Grid-connected Systems Powered by Solar Energy Implemented with Fuzzy based Voltage Source Converters

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Abstract: - Solar energy systems connected to the electrical grid are known as grid-tied solar power systems or solar power-connected grid systems. Grid-tied solar inverters are only capable of producing active electricity since they are made to produce power at a unity power factor. The grid alone can meet the load's requirement for reactive power. Reactive power drawn from the grid relative to active power has increased significantly with the sharp rise in the deployment of distributed energy resources based on renewable energy. This has an impact on the grid's power quality. The amount of reactive power that the grid must supply will decrease if the grid-tied solar inverter is designed to be intelligent enough to provide reactive power in addition to active power. This work's primary goal is to generate the necessary pulses for a three-phase inverter, which will aid in producing reactive power and ultimately help achieve the work's primary objective. Fuzzy logic is a complex approach that takes advantage of the flexibility and adaptability of fuzzy systems to manage Voltage Source Converters (VSCs) for three-phase inverter operation. The primary circuit is simulated in the MATLAB/Simulink environment, giving the desired results.

Key-Words: - Voltage Source Converters (VSCs), Fuzzy logic systems, Reactive power, Solar energy, Grid connected systems, Power factor.

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1 Introduction

Traditionally, grid-tied solar inverters have been built to run at unity power factor, which implies that they can only generate active power. Electrical loads tend to use more inductive reactive power since they are primarily inductive loads. This reactive power requirement is now met solely by the grid. The grid's performance is impacted by the growing number of Distributed Energy Resources (DERs) that only supply active power, resulting in a low site power factor from the utility's perspective. In the past, FACTS devices were used to inject and absorb reactive power to mitigate power quality difficulties. Depending on the need, several FACTS device kinds, including series, shunt, series-series, and series-shunt, are employed. However, these devices have several errors, including enormous size, high cost, large installation space, etc. These factors make it necessary to control the reactive power flow within the power system network since this could also have an impact on voltage regulation. Control schemes to provide reactive power alongside active power for grid-tied solar inverters are explored. The use of VAR compensators by more grid-tied inverters will aid in grid voltage management and lessen the requirement for pricey capacitor banks. There are two primary ways to utilize the reactive power capability of smart inverters: either by oversizing the inverter or by reducing active power, [1], [2]. There is an additional expense associated with oversizing the inverter that must be considered. Active power curtailment refers to the decrease of active power and can be achieved in a variety of ways. For example, the maximum power point can be fixed at, say, 70% of the rated power or the PCC voltage can be used as the reference voltage. Owners of PV systems make less money using this strategy because the installed solar PV panels produce less energy, [3], [4], [5].

Overuse of traditional fossil fuels has destroyed the environment and produced power in recent decades. Resources based on renewable energy (RE) are implemented as an unconventional and alternative power source to address this problem. Feed-in tariffs, the cost of PV panels, and supportive government regulations have all incentivized residential and commercial customers to make use of this technology and support the production of sustainable electricity. On the other hand, combining renewable energy sources (RE) with conventional energy sources improved the distribution network's dependability, particularly under bad circumstances, and also reduced the different limitations of RE resources. Because PV power is stochastic, RE-based grid-interfaced systems use storage devices (compressed air, batteries, and ultra-capacitors) to smooth out the power flow. The battery, which is connected to the DC link using a bidirectional converter (BDC) circuit, is used to regulate the flow of electricity, [6]. When integrating renewable energy sources (RE) with the AC grid, the voltage source converter (VSC) provides better power quality and control over the flow of both active and reactive electricity. Grid code requires RE sources with distribution networks to have autonomous power control (active and reactive), which serves as additional grid assistance, [7], [8]. Consequently, to link with the AC grid directly, a grid-integrated uninterruptible dual-mode power converter is needed. The power quality of grid current and voltage is distorted by the presence of nonlinear loads at the AC side, such as computers, welding machines, lights, special machines, etc., [9]. To address this problem, a grid-interfaced converter is used to implement changeable digital filter-based control, providing harmonic current to the nonlinear loads. According to IEEE standard 519, [10], the power quality at the grid side thereby continues to be harmonic Several control algorithms are used to enhance the power quality of the hybrid solar PV-BES coupled with the grid-interfaced system (HPVBGS), [11]. The estimate of fundamental frequency components from the distorted input signal has made adaptive filtering renowned. These digital filters are very efficient and offer very versatile parameter realizations, [12], [13]. To obtain the desired filter structure in variable digital filters, delay elements are substituted by all-pass filter structures of the appropriate order. The adaptive algorithms' least mean square (LMS) and least mean fourth (LMF) emphasize adaptively altering the weight, [14]. When the grid is not optimal, an adaptive lattice filter is used in the active power filter to compensate for harmonics. Such FIR-based digital filters have also been put through testing by some authors in frequency adaptive synchronization units for grid systems. Other methods have also been proposed for harmonic compensation: fixed frequency PLL (FFPLL), dual SOGI (DSOGI-PLL), synchronous reference frame (SRF-PLL), and second-order generalized integrator (SOGI-PLL), [15]. It removes the requirement for a low-pass filter (LPF) by identifying the essential component of the non-sinusoidal waveform. Nevertheless, to handle highly polluted environments, these structures still require an extra filtering step. In this research, a control scheme based on variable digital filtering (VDF) is proposed and applied to mitigate load current harmonics in HPVBGS. Forming the control independent of load behavior validates the filter's effective operation in the presence of a highly nonlinear load. In this work, switching pulses for VSC are controlled via dual-mode operated digital filter-based control, [16], [17]. In HPVBGS, harmonics are mitigated via the VSC. The single-phase input signal is transformed into distortion-free sinusoidal vectors (in-phase and quadrature-phase) in the α-β frame by the single-phase quadrature signal generator (QSG), which is also necessary for the D-Q transformation needed to generate a reference current, [18], [19].

2 About Fuzzy Logic Controller (FLC)

The rule-based fuzzifier interface and fuzzifier are two crucial FLC phases. In addition to the VSC, another controller included in the suggested control architecture is the FLC. Three blocks are crucial in producing output signals that are then utilized to generate controlling signals for the converter switches. Here, the fuzzification block receives the change in error and error value, and this block output is provided as the fuzzy inference's input [20]. Figure 1 shows the fuzzy inference block, will produce output following the comparison with the rule base, which is then used as input for defuzzification. Eventually, the necessary output will be produced. This procedure will then carry on for the duration of the circuit's operation.

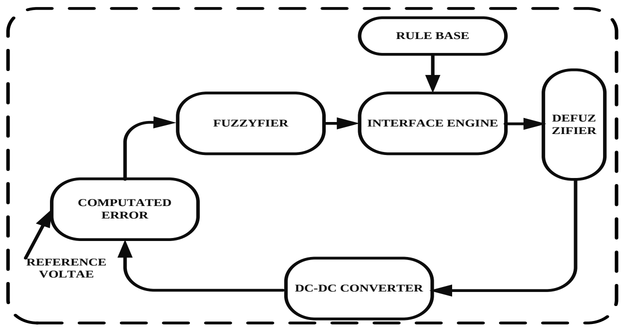

Fig. 1: Block diagram representation of FLC

3 Proposed Model Representation

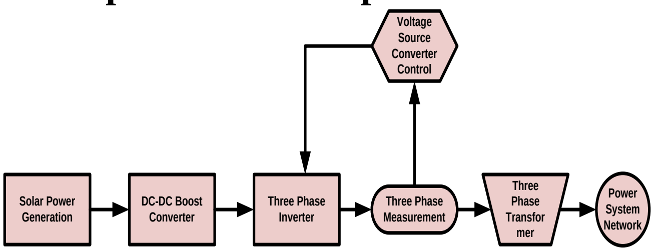

Fig. 2: Block diagram representation with the proposed technique

Figure 2 represents the proposed model with a voltage source converter with the fuzzy logic controller. The complete block diagram includes PV generating systems which are used to produce the power to the load in DC form with some voltage level. The DC-DC converter at the PV side is used here to step up and regulate the output voltage of the PV system. Further, the three-phase inverter is used here to convert the DC voltage of the rectifier into a three-phase AC supply. The three outputs of the converter are given to the power system to feed the loads through three-phase transformers with step voltage which will help to reduce the line losses and will improve the overall system efficacy. The main aim of this model is to develop the controlled pulse signals to the switches of the three inverters with proper control technique and this will be achieved with the use of a fuzzy logic controller which will lead to producing less ripple content out response and improve the overall system performance. Additionally, the projected system will able to provide the reactive power by the non-conventional energy source which will give the extra benefit to the system and reduce the burden on the main grid.

4 Results and Discussions

In this section results related proposed technique were projected with power, voltage, and current waveform representations. The main circuit was implemented in MATLAB/Simulink environment and simulated, obtaining the necessary results.

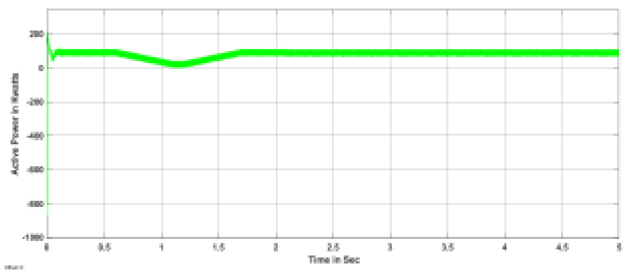

Fig. 3: Active power curve representation of the generated by the non-conventional energy source

Figure 3 shows the active power production generated by the PV array based on the available irradiance and temperature. In this work, the irradiance value considers the max value as 1000 w/m2 and the minimum value as 250 w/m2. Parallel the temperature value is also considered the dynamical value with a minimum of 25 degrees and max value is 50 degrees. Both irradiance and temperature waveforms are represented in Figure 10 and are provided to the PV cell as input to obtain necessary power generation.

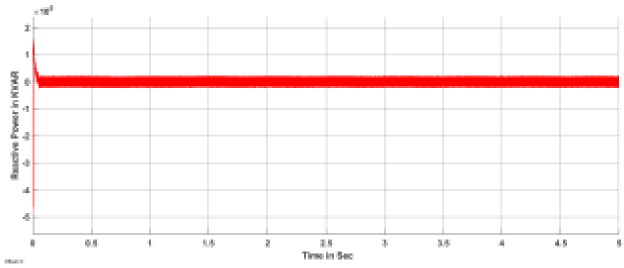

Fig. 4: Reactive power curve representation of the generated by the non-conventional energy source

The reactive power production using nonconventional energy sources is represented in Figure 4. This reactive power production will reduce the overall extra burden on the grid system which helps to improve the overall system efficiency.

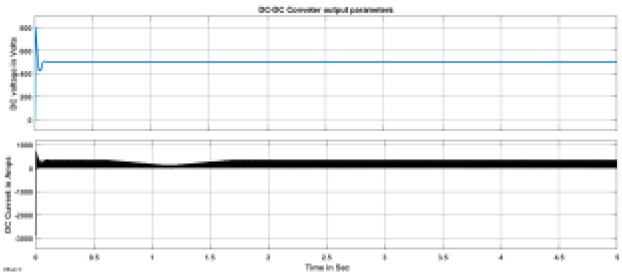

Fig. 5: DC-DC Converter output parameters representation connect at PV Array side

Figure 5 shows the current and voltage value representation of the converter which is connected to the PV array side. Here the current value of the converter follows the irradiance curve.

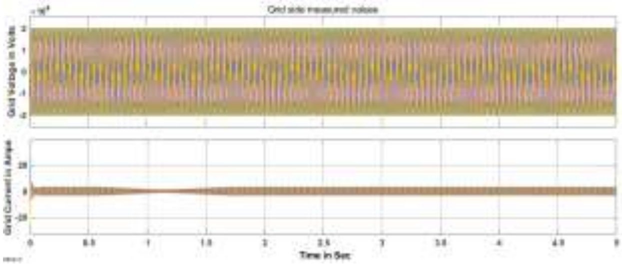

Fig. 6: Representation of the output parameters at the grid side

Grid side current and voltage values representation is shown in Figure 6. Here the grid side voltage looks high and the current value is less since using step up transformer output voltage of the three-phase inverter is increased and the current value is reduced.

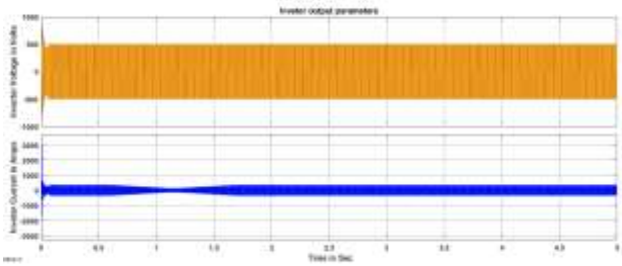

Fig. 7: Representation of the three-phase inverter output parameters

The three-phase inverter output voltage and current values are represented in Figure 7. Here the current values seem more than the grid current value where whereas voltage value is more at the grid side compared to the phase output voltage value.

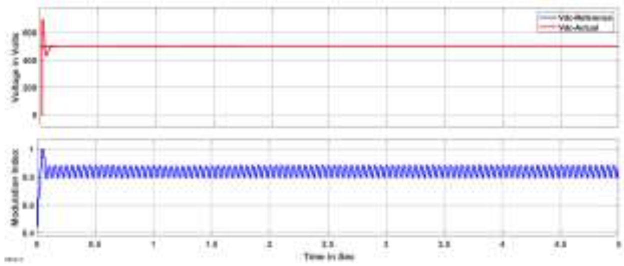

Fig. 8: Modulation index and actual, reference voltage values representation

The modulation index value and actual and reference voltage values of the converter are shown in Figure 8.

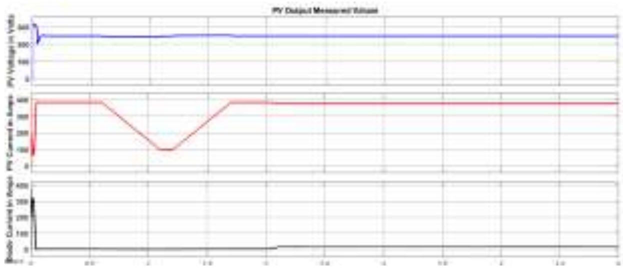

Fig. 9: PV Array output parameters representation

Figure 9 demonstrates the output parameters of the PV array which includes voltage, current, and power curves, here the current value Cleary flowed the irradiance value which is input to the solar plant.

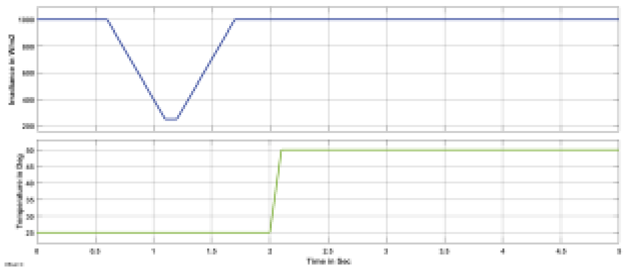

Fig. 10: Input Parameters representation of the solar system

Input parameters to the PV system with irradiance and temperature are represented in Figure 10.

5 Conclusion

RES and utility integration is one of the most important steps towards a smart grid. Solar power generation is one of the renewable energy sources that the government supports. The increasing availability of solar light and the rapid advancement of power electronics technology have led to the growing popularity of photovoltaic systems. The advantage of PV systems is that, depending on their operational and technical specifications, they can function in both standalone and grid-integrated modes. Grid-connected photovoltaic systems have shown themselves to be a workable alternative for heavily stressed grids. As a result, the researcher's ongoing efforts have allowed the modest standalone PV system to become a grid-tied PV system. A grid-tied photovoltaic system's primary benefits are its ease of use, comparatively cheap maintenance and operation expenses, and lower electricity bills. By grid-tied PV system specifications also presents a significant obstacle. To create the necessary active and reactive powers for the linked loads in the entire system, the synchronization between the inverter and the grid is studied. Key ideas in grid synchronization are outlined.

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