Adaptive Voltage Control Strategy of Three-phase Inverter for standalone distributed generation system

[1]Piyush Kumar Singh, [2]Mr. Kaushal Sen, [3]Mrs. Vasundhara Shukla

[1]Research Scholar, [2,3]Assistant Professor
Department of Electrical and Electronics Engineering
Oriental College of Technology, Bhopal (MP), India

***Abstract*: This paper proposes a method of adaptive control of three-phase inverters for autonomous distributed generation systems (DGS). The proposed voltage regulator includes two control terms: an adaptive compensation term and a stabilization term. The adaptive compensation control term is constructed to avoid the direct calculation of the time derivatives of the state variables. Meanwhile, the stabilization control term is designed to asymptotically stabilize the dynamics of system errors. In addition, an optimal fourth order charge current observer is proposed to reduce the number of current sensors and improve the reliability and profitability of the system. The stability of the proposed voltage regulator and the proposed load current observer are fully tested using the Lyapunov theory. The proposed control system can establish a good voltage regulation, such as a fast dynamics response, a small steady state error and a low total harmonic distortion in case of sudden load variation, unbalanced load and non-linear load. Finally, the validity of the proposed control strategy is verified through simulations and experiments on a DGS test bench prototype with a TMS320F28335 DSP. For a comparative study, the feedback linearization control scheme for multiple inputs and outputs is implemented, and its results are presented in this document.**

***Index Terms*: Adaptive control, distributed generation (DG) system (DGS), load current observer, stand-alone, three-phase inverter, and voltage control.**

I. *INTRODUCTION*:

DISTRIBUTED generation systems (DGS) using renewable energy sources (such as wind turbines, photovoltaic panels, biomass and fuel cells) are gaining increasing attention in the electricity sector to replace existing fossil fuels and reduce greenhouse gas emissions from global warming. Today, DGSs are widely used in network-connected applications, but are cheaper in an independent operation in the case of rural villages or remote islands because the connection to the network can lead to higher costs.

In stand-alone applications, the inverter on the load side of the DGS functions similarly to an uninterruptible power supply (UPS). In these applications, the efficiency of regulation of the output voltage output of the inverter is evaluated in terms of transient response time, steady state error and total harmonic distortion (THD). In addition, the quality of the inverter output voltage is strongly influenced by load types, such as sudden load change, unbalanced load and non-linear load. In a conventional proportional-integral (PI) controller was studied. However, the output voltage has a significant amount of steady-state error and its THD is not satisfactory in the case of a non-linear load. The control diagram of the H configuration circuit configuration presented in effectively mitigate the THD of the output voltage under the nonlinear load. Therefore, load-side inverters require advanced control techniques to achieve excellent voltage regulation performance, particularly in the event of sudden load disturbances, unbalanced load and non-linear load.

II. DISTRIBUTED GENERATION

Distributed generation, also called on-site generation, dispersed generation, integrated generation, decentralized generation, decentralized energy or distributed energy generates electricity from many small energy sources. Currently, industrial countries generate most of their electricity in large centralized plants, such as nuclear or fossil fuel (coal, gas) hydroelectric power plants.

Distributed Energy Resource (DER) systems are small-scale energy generation technologies (usually in the range of 3 kW to 10,000 kW) used to provide an alternative or improvement to the traditional electrical system. The usual problems with distributed generators are their high costs.

Low temperature at plants to be enough in a city to be used for district heating and cooling. Distributed generation is another approach. Reduce the amount of energy because it has arrived, perhaps even in the same building. This also reduces the size and number of power lines to be built.

In contrast to the use of a few large-scale generation stations located far from loading centers, the approach used in the traditional electricity paradigm, DG systems employ many small plants but can provide on-site energy with little dependency on the distribution. and the transmission network. DG technologies produce energy in capacities ranging from a fraction of kilowatts [kW] to about 100 megawatts [MW]. Utility scale generation units generate energy in capacities that often exceed 1,000 MW.

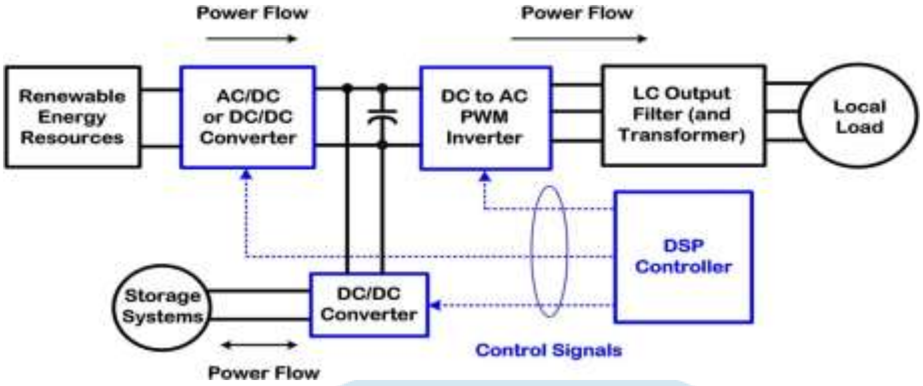

Fig. 1: Configuration of a typical DGS in stand-alone operating mode

Although this control technique can achieve good performance, it is quite complicated and requires accurate parametric values of RLO load. The authors propose control strategies consisting of an RSC in an external loop and a sliding mode control in an internal loop. Although the simulation and experimental results show good voltage performance, the control approach is complicated.

This paper reviews an adaptive voltage controller and an optimal load current observer of three-phase inverters for standalone DGSs. Also, it is analytically proven that the proposed voltage controller and the proposed load current observer are asymptotically stable, respectively. The proposed control method can achieve excellent voltage regulation such as fast transient behaviour, small steady-state error, and low THD under sudden load change, unbalanced load, and nonlinear load. For a comparative study, the feedback linearization for multi input and multi output (FLMIMO) control method is implemented in this paper. Simulation is done by using Matlab/Simulink software, and experiments are carried out on a prototype DGS test bed with a TMS320F28335 DSP. The remaining part of this paper is organized as follows. Section II describes the DGS in a stand-alone operation and the state-space model of the load-side inverter. The design and stability analysis of the proposed adaptive voltage controller are fully addressed in Section III. Section IV illustrates the proposed load current observer and analyse its stability. In Section V, the simulation and experimental results are given to evaluate the performance of the proposed control algorithm. Finally, conclusions are drawn in Section

III. DESCRIPTION OF THE SYSTEM AND MATHEMATICAL MODEL

The configuration of a typical DGS in an independent operation is shown in Fig. 1. Consists of renewable energy sources (eg Wind turbines, solar cells and fuel cells), an AC to DC power converter (wind turbines) or unidirectional dc-dc boost converter (solar cells or fuel cells), a three-phase DC-AC inverter, an LC output filter, a DSP control unit and a local load. As shown in Fig. 1, a transformer can be used to provide electrical isolation or increase the output voltage of the three-phase inverter, but it can generate a higher cost and a larger volume. In addition, storage systems such as batteries, ultracapacitors and flywheels can be used to generate electricity.

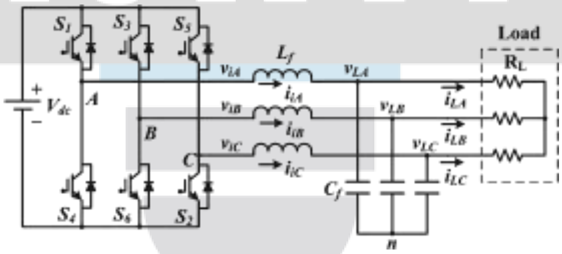

Fig. 2. Circuit diagram of a three-phase inverter with an *LC* output filter for stand-alone DGSs. transient (e.g., start-up or sudden load change) and improve the reliability of renewable energy sources

In this paper, we deal with the voltage controller design of the three-phase inverter for stand-alone DGSs that can assure excellent voltage regulation (i.e., fast transient response, small steady-state error, and low THD) under sudden load change, unbalanced load, and nonlinear load. Thus, renewable energy sources and ac–dc power converters or unidirectional dc–dc boost converters can be replaced with a dc voltage source (V_{dc}). Fig.
2 shows the circuit model of a three-phase inverter with an *LC* output filter for stand-alone DGSs. As shown in Fig. 2, the system comprises four parts: a dc voltage source (V_{dc}), a three-phase pulse-width modulation (PWM) inverter (S_1–S_6), an output filter (L_f and C_f), and a three-phase load (R_L). Note that the *LC* filter is required to suppress high-order harmonic components of the inverter output voltage due to the PWM action and then provide the load with sinusoidal voltages

IV. BLOCK DIAGRAM FOR PROPOSED SYSTEM

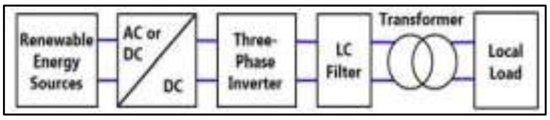

Fig. 3: Block diagram of a standalone DGS using renewable energy sources.

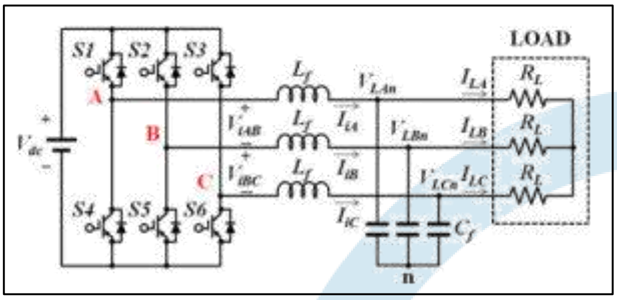

Fig. 4: Schematic diagram of a three-phase dc to ac inverter with an LC filter in a standalone distributed generation system

V. MODELING THE STRATEGY OF THE MODEL AND THE STRATEGY OF THE PROPOSED THEORETICAL SYSTEM

A Model of the state space of a load-side inverter describes a block diagram of an independent DGS that uses renewable energy sources that are wind turbines, solar cells, fuel cells, etc. As shown in Fig. 5.1, the DGS is divided into six parts: an energy source, a DC current converter (wind turbines) or a boost DC-DC converter (solar or fuel cell), a three-phase DC-AC inverter, an LC output filter, an isolation transformer and a local load. In this document, a renewable energy source and an AC to DC power converter or a DC to DC boost converter can be replaced by a rigid DC voltage source (VCC) because this document focuses on the design of a Regulator. robust adaptive voltage for various types of loads. as a balanced load, unbalanced load and non-linear load. Furthermore, this representation may be acceptable because the front-end converter (ie an AC-DC power converter or a DC-DC boost converter) can quickly recover the reduced voltage of the intermediate circuit when a heavy load is suddenly applied. Generally, DG power sources work in conjunction with energy storage devices (eg batteries, steering wheels, etc.) To support DS systems during transients and increase energy quality and reliability.

VI. CONCLUSION

In this document, an adaptive voltage regulator has been proposed for an independent three-phase DGS PWM inverter. The current loading information was estimated by an observer of the optimal fourth order. The stability of the proposed controller and observer has been tested analytically by applying the Lyapunov stability theory. This adaptive control strategy can achieve a more stable output voltage and a lower THD than the FL-MIMO control scheme in the event of a sudden change in load, unbalanced load and non-linear load. The effectiveness and feasibility of the proposed control strategy have been verified through various simulations and experimental results.

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