low turn on and turn off times. This is the most popular method of controlling the output voltage of an inverter in industrial applications.

Benefits include – Microprocessor control – Efficient use of power – Tolerance to analog noise – Not susceptible to component drift.

Design of AC Side Controller:

The simplest way to damp resonance in the ac side LC filter is to add a resistor R Damp across the capacitor, While these resistors result in high losses, as shown in Fig. 5(b), active damping methods emulate damping resistance—effectively giving a virtual resistance of RH = R Damp—by making the CSR bridges produce an additional PWM current I Damp added to id [22]. The virtual resistor controller is shown in Fig. 6. It calculates I Damp after measuring u Cd. The resonance of the ac side LC filter will produce harmonics in the capacitor voltage with frequency near ωac, which appears as the ωac −ωs component in uCd. The fundamental component of capacitor voltage will be dc value in uCd, which produces dc value in iDamp. However, it is not useful for resonance damping but otherwise may cause over modulation. Therefore, a high-pass filter (HPF) should be applied to filter out this dc component



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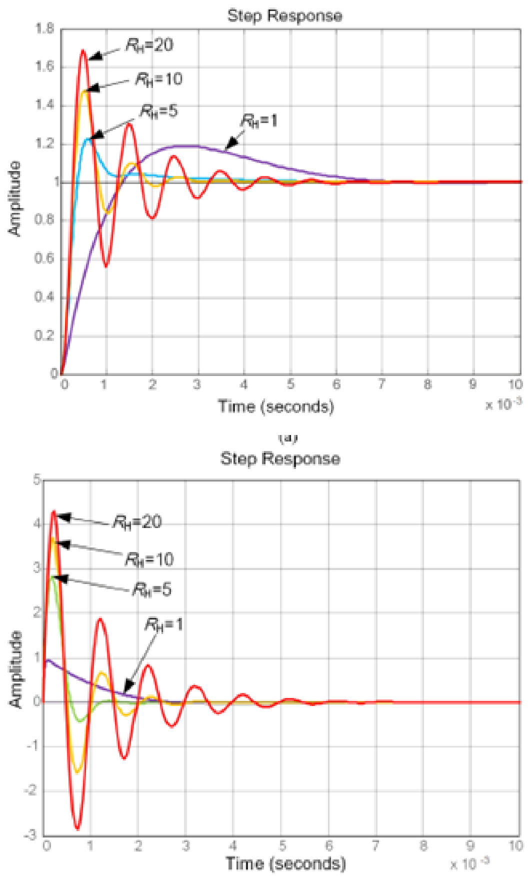
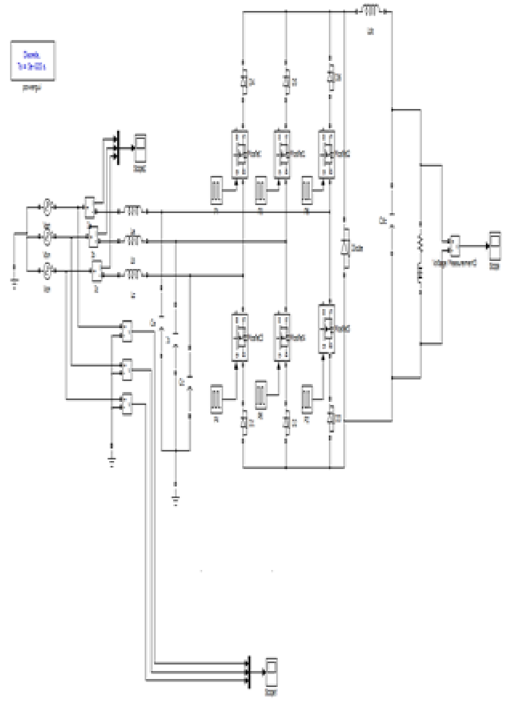


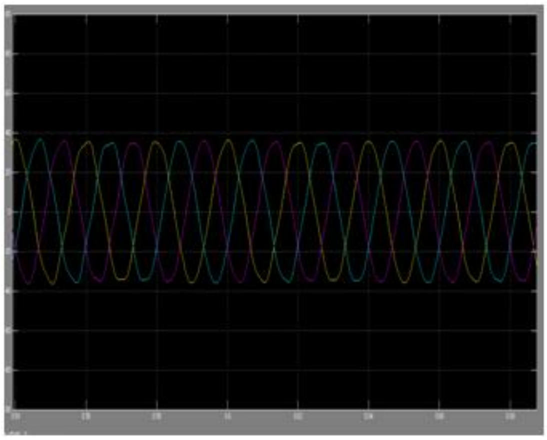
SIMULATION RESULTS:

The performance of the proposed control strategy is first evaluated in MATLAB/Simulink by comparing open-loop control with closed-loop control using the system parameters shown in Table I. The steady-state value of the dc bus voltage (u0) is 432 V. Since the grid voltage can only be measured at the Point of Common Coupling point, a small internal impedance for the grid is assumed in the simulation. waveforms for the step-up to full load under open-loop control. During step-up, a large resonance is apparent in the voltage u0 of the dc side and in the current isa of the ac side. In addition, on the ac side, the waveform of the grid current isa is unsatisfactory.

Main Power Circuit:



SOURCE WAVE FORMS:



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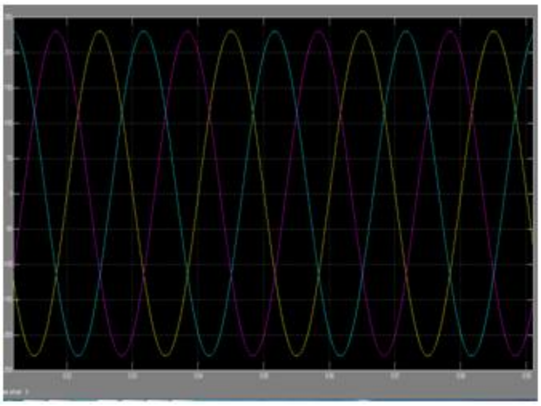
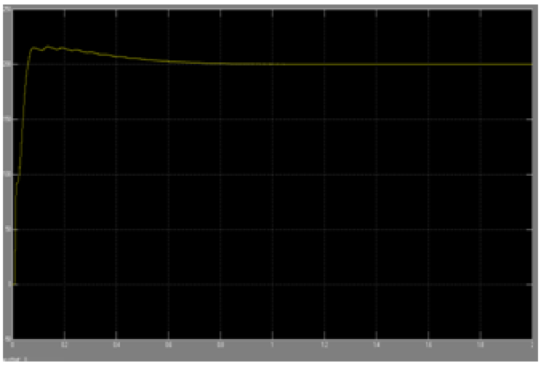
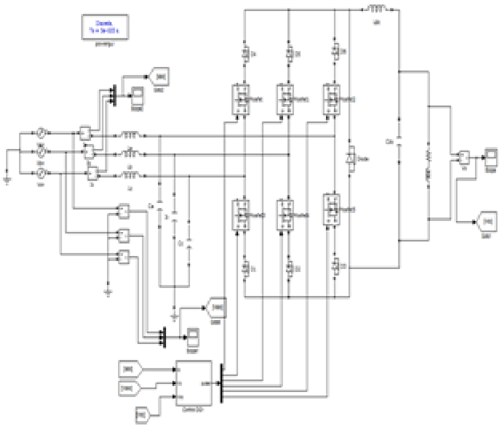
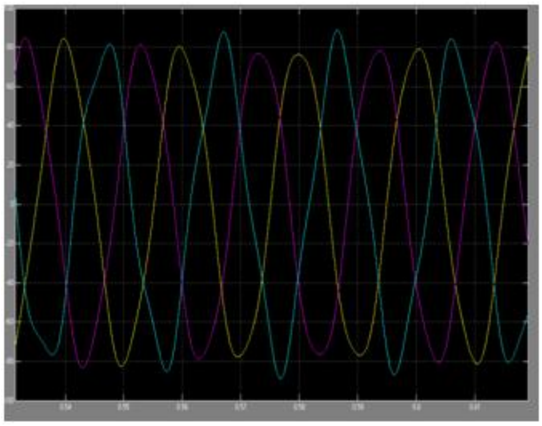


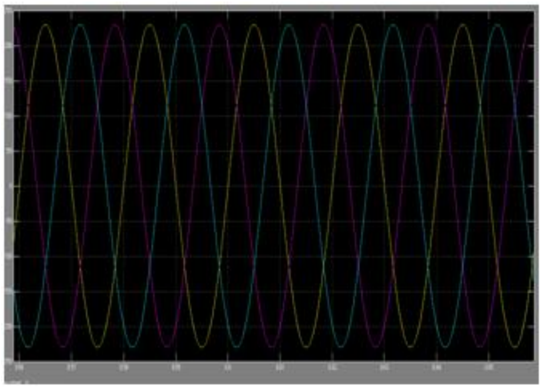


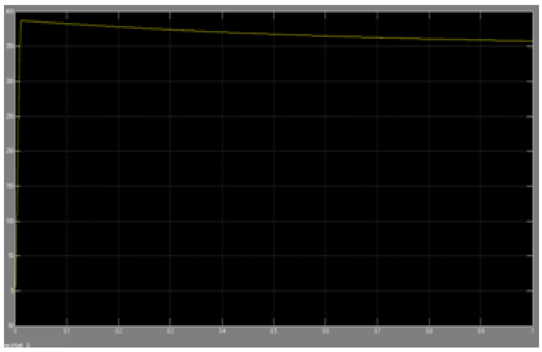
EXTENSION SIMULATION RESULTS:



OUTPUT WAVE FORMS:







CONCLUSION:

In this paper, a dynamic average model of a three-phase PWM CSR in the dq-rotating frame for dc voltage source applications was established. By aligning the vector of the ac capacitor voltage to the d-axis, the dc side and the ac sides can be decoupled. Decoupling facilitates the design of the control algorithm, as the ac and dc sides can be designed and controlled separately. Based on this model, a control strategy composed of a state-variable feedback control strategy for the dc side and an active damping control strategy for the ac side is proposed. Further, a unity power factor is achieved by regulating the q-component of the PWM bridge currents.The validity of the proposed model and control strategies is verified by simulation and experimental results wherein the system exhibits good dynamic and static performance.

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