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Research Article

Modelling of Adaptable Voltage Controller and its Stability Analysis in Distributed Generation System

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Abstract

A Development of Electrical Power System with increase the demand of energy creates many problems in electrical power system which causes interruption of power supply. Hence to ensure uninterrupted power supply during the load shedding or on occurrence of fault in power system a standalone generation system is used. This paper proposes a robust and reliable adaptive voltage control for a distributed generation system in a standalone operation. A stability analysis is performed to ensure the better power quality and stable operation of the system. The proposed model provides excellent voltage regulation performance, fast transient response, zero steady state error and low THD.

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

Introduction

Distributed generation systems (DGSs) using renewable energy sources (such as wind turbines, photovoltaic arrays, biomass, and fuel cells) are gaining more and more attention in electric power industry to replace existing fossil fuels and reduce global warming gas emissions. Nowadays, the DGSs are extensively used in grid-connected applications, but they are more economical in a stand-alone operation in the case of rural villages or remote islands because connecting to the grid may lead to higher cost (Ton Duc Do, Viet Quoc Leu, Young-Sik Choi, Han Ho Choi, and Jin-Woo Jung, 2013).

In stand-alone applications, the load-side inverter of the DGS operates analogous to an uninterruptible power supply (UPS) for its local loads. Control of stand-alone DGSs or UPSs has been an attractive research area in recent years. these applications, the regulation performance of inverter output voltage is evaluated in terms of transient response time, steady-state error, and total harmonic distortion (THD). Furthermore, the quality of inverter output voltage is heavily affected by the types of loads such as sudden load change, unbalanced load, and nonlinear load. In (U. Borup, P. N. Enjeti, and F. Blaabjerg, 2001), a conventional proportional–integral (PI) controller has been investigated. However, the output voltage has a considerable amount of the steady-state error, and its THD is not satisfactory in the case of nonlinear load. The $H\infty$ loop-shaping control scheme which is presented in also cannot effectively mitigate the THD of the output voltage under nonlinear load. Therefore, the load-side inverters require advanced control techniques to achieve excellent voltage regulation performance, particularly under sudden load disturbance, unbalanced load, and nonlinear load. Recently, various advanced control methods have been applied to the load-side inverters in DGS and UPS applications (G. Escobar, A. M. Stankovic, and P. Mattavelli, 2004).

In a repetitive control is used to regulate UPS inverters, but the general problem with a repetitive control is its slow response and lack of systematical method to stabilize the error dynamics. Feedback linearization control techniques are proposed in although these methods can achieve high performance of the output voltage, the control design techniques seem to be complicated. Two iterative learning control strategies are presented in, and these methods are capable of achieving high performance. However, the switching frequency of the inverter is very high, so it results in huge switching losses. In, a model predictive control with a load current observer is proposed. Although the control technique is simple, the THD of the output voltage is still high. In, another predictive control is proposed, but nonlinear load is not investigated. In, a robust PI controller is proposed for an autonomous DG unit. A full set of results is presented in the case of unbalanced RLC load, but the

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*Corresponding author **Snehasish Bansriar** is a PG Student and **Roshan Nayak** is working as Assistant Professor results about nonlinear load are not presented. Sliding-mode control techniques are applied for inverters. Although good performance can be obtained, the controller designs are only for single-phase inverters, and the results of nonlinear load are not presented (A. Houari, H. Renaudineau, J. P. Pierfedrici, and F.Meibody-Tabar,2012). A robust servomechanism control (RSC) is used to control three-phase inverters of a DGS in stand-alone mode. Even though this control technique can achieve good performance, it is quite complicated and needs exact parameter values of an RLC load. The authors propose the control strategies that consist of an RSC in an outer loop and a sliding-mode control in an inner loop. Even if the simulation results show good voltage performance, the control approach is complicated. This paper proposes 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 behavior, small steady-state error, and low THD under sudden load change, unbalanced load, and nonlinear load.

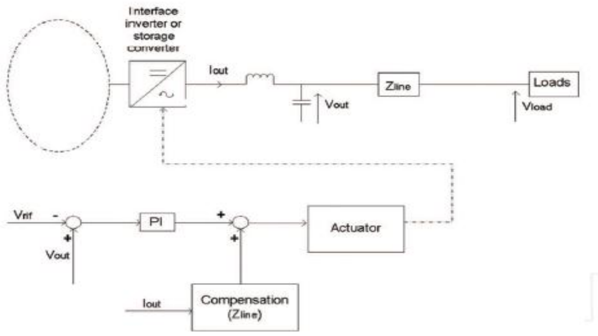

Fig. 2 Stand-alone voltage regulation schema

In case of more than one generation unit connected in parallel in an stand-alone configuration (islanded micro grid) a different control algorithm is needed for the interface converters. Several techniques have been studied to manage the parallel operation of standalone inverters and to assure a correct power sharing between the generation units. The more complex control techniques relay on a communication system between generation units. Other techniques can be implemented if no communication system is installed. The accomplishment, in every node of the islanded micro grid, of the power quality requirements on the voltage value is a problem concerning the coordination between the regulation actions of each interface converter.

Model Description

The system consists of two three-phase three-level PWM voltage source converters connected in twin configuration The inverter feeds an AC load (1kW, 500 var 60Hz @ 208 Vrms) through a three-phase transformer. Harmonic filtering is performed by the transformer leakage inductance (8%) and load capacitance (500 var).Each of the two inverters uses the Three-Level Bridge block where the specified power electronic devices are IGBT/Diode pairs. Each arm consists of 4 IGBTs, 4 antiparallel diodes, and 2 neutral clamping diodes. The inverter is controlled in open loop. Pulses are generated by the Discrete 3-Phase Discrete PWM Generator block. This block is available in the Extras/Discrete Control Blocks library. This PWM generator or modulator can be used to generate pulses for 3-phase, 2-level, or 3-level converters using one bridge or two bridges (twin configuration). In this demo, the PWM modulator generates two sets of 12 pulses (1 set per inverter) at P1 and P2 outputs. Open the 'Discrete 3-phase PWM Generator' menu. Notice that the generator can operate either in synchronized or un-synchronized mode. When operating in synchronized mode, the carrier triangular signal is synchronized on a PLL reference angle connected to input 'wt'. In synchronized mode, the carrier chopping frequency is specified by the switching ratio as a multiple of the output frequency.Three sinusoidal 0.85 pu modulating signals are provided by the 'Discrete 3-phase Programmable Source' to obtain a modulation index of 0.85. The carrier signals are synchronized on the modulating signals. in the PWM Generator block, you can instead select 'Un-synchronized' and 'Internal generation of modulating signals'. In such a case the magnitude (modulation index), frequency and phase angle of the output signals are specified. directly inside the PWM Generator block menu.For this example the DC bus voltage is 400V (+/- 200 V), chopping frequency is 1080 Hz (18*60 Hz), magnitude of the three modulating signals is 0.85 (corresponding to a modulation index m = 0.85) and the frequency of the three generated signals is 60 Hz.

A Distribution Static Synchronous Compensator (D-STATCOM) is used to regulate voltage on a 25-kV distribution network. Two feeders (21 km and 2 km) transmit power to loads connected at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The 600-V load connected to bus B3 through a 25kV/600V transformer represents a plant absorbing continuously changing currents, similar to an arc furnace, thus producing voltage flicker. The variable load current magnitude is modulated at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 5.2 MVA, while keeping a 0.9 lagging power factor. This load variation will allow you to observe the ability of the D-STATCOM to mitigate voltage flicker.

The D-STATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-sourced

PWM inverter. When the secondary voltage is lower than the bus voltage, the D-STATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the D-STATCOM acts like a capacitor generating reactive power.

The D-STATCOM consists of the following components:

a 25kV/1.25kV coupling transformer which ensures coupling between the PWM inverter and the network. a voltage-sourced PWM inverter consisting of two IGBT bridges. This twin inverter configuration produces less harmonics than a single bridge, resulting in smaller filters and improved dynamic response. In this case, the inverter modulation frequency is 28*60=1.68 kHz so that the first harmonics will be around 3.36 kHz. LC damped filters connected at the inverter output. Resistances connected in series with capacitors provide a quality factor of 40 at 60 Hz. a 10000-microfarad capacitor acting as a DC voltage source for the inverter a voltage regulator that controls voltage at bus B3 a PWM pulse generator using a modulation frequency of 1.68 kHz anti-aliasing filters used for voltage and current acquisition.

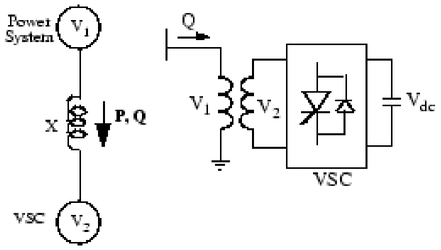

Fig.2 Circuit diagram of statcom

$$P = \frac{V1V2\ sin\delta}{X}$$

Where V_1 and V_2 = Line to Line voltage
X= reactance of interconnection transformer and filters.
$\delta = angle\ of\ V1\ with\ respect\ to\ V2$

In steady state operation, the voltage V2 generated by the VSC is in phase with V1 (δ=0), so that only reactive power is flowing (P=0). If V2 is lower than V1, Q is flowing from V1 to V2 (STATCOM is absorbing reactive power). On the reverse, if V2 is higher than V1, Q is flowing from V2 to V1 (STATCOM is generating reactive power). The amount of reactive power is given by

$$P = \frac{V1(V1 - V2)}{X}$$

A capacitor connected on the DC side of the VSC acts as a DC voltage source. In steady state the voltage V2 has to be phase shifted slightly behind V1 in order to compensate for transformer and VSC losses and to keep the capacitor charged.

Block diagram of standalone system

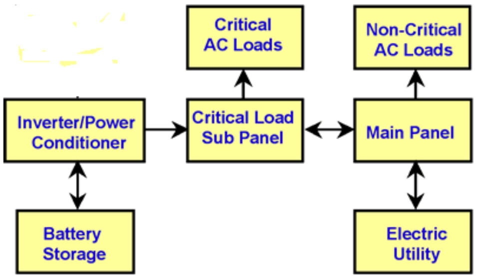

Fig.3 Block diagram of standalone system

Power systems are able to operate normally in grid-connected mode and still operate critical loads when utility service is disrupted, providing that battery storage is used. This type of system is popular for homeowners and small businesses where a critical backup power supply is required for critical loads such as refrigeration, water pumps, lighting, and other necessities. Under normal circumstances, the system operates in grid-connected mode, serving the on-site loads or sending excess power back onto the grid while keeping the battery fully charged. In the event the grid becomes de-energized, control circuitry in the inverter opens the connection with the utility through a bus transfer mechanism, and operates the inverter from the battery to supply power to the dedicated loads only. In this configuration, the critical loads must be supplied from a dedicated sub panel. The diagram below shows how a solar power system might be configured to operate normally in grid-connected mode and also power critical loads from a battery bank when the grid is de-energized.

Result and discussion

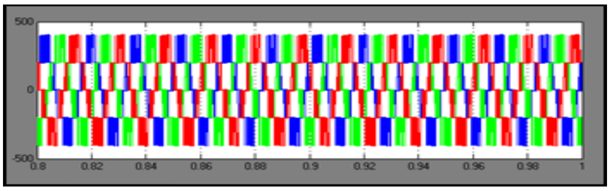

Fig. 4

Figure 4 shows the output voltage of standalone system which consists of battery bank. The output of battery banks is fed to the inverter and the three phase ac output of inverter fed to the a conventional three phase grid. The output of inverter fed to grid and further power quality is improved using D-Statcom.

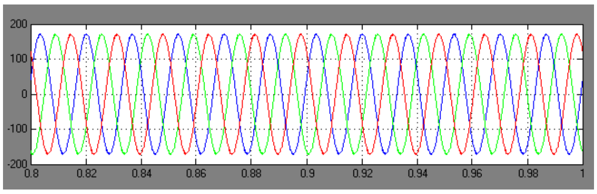

Fig.5

Figure 5 shows the compensated power at the load end

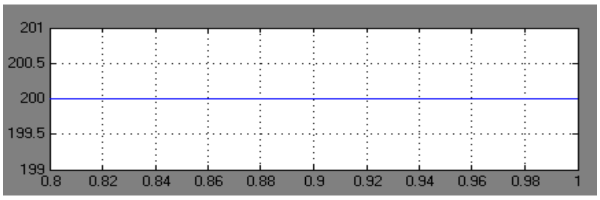

Fig.6

Figure 6 shows the output voltage of battery bank.

Conclusion

In this paper, an adaptive voltage controller has been proposed for a three-phase inverter of stand-alone DGSs. The comparison between voltage waveform of standalone system and voltage shows that we get regulated voltage and improved power quality. This adaptive control strategy can achieve more stable output voltage and lower THD under sudden load change. The effectiveness and feasibility of the proposed method strategy were verified through various simulation results.

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