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DECOUPLED ACTIVE AND REACTIVE POWER CONTROL FOR LARGE-SCALE GRID-CONNECTED PHOTOVOLTAICSYSTEMS USING CASCADED MODULAR MULTILEVEL CONVERTERS AND ALSO USING FUZZY LOGIC CONTROLLER

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ABSTRACT:

Renewable energy resources (RES) are being increasingly connected in distribution systems utilizing power electronic converters different controllers, such as pi &fuzzy logic controller. Renewable energy technologies such as Photovoltaic, solar thermal electricity using dishstirling systems, and wind turbine power are environmentally advantageous sources of energy that can be considered for electric power generation. Power distribution and controlling the cascaded PV system faces tough challenge on output voltage over modulation when considering the varied and non uniform solar energy on segmented PV arrays. Finally, a 3-MW, 12-kV PV system with the proposed control strategy is modeled and simulated in MATLAB/SIMULINK. A downscaled PV system including two cascaded 5-kW converters with proposed control strategy is also implemented by using the fuzzy logic controller. Simulation results are provided to demonstrate the effectiveness of the proposed control strategy for large-scale grid-connected cascaded PV systems.

INTRODUCTION:

In hybrid power systems, a number of power generators and storage components are combined to meet the energy demand of remote or rural area, or even a whole community. In addition to PV generators, diesel generators, wind generators, small hydro plants, and others sources of electrical energy can be added as needed to meet the energy demand in a way that fits the local geography and other specifics. Before developing a hybrid electric system for a specific site, it is essential to know the particular energy demand and the resources available at that site. Therefore, energy planners must study the solar energy, wind, and other potential resources at the site, in addition to the energy demand. This will allow them to design the kind of hybrid power system that meets the demands of the facility at best.

In this chapter, a brief technical description of some different hybrid power system configurations is considered. It also includes notes about hybrid power system topologies, modularization, and standardization. Among of these renewable energy, solar energy is much easier to be harvested, converted, and delivered to grid by a variety of power converter. In particular, large-scale grid-connected photovoltaic (PV) systems play a major role to achieve PV grid parity and have been put forward in high penetration renewable energy systems. As one type of modular multilevel converters, cascaded multilevel converters share many merits of modular multilevel converters, e.g., lower electromagnetic interference, low device rating, improved harmonic spectra, modularity, etc., but also is very promising for the large-scale PV system due to its unique advantages such as independent maximum power point tracking (MPPT) for segmented PV arrays, high ac voltage capability, etc.

However, cascaded multilevel converters in PV systems are different from their some successful application such as medium voltage motor drive, static synchronous compensator (STATCOM), harmonic compensator, solid state transformer, which are connected with symmetrical segmented dc sources. PV systems with cascaded multilevel converters have to face tough challenges considering solar power variability and mismatch of maximum power point from each converter module due to manufacturing tolerances, partial shading, dirt, thermal gradients, etc. In a cascaded PV system, the total ac output volt- age is synthesized by the output voltage from each converter module in one phase leg, which must fulfill grid codes or requirements. Because same grid current flows through ac side of each converter module, active power mismatch will result in unsymmetrical ac output voltage of these modules. The converter module with higher active power generation will carry more portion of the whole ac output voltage, which may cause over modulation and degrade power quality if proper control system is not embedded into the cascaded PV system.

Several control strategies have been proposed for the cascaded PV system with direct connection between individual inverter module and segmented PV arrays. But they did not consider the fact that PV arrays cannot be directly connected to the individual inverter module in high-voltage large-scale PV system application due to the PV insulation and leakage cur- rent issues. Even if there are low- frequency medium-voltage transformers between the PV converters and grid, there are still complicated ground leakage current loops among the PV converter modules. Therefore, those methods are not qualified for a practical large-scale grid-connected cascaded PV system. Moreover, reactive power compensation was not achieved.

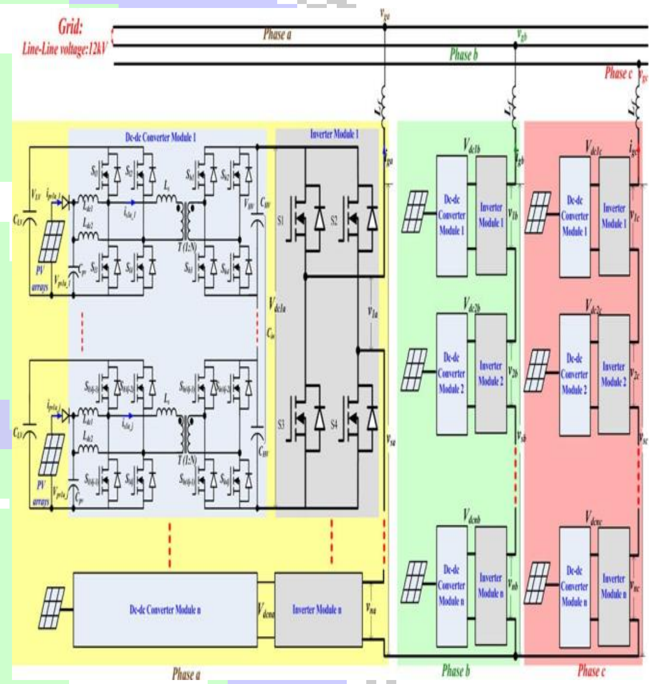


fig. 1 Proposed grid-connected PV system with cascaded multilevel converters at 3 MW.

SYSTEM CONFIGURATION AND POWER FLOW ANALYSIS

System Configuration

The proposed large-scale grid-connected PV system is presented in Fig. 1, which demonstrates a three-phase two-stage power conversion system. It includes n cascaded multilevel inverter modules for each phase, where each inverter module is connected to j cascaded CF-DAB dc–dc converter modules with high voltage insulation [32]. This configuration features many impressive advantages comparing with traditional PV systems with line-frequency transformer. The cascaded multilevel inverters are directly connected to the grid without big line-frequency transformer, and the synthesized output voltage from cascaded modules facilitates to be extended to meet high grid voltage requirement due to the modular structure. Each dc–dc converter module is interfaced with segmented PV arrays and therefore the independent MPPT can be achieved to harvest more solar energy. Moreover, it is immune to the double-line-frequency power ripple propagation into PV arrays. Particularly, the ground leak- age current and PV insulation issues are effectively suppressed. In addition, flexible control strategies are able to be explored and applied in this topology owing to more control variables and control degree-of-freedom. Although there is no accurate number about the cost benefits comparing with the traditional PV system with line-frequency transformer, it is obvious that the proposed PV system will have lower cost due to high power density and modular structure, which will significantly reduce the cost of the power platform using to install the PV system. This paper is focused on active and reactive power distribution control of the cascaded multilevel inverters in the proposed PV system. The detailed dc–dc converter design has been provided in [32] and will not be repeated in this paper. The selected application is a 3-MW/12-kV PV system in this paper. The n is selected to be 4 considering the tradeoff among the cost, lifetime, passive components, switching devices and frequency selection, and power quality. As a result, power rating of each inverter module is 250 kW. The average dc voltage of each inverter module is 3000 V based on the requirement of inverter output voltage, power devices as well as power quality. The second-order voltage ripple on the dc side is allowed to 20% even higher. Hence the filter in each dc–dc converter module, Ldc1 and Ldc2 are dc inductors, and Ls is leakage inductor. CPV is high-frequency filter capacitor paralleled with PV arrays. High-frequency trans- former with turn ration N is connected between low-voltage side (LVS) converter and high-voltage side (HVS) converter. CLV are LVS dc capacitor and CHV are HVS dc capacitor. The detailed parameters have been provided.

Power Flow Analysis

In the cascaded PV system, power distribution between these modules is primarily dominated by their respective ac output voltage because the same grid current flows through these modules in each phase as shown in Fig. 1, to demonstrate the principle of power distribution between four PV inverter modules in phase a. The same analysis can be applied for phase's b and c. considering the relative stability of the grid voltage is used for the synchronous signal.

CONTROL SYSTEM DESIGN

Fig. 1 shows the proposed control system of the grid- connected cascaded PV converters including CF-DAB dc–dc converters control and cascaded multilevel inverters control in phase a. The same control system can be applied in phase's b and c.

CF-DAB DC–DC Converters Control

Fig.1 shows the CF-DAB dc–dc converters control for one unit of dc–dc converter module 1 in Fig. 1 The same control can be used to other units. Due to the dual-active-bridge structure, this control has two degrees of freedom: the duty cycle D and the phase shift angle ϕ, by which the PV voltage and LVS dc-link voltage VLV are controlled, respectively. V 1a 1 is directly controlled by the duty cycle D so that it can be well kept at the reference voltage V ∗ algorithm [32]. Usually the bandwidth of the duty cycle loop is about several kHz (e.g., 10 kHz in this paper), which is much higher than 120 Hz; thus, the double-frequency component in the LVS or HVS is blocked and high utilization factor of MPPT is reached in the PV side. For simplicity, a simple high band- width PI controller is applied. The PV voltage and current are both sensed for the calculation of voltage and change in voltage which are used in MPPT algorithm. The MPPT algorithm generates a reference voltage.

Cascaded Multilevel Inverter Control:

In the cascaded multilevel converter control showing in Fig. 1(b), active power distribution between cascaded PV converter modules is decided by the individual maximum power available from PV arrays. Considering dc capacitors connected with cascaded multilevel inverter modules have the same capacitance, reactive power from each module can be synchronously controlled to reduce the over modulation risk regardless of active power change. Therefore, the proposed control strategy can be called decoupled active and reactive power distribution control. The double-loop d q control based on discrete Fourier transform PPL method.

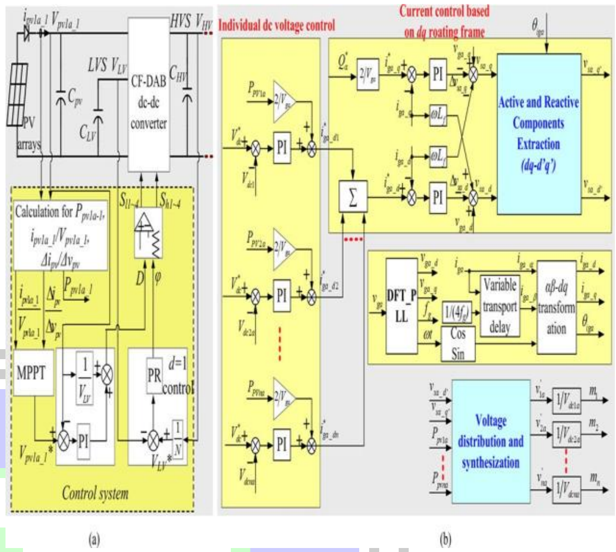


Fig. 2 Proposed control system of the grid-connected cascaded PV converters in phase a. (a) CF-DAB dc–dc converters control of one unit in module 1. (b) Cascaded multilevel inverters control.

SIMULATION VERIFICATION:

The large-scale grid-connected cascaded PV system with the proposed control strategy is validated in SIMULINK/ MATLAB. The system consists of a PV hybrid source with the main grid connecting to loads at the PCC as shown in the photovoltaic and the PEMFC are modeled as nonlinear voltage sources. These sources are connected to dc–dc converters which are coupled at the dc side of a dc/ac inverter.

In simulation results in the case tradition active power and reactive power and proposed active power and reactive power, control by using the multilevel converters. The same model can be used in phases b and c. Considering the characteristics of PV arrays, the equivalent input current source i_ PV and voltage source V _ PV are developed in this model summary of the chapter. The key circuit parameters in simulation are listed in Table I. In this simulation, the fixed simulation step is set to be 1 us considering the synchronization between simulation points and switching instant [37]. The settling time is about 0.04 s as shown in Fig 2. In this paper, the reactive power injection into grid (inductive reactive power) is defined as negative and reactive power absorption from grid (capacitive reactive power) is defined as positive. The active power injection into grid is defined as positive and active power absorption from grid is defined as negative. Figs. 3 and 4 show the system performance in phase a with traditional control strategy.

Simulation results of PV system with traditional active and reactive power control in phase a. (a) Power distribution

Mat lab model for Proposed grid connected p v converters in traditional active &reactive power control .

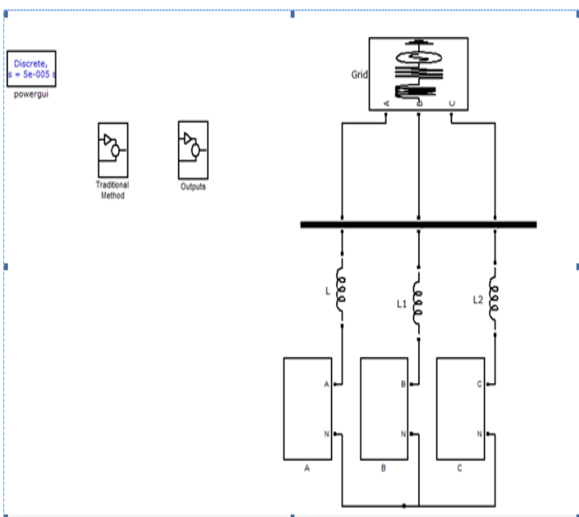


Fig.3 A 3-MW, 12-kV PV system with the proposed control strategy with traditional method is modeled and simulated in MATLAB.

In the above figure consists of large scale grid with 3mw 12 k v p v system that grid should be connected to three phases a, b, c with a proposed control technique, by showing above fig consists in phase a shows the proposed control system of the grid-connected cascaded PV converters including CF-DAB dc–dc converters control and cascaded multilevel inverters control in phase a. dc–dc converters control for one unit of dc–dc converter module 1 in Fig. 1 [32]. The same control can be used to other units. Therefore, the proposed control strategy can be called decoupled active and reactive power distribution control. The decoupled active and reactive power control including active and reactive components ex- traction, voltage distribution and is executed in multilevel inverter control system to achieve independent active and reactive power distribution.

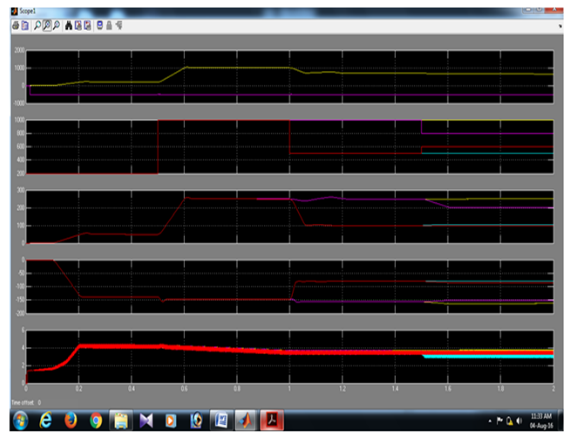


Fig4: Simulation results of p v system with active and reactive power distribution on phase a.

In the figure

1).consists 1 phase grid power includes active power and reactive power.

2). Wave form represents the p v array irradiation.

3).wave form consists of active power of grid modules.

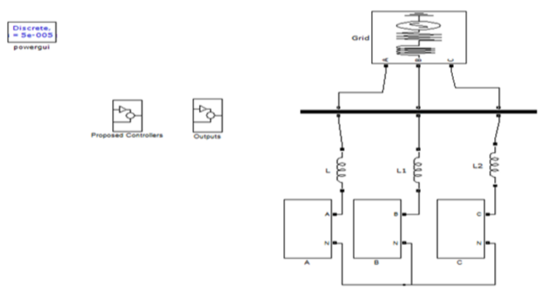
4). wave form consists of reactive power of grid modules.

5). wave form consists of grid current.

6). wave form consists dc voltage.

Simulation results of PV system with traditional active and reactive power control in phase b (power distribution):

Fig :5 Mat lab model for Proposed grid connected p v converters in traditional active &reactive power control .



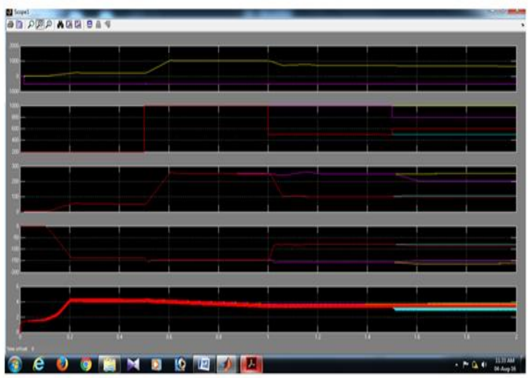


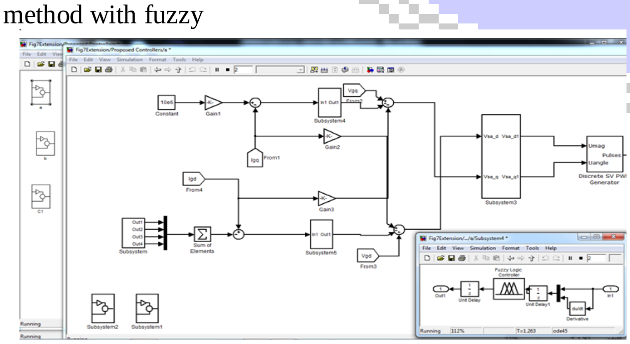
Fig6 : Simulation results of p v system with active and reactive power on phase b.

In the figure

Simulation results p v system traditional method with fuzzy:

A 3-MW, 12-kV PV system with the proposed control strategy with traditional method is modeled and simulated in MATLAB with fuzzy logic controller.

Fig 7:Simulation results p v system traditional method with fuzzy



Control circuit with Fuzzy Controller

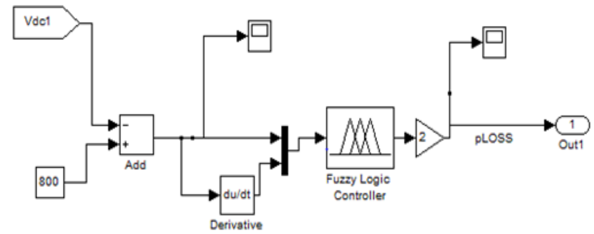


Fig :8 Simulation waveform results p v system traditional method with fuzzy on normal graph

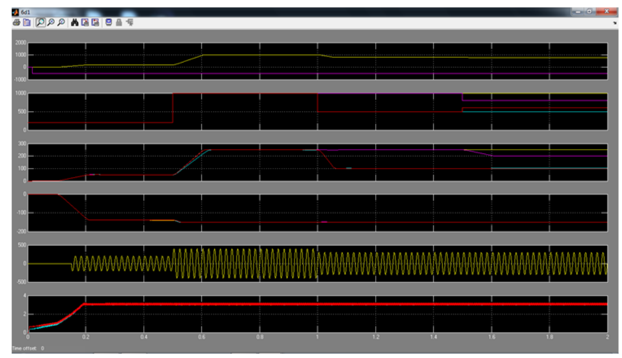
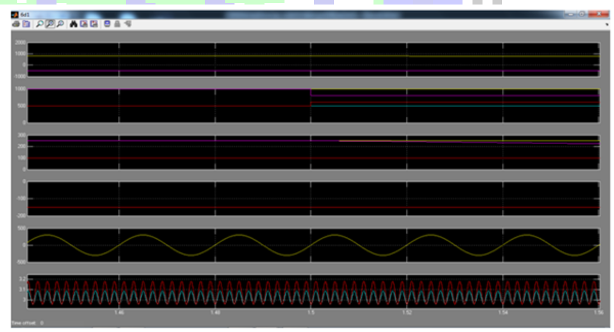


Fig :9 Simulation waveform results p v system traditional method with fuzzy on zoomed graph.



Zoomed graph

Under the same conditions, the proposed control strategy can improve the system operation performance the active and reactive power can be independently controlled. Although the solar irradiation on first and second inverter modules is different from one on third and fourth inverter modules after 1 s, the reactive power from them is controlled to be symmetrical. By this proper reactive power distribution, the over modulation caused by the active power mismatch is eliminated. Even when different active power is generated from the four inverter modules after 1.5 s, the effective reactive power compensation can ensure the system with good power quality and stability as shown in Fig. 7(b). It can be seen that THD is only 2.532%. The dc voltages on the four modules, Vdc 1a –Vdc 4a , have good dynamic performance and are controlled to vary with 20% rated voltage but do not affect power quality.

The simulation results of three-phase cascaded PV system with the proposed control strategy. The solar irradiation for PV inverter modules changes from 200 to 1000 W/m2 at 0.5 s.

PV inverter modules in phase b is different from ones in phases a and c. Therefore, different active power is generated from three phase. At 1.5 s, different solar irradiations in the three- phase result in different active powers, grid power phases a, b, c, with 1, 0.8, and 0.6 MW, respectively. Thanks to this effective control strategy, the reactive power in the three phase c be controlled to be same with 0.5 MVAR. In this Different from one on third and fourth inverter modules after 1 s, the reactive power from them is controlled to be symmetrical. By this proper reactive power distribution,

CONCLUSION:

The overall goal of this thesis is to investigate the operation of a grid connected PV system with decoupled active and reactive power control using cascaded modular multilevel converters. The hybrid system, composed of a PV array was considered. This project has presented an available method to operate a grid-connected system. A comparison between different system operating strategies such as dc-dc converter module and cascaded multilevel inverters module are studied. The main conclusions and recommendations drawn from this work are summarized next.

The purposes of the proposed operating strategy presented in this paper are to determine the control mode, to minimize the number of mode changes, to operate PV at the maximum power point, and voltage distribution and power distribution and mitigate the aforementioned issues.

With the operating algorithm, PV always operates at maximum output power, maximum value. The change of the operating mode depends on the current load demand, PV output and the constraints The output voltage for each module was separated based on grid current synchronization to achieve independent active and reactive power distribution.

In brief, the proposed method is a simplified and flexible method red hybrid source in a grid-connected micro grid. It can improve the performance of the system's operation; the system works more stably while maximizing the PV output power. Moreover, it was demonstrated that the risk of over modulation of the output voltage from the cascaded PV inverter modules can be effectively reduced, which improves system power quality and stability.

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