REACTIVE POWER CONTROL FOR SINGLE-PHASE GRID-TIE INVERTERS USING QUASI-SINUSOIDAL WAVEFORM

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ABSTRACT:

The project presents a reactive power control technique for single-phase Photovoltaic (PV) inverters, especially unfolding inverters. The proposed system retains the benefit of the unfolding inverters having low material cost and semiconductor losses, and tackles the drawback of the standard unfolding inverter not having capability of reactive power injection. It is important to note that reactive power delivery is mandatory for PV inverters according to the recent announced regulations. The concept is based on changing the shape of the grid current waveform but keeping the same zero crossing points as in the unity power factor condition. The current waveform is governed by real power and reactive power, at the price of an acceptable deformation. The operating principles of the proposed technique and mathematical derivations of the grid current function are provided in the paper. Experimental results in a grid-tie inverter prototype have shown a good agreement with the derived theory, and they confirm the feasibility of using the proposed technique in grid-tie inverters.

Keywords: Reactive power, PV system, current waveform, grid tie network, zero crossing points.

1. INTRODUCTION:

Unfolding grid-tie inverters are generally used in Photovoltaic (PV) and Fuel Cell (FC) applications. This is because a simple controller can be applied and it can minimize the number of high frequency switching semiconductors, e.g. MOSFETs. This leads to low component cost and high efficiency. Fig. 1 shows a typical system block diagram of an unfolding grid-tie inverter. The front stage is a dc-dc converter, which converts a dc current from a voltage source, such as PV Cells, to a rectified sinusoidal inductor current. The second stage is a line frequency inverter to unfold the inductor current into a bipolar sine wave current, which is synchronized with the grid voltage. Typically, semiconductor switches in the line frequency inverter are SCR thyristors. It is well-known that SCR are turned off at zero current with relatively long commutation time which makes difficult for the injection of reactive power. Thus, the impossibility of injecting reactive power is the main drawback of unfolding inverters.

However, a new regulation has been recently published to require that PV inverter products must have the capability to adjust Power Factor (PF) up to 0.95 in either inductive or capacitive modes. In consequence, a lot of already designed commercial products are facing the problem of not passing such a regulation. Some advanced modulation methods have been proposed recently to satisfy the PF regulation, but they cannot be applied to unfolding inverters since the zero crossing points of grid voltage and current are not the same. Thus, manufacturers have to redesign PV inverter system completely using different semiconductors or changing topology to be more complicated and expensive such as Neutral Point Clamped (NPC) inverters to satisfy the regulation in their future products.

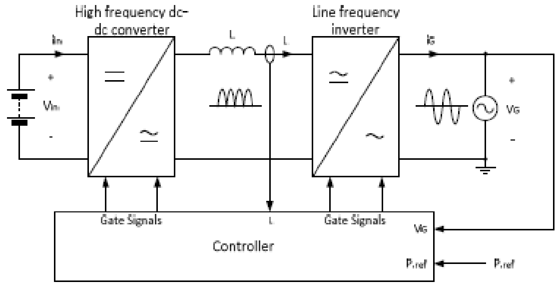


Fig.1.1. Proposed system.

2. PREVIOUS STUDY:

Beside the regulation, unfolding inverters give a high efficiency when using MOSFETs in the line frequency inverter stage instead of SCRs. A commercial single phase PV inverter system can achieve 97.8% European efficiency with using Silicon MOSFETs only in the inverter stage. The MOSFETs effectively reduce the conduction loss comparing to SCRs. However, the zero crossing points of grid current and gird voltage have to be synchronized, otherwise it will produce a short circuit path by the body diodes, otherwise, a cascaded blocking diode is required for each MOSFET. The high efficiency advantage does not exist anymore due to a high conduction loss at the diodes. Nevertheless, reactive power cannot be delivered to the grid. A manufacturer has provided a solution which changes the shape of the gird current waveform to give a capability of generating 0.95 power factor. However, there are no further literatures to provide the operating principles and the performance evaluations by using the method.

3. PROPOSED SYSTEM:

Due to the industrialization of developing countries, the increasing worldwide population, and the overall desire for an improved quality of life, there is an ever-increasing global demand for electrical power. Combustible fossil fuels and nuclear sources account for approximately three quarters of the electricity produced globally; however, these supplies are limited. Due to the finite nature of these resources, researchers are interested in generating power from renewable sources in order to find a more environmentally sustainable way to produce electricity. Through advances in technology and manufacturing techniques, photovoltaic (PV) cells that harvest solar energy have become economically competitive with other technologies that generate power from renewable sources. While PV systems can be installed in a centralized generating facility, they are uniquely suited for distributed generation applications. Solar farms use PV cells to generate large quantities of power in a single location. They are comparable to the generating facilities of more traditional fuels, but less efficient from an energy density (power produced per square foot of land occupied) point of view. Due to safety and aesthetic concerns associated with traditional generation facilities, they are often constructed away from heavily populated areas. The electricity produced at these facilities must be transmitted long distances to the end user, which requires a costly, complex infrastructure and exposes the entire system to higher levels of power loss and security risks. Conversely, PV systems can produce power closer to the end user, albeit in smaller quantities. PV cells do not benefit from the same economy of scale as traditional generation technologies and thus generally do not become more effective when cells are conglomerated or enlarged. Their small packaging and the widespread presence of the fuel source, sunlight, makes solar power especially attractive for geographically distributed residential and commercial applications.

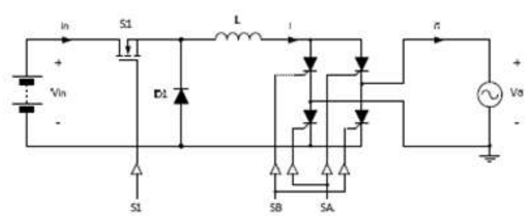
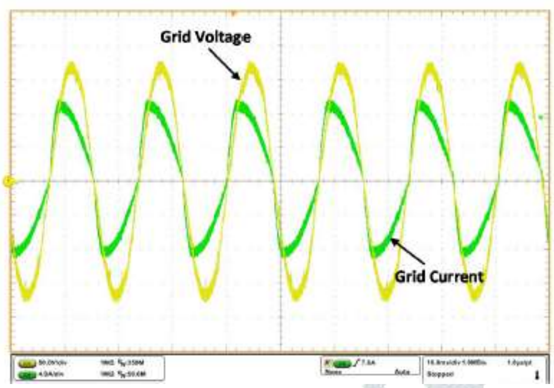


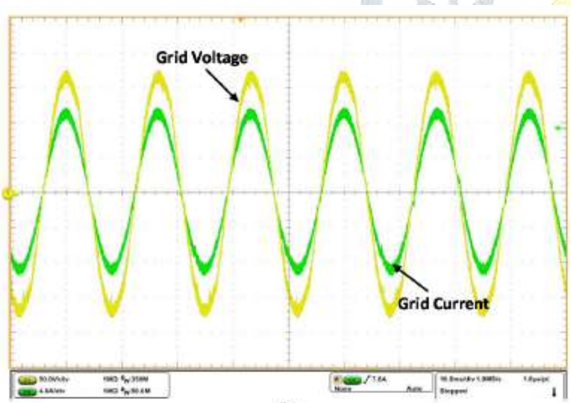
Fig.3.1. Proposed simulation model.

4. SIMULATION RESULTS:

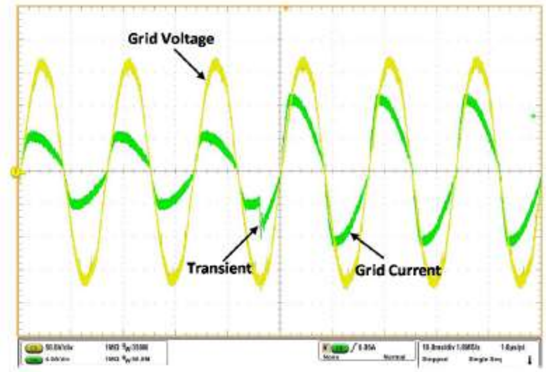
The goal for this control technique is to achieve reactive power injection with relatively low THD. As shown in Fig, with same power factor, QSW signal always has the lowest THD among those three waveforms. QSW also has advantage that the property of sinusoids is widely used in many phase control cases. QSW can achieve a THD of 0 and the PF can be controlled in a relatively big range from 0.86~1. Above all, the proposed waveform, Quasi Sinusoidal Waveform, has ability to shift phase of its first order harmonic with relatively low THD.

The concept of proposed control is to keep the zero crossing points of grid current and voltage to be the same, but shift the first order component of grid current to carry reactive power. The ideal grid current waveform was shown in Fig. Since the zero crossing points are the same as those of grid voltage, this same reference can be applied to various types of inverter to inject reactive power into the grid. Fig. Show two typical grid-tie inverters, an unfolding inverter and a unipolar switching full-bridge inverter [24], respectively. The typical gate signals of two converters are identical, SA and SB switch with the line frequency, e.g. 60 Hz, and S1and S2 switch at a high frequency, e.g. 20 kHz, to shape the inductor current.





According to the standard, all harmonic current amplitudes are with the limits. Furthermore, the comparison shows that experimental value is very close to theoretical value. For _ _ 0.78, THD measured by power analyzer is 16.7%, which shows a good agreement with the theoretical value in Fig.



5. CONCLUSION:

This project presented a control technique for single phase grid-tie inverters. The control technique allows reactive power injection to unfolding topologies, which were limited to unity power factor operation. The idea was to provide a Quasi Sinusoidal Waveform as a grid current reference to inject reactive power. The mathematical models were provided and explained. A prototype of a unipolar switching full-bridge inverter was built and evaluated for the QSW technique. Working principle of new controller was explained. By comparing measured values and theoretical values, experimental results showed a good agreement with the theory. It was shown that reactive power injection is possible by generating quasi sinusoidal waveform current through the inverter, without changing any hardware components.

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