Uncertainties and variations of power generation through photovoltaic (PV) sources are major challenges for their integration with the distribution grid. Voltage rise and voltage drop issues limit the increase in PV penetration and loading levels, respectively. Moreover, it is important to maintain voltage levels as per grid code while ensuring that the PV power generation is not curtailed. In this paper, a voltage control method using smart transformer (ST) via dynamic optimal setpoints and limit tolerance is proposed in a residential distribution network. Performance indicators are developed to understand the impact of the proposed method on the system voltage profile. A method to determine the optimal inputs for voltage control methods depending on the day-ahead predictions of load demand and PV power profiles is developed. Further, a voltage control method of switching among three setpoints based on the voltage that determines the load side ac reference voltages for ST is proposed. The proposed method is compared with the method of switching between two setpoints based on current. The proposed method provides an improved voltage profile in the distribution network, which is tested on a CIGRE low voltage residential distribution network using PSCAD.
References


Related content

Research on the smart modular cascaded solid state transformer interfaced to distributed photovoltaic power generation system

- Hengyang Zhao ; Taiyun Zhu ; Dengfeng Cheng ; Binbin Li ; Jinjin Ding ; Yuanzhi Li
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- Distributed photovoltaic (PV) power generation system has recently gotten more and more attention in renewable energy fields. Solid state transformer (SST) is a kind of power electronics equipment which utilises power electronics technology to achieve voltage conversion. This paper adopts a topology of single-phase smart modular cascaded SST which consists of three stages, cascaded modular rectifier stage, the dual active bridge (DAB) converter stage, and the single-phase full-bridge inverter stage. The output-parallelled DAB converters offer a DC-bus port. This study proposes an improving MPPT method for the PV cells which directly connect to the DC-bus port. Rectifier stage adopts a single-phase d–q vector-based common-duty-radio controller aiming at balancing each modular current, DAB stage utilizes a voltage feedforward and feedback-based controller to regulate each modular voltage. The DC-bus voltage could be regulated to track MPP of PV cells. Compared to conventional control strategy, the improving one simplifies the circuit structure, reduces the controlled variables, provides the possibility of increasing the number of cascaded modules, and makes it easier to access to distribution network. Simulation results are presented to proving the proposed control strategy. In addition, a 6kW experimental prototype is built to validate the effectiveness.

Control, implementation, and analysis of a dual two-level photovoltaic inverter based on modified proportional–resonant controller

- Nayan Kumar ; Tapas Kumar Saha ; Jayati Dey
This study presents a modified proportional–resonant (M-PR) control topology for single-stage photovoltaic (PV) system, operating both in grid-connected and stand-alone modes. Dual two-level voltage source inverter fed three-phase open-end winding transformer is used to supply the load in this scheme. The M-PR controller is developed for the inner current control loop of the system. The M-PR controller has the ability to track ac current with zero steady-state error. The outer dc-link voltage control loop is developed through the indirect vector control method at synchronously rotating reference frame. The control scheme ensures improved performance of the system at variable solar irradiance and load disturbances. The performance analysis of the dual two-level PV inverter is carried out for different operating conditions. The control scheme is implemented in MATLAB–SIMULINK environment. The theoretical results are verified through experiments in a laboratory prototype. The experimental results show close match with their theoretical counterparts.

Modelling and simulation of Grid-connected PV System in DlgSILENT/PowerFactory

Zheng Fei; Ding Mingchang; Zhang Junjun

With a large number of PV power station integrated to the grid, some problems such as the grid-connected stability, relay protection, etc. brought out by it. In this paper, dynamic modelling and control strategy of grid-connected PV power stations were researched based on DlgSILENT. First, the equivalent model for PV power station was established consisting of PV arrays, power inverters, transformers, transmission line and grid. Second, control system including maximum power point tracking control, voltage and current double-loop control and relay protection control was modelled. Finally, based on a 10MW grid-connected PV power station in the northwest of China, simulations were given to verify the dynamic model and control strategy of PV power station.

Integration of solar PV into grid using a new UPQC with differential inverter control

Sivarajan Kakkattil Narayanan; Nirmal Sivarajan; Jasmin Erakkath Abdu; Jayanand Balakrishnan

Integrated photovoltaic (PV) distribution systems voltage stability is of great significance in supporting all connected equipment smooth functioning in the distribution network. Voltage profile maintenance is one of the challenging tasks in PV integration. To maintain a constant voltage profile to a sensitive load of 22 kVA is the main idea of this study. A single-phase PV-integrated distribution system is selected for the study. The novelty is that differential inverters are used for dynamic voltage restorer and distribution static synchronous compensator of the unified power quality conditioner (UPQC). Active power decoupling facility is the main advantage using the differential inverter. The research work objective is to synchronise a 10 kW solar PV system to the distribution system using this new UPQC. The research work discusses and derives the most suitable control strategy for the UPQC with battery energy storage system. A 20 kVA UPQC is designed for the PV integration and to increase voltage stability of the distribution system. The frequency, voltage and reactance/resistance ratio of the distribution system is assumed to be constant. A prototype model of differential UPQC is developed. Experimental and simulation results validate the main objective.

Design of a novel voltage regulating distribution transformer with a power electronic-assisted booster system

Guiyang Jin; Keji Yang; Jun Liu
Distribution grid is facing challenges arising from more and more renewable power generation connected to distribution networks. Heavy embedded generation has led to frequent voltage fluctuations in the form of under-voltage and over-voltage. Voltage control using traditional voltage regulators are unable to cope with this situation which limits the power output from renewable power generation. A novel design of a main transformer combined with a second booster transformer is proposed which provides frequent voltage regulation no matter under-voltage or over-voltage of distribution networks. The modification in the voltage is produced by the second booster transformer which has taps developed through a combination of no-load mechanical switches and hybrid switch. The hybrid switch consists of a mechanical switch and two bidirectional semiconductor switches. Mechanical switches ensure low steady-state losses and the power electronic switches are used for arc-free tap changing. The novel design of the transformer is cost-effective, efficient, and can regulate voltage quickly and frequently.

Voltage sensitivity-based demand-side management to reduce voltage unbalance in islanded microgrids

- Halil Çimen and Nurettin Çetinkaya
- View description Hide description

Microgrids (MG) provide advantages such as providing energy supply to areas far from the distribution grid, efficient use of resources by supporting demand management and having a more dynamic grid. However, if an advanced control system is not implemented in the islanded MG, problems of power quality may arise. One of these problems is the voltage unbalance. Increasing the number of single-phase roof-mounted PV plants and the number of electric vehicle charging stations in recent times may negatively affect voltage unbalance. One of the methods used to mitigate this problem is the demand-side management (DSM). Here, a solution method based on DSM is presented for the voltage unbalance problem that may occur in an islanded MG. Thermostatically controlled loads, which are often used for DSM, are preferred as controllable loads. A new and novel control algorithm based on voltage sensitivity have been developed. Effects of TCLs on different buses and phases are determined with voltage sensitivity matrix including neutral components. The proposed control algorithm reduces successfully both the voltage unbalance factor and the number of controlled TCLs. The algorithm was tested with the PSCAD/EMTDC analysis software.