Sliding Mode Control for Three Level NPC Converter

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***Abstract*:- A two-stage control scheme consisting of an adaptive-gain second-order sliding mode (SOSM) controller and a switched high-gain observer (HGO) is proposed for the three-level neutral-point-clamped (NPC) converter. The adaptive gain SOSM control method is applied both in the voltage regulation loop and instantaneous power tracking loop, thus the boundary of the disturbance derivative does not need to be known a priori. Compared with the fixed-gain SOSM, it provides a faster dynamic and a better steady state response for the NPC converter. On the other hand, the conventional disturbance compensation observer used in the power system suffers from the adverse effects of measurement noise, which limits the performance of the observer. A switched HGO is combined with the adaptive gain SOSM controller in the voltage regulation loop to address this issue. By using a switched observer gain, the switched HGO greatly diminishes the performance degradation induced by the inevitable measurement noise.**

INTRODUCTION

During the past few years, the active front-end (AFE) converters have been considered as a promising alternative in many industrial applications such as motor drives and dc microgrids (MGs). In comparison with the conventional diode-based rectifier, the AFE presents reliable dc-link voltage

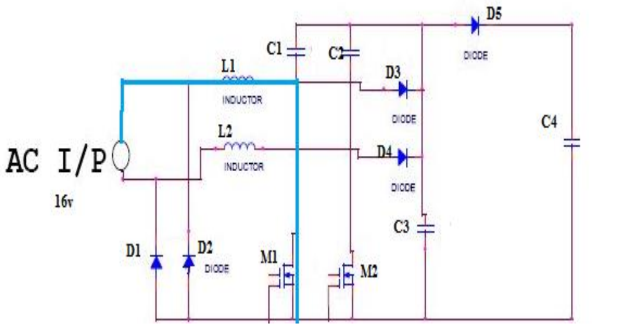
regulation, bi-directional power flow and low current harmonic distortion. In the grid-connected AFE converter applied in a common dc MG is presented, and a solar photovoltaic system, an energy storage system, wind turbines and dc loads are included. The grid-connected AFE rectifier, as an interface between the ac grid and dc MG, always play a crucial role in the whole system. The three-level neutral-point-clamped (NPC) converter, as a high performance multilevel topology, is becoming a promising alternative for the grid-connected converter in dc MGs, because of its advantages over the conventional two-level converter like higher voltage rate and better waveform quality.

The control of three-level NPC converter still remains a challenging issue both in academic and industrial areas owing to the strong nonlinear nature of the system model, variation of the system parameters and the unknown external disturbances. To deal with these issues, numerous advanced nonlinear control approaches have been proposed, such as model predictive control, passivity-based control, neural networks control and SMC. Among them, the SMC is a promising alternative to manage the NPC converter due to its characteristics including finite-time convergence and the robustness regarding the system uncertainties. In spite of these attractive features, the conventional SMC inevitably induces the chattering problem, which has an adverse effect on the operation of power system. One attractive solution for the chattering attenuation is the super-twisting algorithm, which is one of the SOSM control. The discontinuous function used in common SMC is hidden under the integral in this algorithm, thus the chattering phenomenon is greatly attenuated. In a SOSM controller is proposed for the LC-coupling hybrid active power filter as a current controller, which provides a good dynamic and steady state performance. In a SOSM controller is applied both in voltage and current loop for the three-level NPC converter. In addition, the application of the SOSM controller can also be found in grid-connected converter DC-DC converter and motor drive. Nevertheless, although the SOSM controller is an attractive solution, it requires the information of the boundary of the disturbance derivative. In addition, the gains of the SOSM controller cannot be too high to prevent a large amplification of chattering, which limits the behavior of the SOSM controller. To solve the aforementioned challenges, in this paper, an adaptive-gain SOSM based control strategy for the three level NPC converter is proposed. In comparison with the SOSM controller, this method does not need the knowledge of the boundary of the disturbance derivative.

Additionally, this algorithm does not over-estimate the values of the gains in SOSM thanks to the existing adaptive law, thereby the control gains will be adjusted automatically to prevent unexpected chattering magnification. On the other hand, the dc bus plays an important role in dc MGs; thereby it is crucial to assure a stable dc-link voltage. However, the connection or disconnection of the dc load, and the power fluctuations in energy sources, both may induce voltage fluctuations in the dc bus and affect the operation of the whole dc MGs. Therefore, it is necessary to introduce a disturbance compensation technique to improve the disturbance rejection ability of the power system. In an ESO is integrated into the voltage loop to attenuate the fluctuations in the dc-link voltage caused by the external perturbations. In a ESO based H1 control scheme is designed for the dc voltage regulation with unknown disturbances. In an overview of the HGO is given, and the application of HGO used in the permanent magnet synchronous motor as a disturbance compensation technique is also introduced.

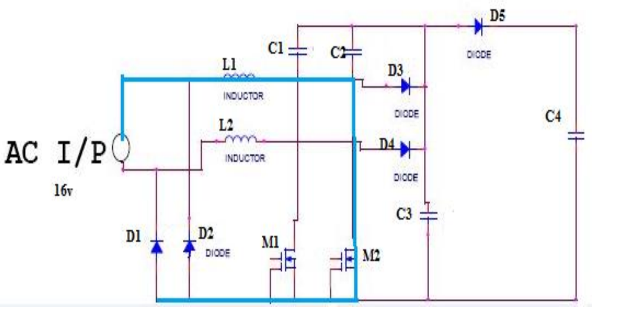
MODES OF OPERATION

MODE 1:



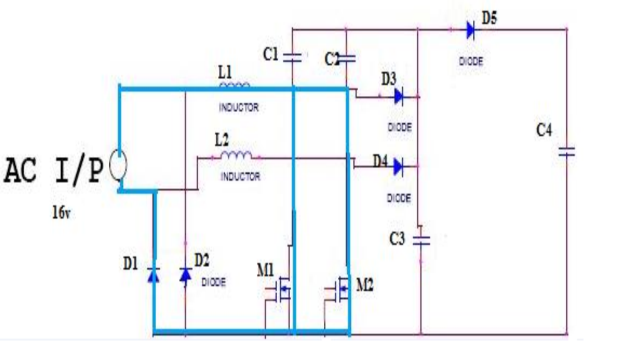
This above circuit the ac input is given to the input of SEPIC rectifier unit. The Rectifier unit converts AC to DC power and Turn ON a M1 Switch. That time M2 switch is turn OFF. Those processes occur M1 activated and C1 also charging and boosting the SEPIC output and energies the overall output.

Mode 2:



This above circuit the ac input is given to the input of SEPIC rectifier unit. The Rectifier unit converts AC to DC power and Turn ON a M2 Switch. That time M1 switch is turn OFF. Those processes occur M2 activated and C2 also charging and boosting the SEPIC output and energies the overall output.

Mode 3:



This above circuit the ac input is given to the input of SEPIC rectifier unit. The Rectifier unit converts AC to DC power and Turn ON a M1 & M2 Switch. Those processes occur M1& M2 activated and C1 and C2 also charging and boosting the SEPIC output and energies the overall output.

SLIDING MODE CONTROL

In control systems, SMC is a nonlinear control scheme that changes the dynamics of a non-linear structure by solicitation of a discrete control gesture (or more rigorously, a point valued control gesture) that powers the system to "slide" over or nearby a trajectory of the system's normal behaviour. The SMC/ state feedback design are discrete in nature. Instead it can change the state space from one continuous position to another structure. Hence, SMC is a variable parameter control method. The several control arrangements are intended so that trajectories all the time moves near an adjacent region with a changed control arrangement, and so the final trajectory exists nearby or within one control arrangement. As an alternative, it will slide along the margins of the control arrangements. The motion of the system as it slides over these margins is called a sliding mode and the coordinate's locus containing of the boundaries is called the "sliding (hyper) surface".

The decision rule, termed the switching function, has as its input some measure of the current system behaviour and produces as an output the particular feedback controller which should be used at that instant in time. In sliding mode control, Variable Structure Control Systems (VSCS) are designed to drive and then constrain the system state to lie within a neighbourhood of the switching function. One advantage is that the dynamic behaviour of the system may be directly tailored by the choice of switching function - essentially the switching function is a measure of desired performance. Additionally, the closed- loop response becomes totally insensitive to a particular class of system uncertainty. This class of uncertainty is called matched uncertainty and is categorised by uncertainty that is implicit in the input channels. Large classes of problems of practical significance naturally contain matched uncertainty, for example, mechanical systems and this has fuelled the popularity of the domain.

NPC CONVERTER

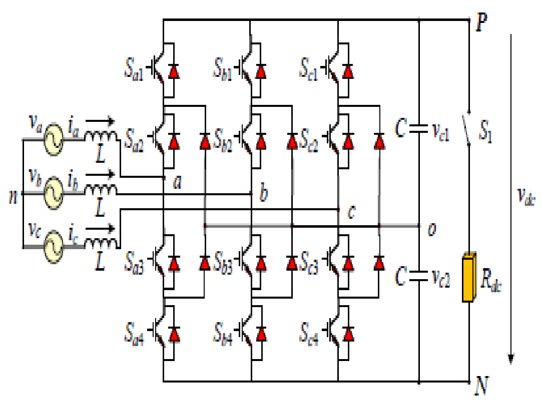


Fig: The Topology of three phase three level NPC Converter

The schematic diagram of the three-phase three-level NPC converter is shown in Fig. In the ac side, the ac grid is connected to NPC converter through the three-phase line inductors L. In the dc side, a dc load is connected. The NPC converter target, as the interface between the ac grid and dc load, is to achieve the objectives of power

transmission providing a stable dc-link voltage for the dc side.
Under the assumption that the ac grid is balanced as well as, following the circuit configuration presented in Fig. , the ac current dynamics and the dc-link voltage dynamics in the stationary coordinate frame can be deduced as

$$L\begin{bmatrix}\frac{di_\alpha}{dt}\\ \frac{di_\beta}{dt}\end{bmatrix} = \begin{bmatrix}v_\alpha\\ v_\beta\end{bmatrix} - \frac{v_{dc}}{2}\begin{bmatrix}\delta_\alpha\\ \delta_\beta\end{bmatrix},$$
$$C\frac{dv_{dc}}{dt} = \delta_\alpha i_\alpha + \delta_\beta i_\beta - \frac{2v_{dc}}{R_{dc}}.$$

On the other hand, as a control objective in the inner loop, the instantaneous active are reactive powers can be deduced as

$$p = i_{\alpha\beta}^T v_{\alpha\beta}, \quad q = i_{\alpha\beta}^T J v_{\alpha\beta},$$

In this work, an effective output regulation subspaces based direct power control (ORS-DPC) technique proposed in is utilized in the inner loop to regulate the active and reactive powers, respectively. The active and reactive powers remain constant while the system is operating in steady state, that is, which yields:

$$\delta_{\alpha\beta}^* = \left(\frac{2}{v_{dc}} + \frac{2L\omega q}{v_{dc}\|v_{\alpha\beta}\|^2}\right)v_{\alpha\beta} - \left(\frac{2L\omega p}{v_{dc}\|v_{\alpha\beta}\|^2}\right)Jv_{\alpha\beta},$$

HIGH GAIN OBSERVER

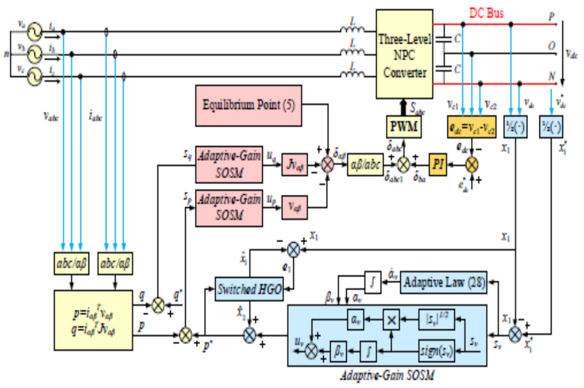


Fig: Proposed Switched HGO

For the NPC converter in accordance with the parameters selected above and assessing the observer performance in the experiments. Finally, due to the forward voltages and the losses existing in the actual power converter, a experimental fine-tuning is requested to ultimately achieve the desired dynamic and steady state behaviour. B. Adaptive-Gain Second-order Sliding Mode Control For the sake of providing a fast dynamic and satisfactory steady state behaviour for the NPC converter, an adaptive-gain SOSM control strategy is applied in the voltage regulation loop to force the dc-link voltage to track the reference value and in the power tracking loop to drive the active and reactive powers to the desire values. 1) The Adaptive-Gain SOSM Controller in Voltage Regulation Loop: The objective of the voltage regulator is to drive the dc-link voltage convergence to its desired value. At first, a fixed-gain SOSM control method is designed.

SIMULATION DIAGRAM

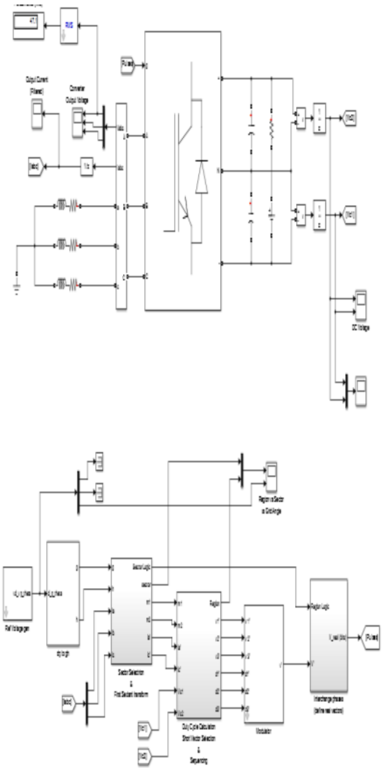


Fig: Simulation diagram

Output current

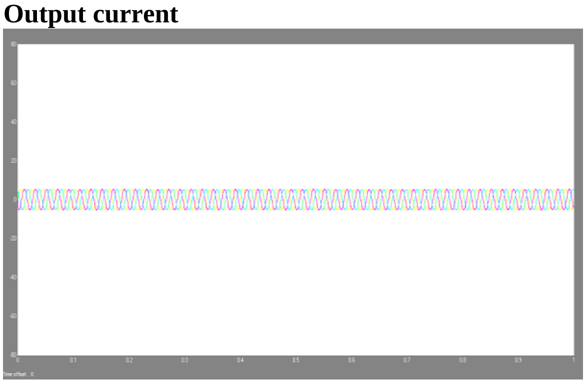


Fig: Simulation Graph on Output Current

Output voltage

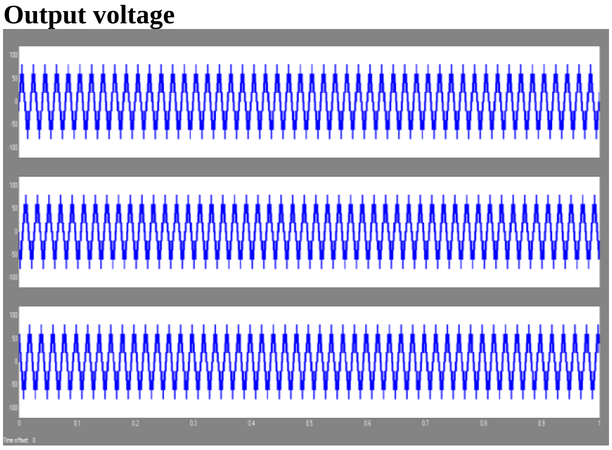


Fig: Simulation Graph of Output Voltage

DC Voltage Output

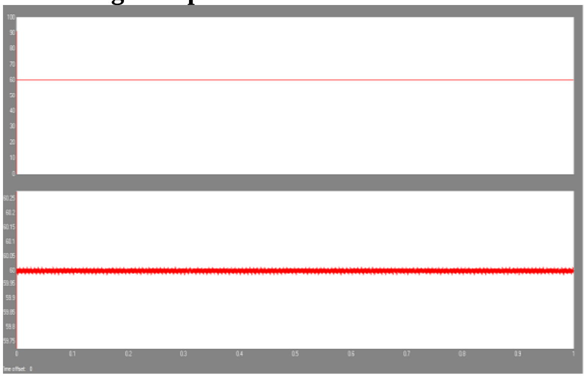


Fig: Simulation Graph on DC Voltage Output

DC voltage output

Fig: Simulation Graph on DC Voltage Output

Region vs Sector vs Grid angle

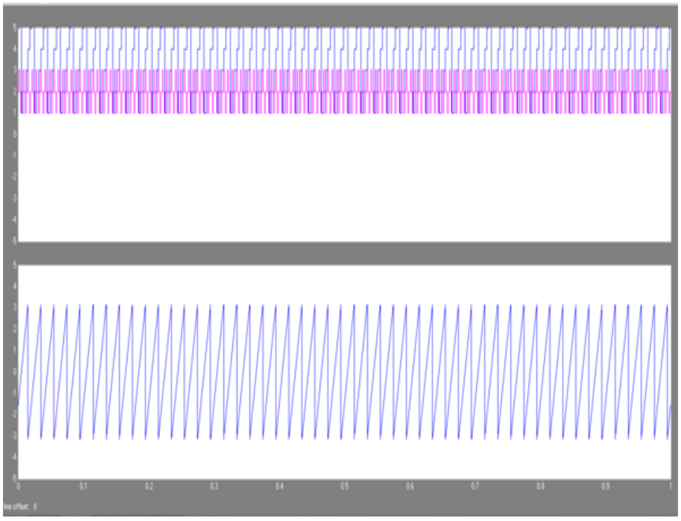


Fig: Simulation Graph on Region vs Sector vs Grid Angle

CONCLUSION

A switched HGO based adaptive-gain SOSM control scheme is proposed for the NPC converter. In the voltage regulation loop and power tracking loop, two adaptive gain SOSM controllers are adopted respectively to enforce the dc-link voltage and instantaneous power to their references. The information of the upper bound of the disturbance derivative, which is not easy to be estimated in NPC converter, is not required. Additionally, ascribing to the dynamically adapted gains, this algorithm also provides faster transient response and more satisfactory steady state behaviour for the NPC converter compared with the SOSM method. Moreover, for the sake of preventing the collateral effects on control performance caused by external disturbance, a switched HGO is also integrated in the voltage regulator. Compared with the conventional linear observers, this method utilizes a switched observer gain to overcome the trade-off between the speed of disturbance estimation and the measurement noise sensitivity, which not only enhances the immunity to measurement noise but also preserves high disturbance rejection ability. The performance evaluation of the proposed control method has been carried out by comparing with the ESO-SOSM control scheme. The experimental results show that the proposed controller simultaneously provides a prominent dynamic and steady state performance as well as a rather high disturbance rejection characteristic, which is suitable for the grid-connected NPC converter.

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