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Improvement Techniques of Power Quality Issues on Grid-Connected Solar Power Systems

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Abstract—This paper signifies the power quality issues that arise when renewable energy systems are incorporated into microgrids and provides an overview of several power electronic and FACTS devices that can be used to alleviate these issues. In this study, challenges regarding the integration of Solar photovoltaic (PV) systems are covered. Different Power Quality issues used by researchers have been categorised and made available for reference. For consideration, different methodologies used to minimise the various Power Quality issues are also provided. In power systems, power quality is emphasised as a crucial factor. Grid-connected solar power plants' size and capacity are also significantly growing. The primary function of a Solar Energy Conversion System (SECS) is not only to collect the maximum power from solar, but also to ensure some ancillary services and enhance the quality of power, in other places due to the progressive integration of nonlinear loads into the grid. Solar photovoltaic (PV) power has remained a key consideration in the electrical energy producing sector due to its numerous benefits. A lymphoblastoid cell lines LCL filter is used in a double-stage triple-phase grid-connected solar PV (SPV) system to improve power quality. A DC-DC converter and a DC-AC converter are used in this manner to connect the PV systems to the electrical interface. A 3-phase DC-AC converter is used to convert enhanced DC into AC, which is then sent into the grid. In place of an inverter, a 3-phase voltage converter is used to connect the voltage generated by the PV system to the grid via an AC transmission line. In this proposal, a maximum power point tracking (MPPT) technology is employed to boost the efficacy of the PV array's power quality in the face of variable weather conditions. As a result, the most energy could be extracted from the solar PV array and linked with the grid. FFT testing in MATLAB is used to quantify the improvement in power quality achieved by using an LCL filter. The recommended proposal has a very low total harmonic distortion (THD), demonstrating its usefulness. Furthermore, the results establish the applicability of the suggested system and prolong future developments of renewable energy with a significant improvement in power quality

1. Introduction

Power quality is vital in electrical systems, and it is also significant in solar photovoltaic (PV) systems. The properties of electrical power that influence its acceptability for use by electrical equipment are referred to as power quality. Voltage, frequency, waveform, and continuity are examples of these qualities. Solar PV systems harness the energy of the sun and convert it into usable electricity. Solar PV power is fundamentally variable and can be influenced by environmental factors such as temperature, shade, and cloud cover. This fluctuation can have an impact on the system's power quality as well as the performance and dependability of the electrical equipment linked to it.

Many strategies can be utilised to improve the power quality of a photovoltaic (PV) solar power system. One way is to employ power conditioning equipment, such as inverters, to transform the variable DC power generated by solar panels into stable AC power appropriate for use by electrical equipment. Furthermore, the usage of energy storage systems such as batteries can help to smooth out the variability of the electricity generated by the solar PV system, thereby enhancing its quality. The use of active and passive filters is another method for improving the power quality of a solar PV system. These filters can remove undesirable harmonics and other electrical power disturbances, lowering the risk of equipment damage and enhancing overall reliability.

Overall, enhancing a solar PV system's power quality is critical for maximising its performance, dependability, and efficiency. Solar PV systems can deliver high-quality electrical power that satisfies the needs of the connected equipment while reducing the risk of system failures and downtime by using the proper power conditioning equipment, energy storage systems, and filters.

According to the International Energy Agency's (IEA) PV power systems programme, roughly 39.9 GW of PV systems were installed globally in 2013, an increase of 7.9 GW over the previous two years. In Europe, PV installations fell that year, with only 10.3 GW installed compared to 17 GW in 2012. China installed the most PV systems in the world in 2013, with 11.3 GW, followed by Germany with 3.3 GW and Norway with 0.6 MW. The current installed capacity of renewable energy sources (wind, solar, biomass, and small hydro) in India is likewise around 29 GW, with the entire renewable potential in the country estimated to be 106 GW by 2032.

Due to the rising need for green electrical energy, as well as the decrease of traditional power sources such as natural gas, oil, coal, or nuclear, renewable energy sources are becoming more popular in energy production. The solar PV source is the most prominent form of energy production due to its low pollution, low waste, low cost, and easy manufacturing. Nowadays, solar PV energy generation moves seamlessly from the low-power grid system to the high-power grid system [1]. The growing load requirement and the integration of diverse energy sources occur via transmission lines to regulate accumulation and continuity, reduce supply power bank demands, and replace any traditional sources with nonconventional, green, renewable renewable sources [2], [3]. Regrettably, an increase in unbalanced loads is the cause of greater problems with harmonics power quality in a distributed system than than the central grid.

Unbalance is created by an uneven distribution of single-phase load voltage, as well as an uneven generation level or distribution level voltage. An uneven load will affect distinct load parameters in the relevant node at any given junction in a grid [4]. A To fulfil the unbalanced demand load, a control technique is required in grid unification, and both the active and reactive components must be adjusted [5]. The rising magnitude of power shortage concerns and climate problems has rooted for smart grid innovations to become one of the most urgent problems explored by current scholars [6]. The incorporation of unconventional renewable energy sources such as wind, PV, or fuel cells into circulation channels results in a dependable and consumable energy supply. Concurrently, the periodic inconsistency of principal sources, the rising employment of the power electrical equipment, and the recurrent un-balanced loads bring about furtive issues of power quality [7], [8].

An LC filter can be used for power conditioning to reduce ripples [9]. Nonetheless, it is costly due to its high-value inductance for medium to high energy needs [10]. As a result, an LCL filter is used. lymphoblastic cell lines The LCL design attribute is the most important in an overall system and plays an essential role in system stability [11]. The LCL filter scheme must address cost issues, such as the higher value of capacitance, which is affordable, and the lower amount of inductance, which is enormous and expensive. Furthermore, the grid's stability is determined by its impedance, therefore careful planning is required while building the LCL filter [12]. The resonance frequency of the LCL filter changes as the grid impedance changes, resulting in grid stiffness. Hence, for the solar PV system to work in conjunction with the grid, a control plan and synchronisation are required [13]. The synchronous control of the reference frame is carried out for frequency synchronisation using a phase-locked loop (PLL) [14], [15].

This paper focuses on the design of a 2-stage 3-phase grid-connected PV system and its power quality improvement using an LCL filter, MPPT technique and various other techniques by comparing them using MATLAB.

2. Research method

This paper mainly includes power quality improvement of the solar PV grid. The methodology used here is based on the synchronous reference frame theory.

2.1. Solar PV cell

Any substance that converts solar light into electrical power via the photovoltaic effect is referred to as a PV cell. Figure 2 shows the solar cell circuit diagram. Solar cells can be organised into huge groups known as arrays. These arrays, made up of thousands of individual cells, can function as central electric power plants, converting sunlight into electrical power and transmitting it to users [16]. A PV cell is made of a substance with semiconductor qualities; "semi" means it can transport electric current better than an insulator but not as well as a conductor, such as metal [17]. The efficiency of a photovoltaic cell is defined as the amount of electrical power generated by the cell in relation to the amount of solar energy radiated. The cell efficiency specifies how effective the photovoltaic cell is at converting energy from solar radiation to electrical energy [18]. The amount of power created by photovoltaic cells is controlled not only by the qualities of the available light, but also by the cell's numerous execution properties [19].

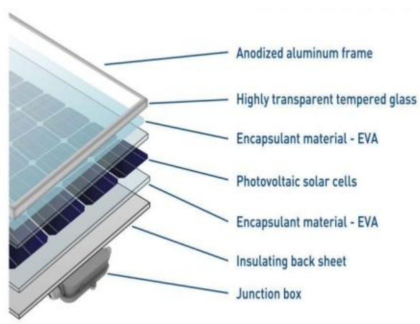

Figure 1. Structure of PV Module

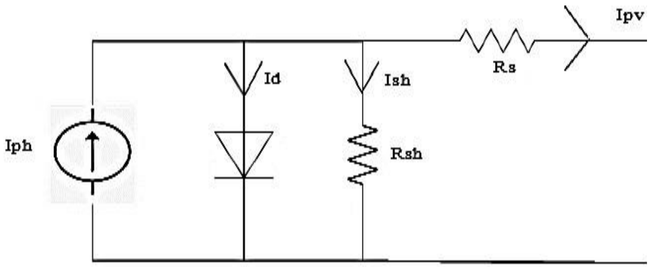

Figure 2. Circuit diagram of solar cell

2.2. Maximum power point tracking (MPPT)

Solar cell efficiency is low; therefore, maximum power tracking methods are used to improve efficiency are utilised to extract the most power feasible from a variable source. The I-V characteristics of photovoltaic power generation are non-linear, and power is fed to a specific load. This can be enhanced by utilising a boost converter with an MPPT-controlled duty cycle. The nonlinear I-V and P-V properties of a solar cell are visualized. The power is 0 at both the beginning and end of the curve. Because the maximum current and voltage do not occur at the same time, a specially designed operating point is used to keep the operating point at a maximum power value.

The P&O MPPT method has the following properties:

- This method's control strategy is straightforward.
- The control variables are voltage and current.
- This approach is applicable to both analogue and digital modes.
- There is no need for parameter tweaking.
- The cost of adopting this method is prohibitively expensive.
- The complexity of this circuit is considerable.
- This is useful for stand-alone systems.
- DC-DC converters are the type of converters utilised.
- Not suited when atmospheric conditions are rapidly changing.

The perturb and observe (P&O) approach tracks the MPPT by frequently increasing or decreasing the magnitudes of voltage at the PV's MPPT [20]. Figure 3 depicts the flow chart of the P&O algorithm. The application of this approach is rather simple. It cannot, however, follow the MPPT if the irradiance changes rapidly with time [21]. The P&O approach may achieve top-level performance if an accurate predictive and adaptive hill climbing strategy is used [22].

2.3. Boost converter

A boost converter is a DC-to-DC converter that boosts the voltage from the source and feeds it to the load [23]. Figure 4 displays a boost converter circuit diagram. Filters made of capacitors (sometimes in conjunction with inductors) are commonly affixed to the load and source filters of such a converter to reduce voltage fluctuations [24]. The boost converter is also known as the "constant current input source" because the inductor connected to the source creates a constant input current. PWM is used to control the regulating switch [25].

2.4. Phase-locked loop (PLL)

A phase-locked loop (PLL) is a control system that uses a voltage-driven oscillator to generate and alter an output signal that is in time with the input signal [26]. The most manageable phase-locked loop system is a variable frequency oscillator coupled with a phase detector in the feedback loop. Although the oscillator generates a periodic signal, the phase detector correlates its phase with the input signal, regulating the oscillator to keep those coordinated [27]. As the PLL enters a lock, a steady-state error signal is created. By connecting the phase detector and the VCO with an amplifier, the actual error magnitude between the input and output signals can be reduced to negligible levels. However, because the VCO controls the fitting frequency and voltage

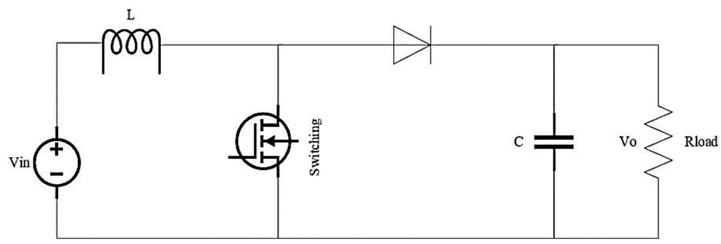

Figure 3. Circuit diagram of boost converter

3. Results and Discussion

The grid-connected PV system is subjected to various perturbations, such as continually fluctuating voltage. load and changing irradiance level. The system is examined in this paper under these two perturbations.
To analyse system performance, two cases are created:

i. Variation in irradiance level.
ii. Modifications to the three-phase load.

The simulation lasts two seconds and is divided into two one-second halves. The irradiation level is varied in the first section. The irradiance level is 600 KW/m2 between 0 and 0.3 seconds, 700 KW/m2 between 0.3 and 0.5 seconds, 800 KW/m2 between 0.5 and 0.6 seconds, and 1000 KW/m2 between 0.6 and 2.0 seconds. In the second scenario, the three-phase load value is changed in the second section of the simulation, at time 1.5 second, and the load is doubled (14.65 KW to 25.95 KW).

Load and irradiance level changes

As previously stated, the irradiance level is adjusted at 0.3, 0.5, and 0.6 seconds, and the load at 1.5 seconds. The waveforms below demonstrate the varied findings obtained.

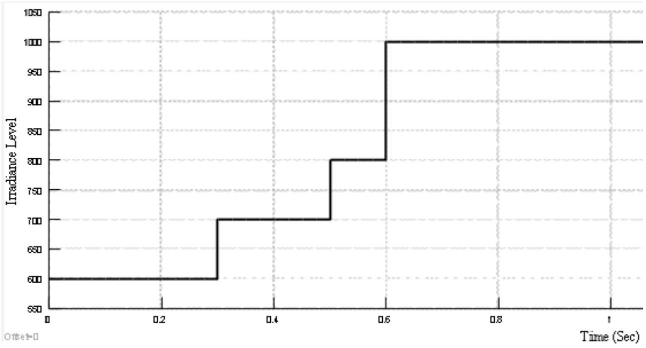

Figure 4: Level of illumination

4. Conclusion

This paper covers the system dynamics of grid linked solar power system. For various irradiance and load circumstances, the output voltage and current, as well as the output power against voltage, are observed. The largest variation in power with parameters is seen. MPPT approaches for solar cells have been developed, and the features at various irradiance levels have been examined.

It is explained how to build a boost converter using the maximum power point strategy based on the P&O method. The operation of the boost converter is observed under various operating settings such as switch on and turn off. The boost converter input and output voltages are shown, and their significance is discussed. The use of a boost converter in conjunction with a maximum power point tracking controller allows the converter to obtain highest power from solar cell.

A comparison is made between several scenarios. THD analysis is performed for two scenarios: low irradiance and high load, and vice versa. It has been discovered that as the irradiance level rises, so does the penetration of the PV system. A comparison is made between several scenarios. THD analysis is performed for two scenarios: low irradiance and high load, and vice versa. It has been discovered that as the irradiance level rises, so does the penetration of the PV system.

A thorough model of a two-stage grid-connected PV system is built and implemented in this article. The voltage source's inverter management system constructively regulates and limits the capacitor dc-link voltage to 600 V. The reactive power is near zero as it is absorbed into the utility grid, hence preserving the power factor (PF) to 1. The well-designed LCL filter reduces harmonics while enhancing power quality. The total harmonic distortions of the grid current are reduced to less than 5% by applying an LCL filter. Lastly, this review paper aims to improve power quality in the development of renewable energy power generation and smart grids.

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