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A Review on Solar Multilevel Inverter for the Production of Free Energy Due to the Structure with Long-life Feature

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Abstract

Multilevel inverters play a major role in medium voltage, high power and renewable applications. It is also used in certain applications where high switching frequency, and high output voltage gain are required. The switching transient period of a MOSFET should be minimal because a high dv/dt rate could result in permanent damage to the MOSFET. The harmonics present could cause many problems and so it has to be minimized. The harmonic content in the output voltage and the electromagnetic interference can be reduced with the help of small filters. It uses high switching frequency pulse width modulation for switching as it leads to high efficiency, and fast response, with a small and low-cost filter. There are classical and optimization techniques for harmonic reduction. Compared to the classical method, advanced optimization techniques are vital in determining the switching angles, switching positions and harmonic reduction because of their simplicity. There exist a few optimization techniques for harmonic reduction in multilevel inverters which include the Firefly algorithm, Genetic algorithm, Firefly Assisted Genetic Algorithm, and Grey Wolf Optimization algorithm. Here a novel 15-level inverter design based on Grey Wolf Optimization (GWO) for green energy applications is proposed. The number of switches used in the circuit is minimized with the Grey Wolf Optimizer (GWO) algorithm applied to the 15-level inverter. In the proposed work, the required fundamental voltage is maintained at the rated voltage and a few high-order harmonics are excluded. The best switching angles for a cascaded multilevel inverter are estimated using the natural leadership hierarchy and hunting mechanism of grey wolves. The total harmonic distortion of the proposed system is reduced to 6.629%. The following are the objectives of the Research work To perform the comparative analysis of classical multilevel inverter schemes, To design a multilevel inverter with minimized current harmonics, low voltage stress and increased efficiency, To tune the parameters of multilevel inverter by Grey Wolf Optimization (GWO) and reduce the harmonic distortion.

Keywords: Genetic Algorithm, fossil fuel, PV capacity, cascaded multilevel inverter, current harmonics, Fuel Cells

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INTRODUCTION

World Energy Status

Fossil fuels are widely used energy sources due to the Industrial Revolution. Enormous energy is released during the fossil fuel combustion process. However, the combustion process emits toxic gases and spoils the atmosphere. The extraction of fossil fuels results in global warming due to pollution such as soil degradation, water deterioration, air pollution etc. At present, the highest energy source and consumption around the world is from fossil fuels. As per the world statistics, the energy that comes from fossil fuels is 86.58%. Around the world, the energy demand keeps rising from 13934 TWh in 2001 to 24673 TWh in 2025 at a 2.3% rate annually, but only limited fuel reservation, and now, the world searching for an alternate energy source. As per the current statistics, the reservation of sources like Coal is for 146 years, oil is for 40 years, and natural gas is for 58 years (Source: www.eolss.net; www.ren21.net). The depletion of fossil fuels, pollution, and global warming have become a serious issue. The sources such as wind energy, Fuel Cells (FC), and Photo-Voltaic (PV) energy are clean and green energy to save the environment. Out of which, the energy source from the solar PV and the FC is an important renewable energy source. The global energy shortage results in the highest priority for the Solar Photo-Voltaic (SPV) system given for energy development around the world.

The advantages of the SPV energy system are as follows:

1. Free and unlimited resource,
2. The production of energy is noiseless due to the structure with long-life features,
3. It consists of static parts that allow less maintenance,
4. No need for a water source,
5. Extended for any capacity as per the consumer needs,
6. No hazardous gas emissions,
7. No need for a qualified technician,
8. Distributed system installation.

At present, among the various renewable energy sources, the SPV energy system has significant growth in installation and investigation (Source: www.bp.com; www.ec.europa.eu). The leading and cost-competitive source is SPV in the energy market across the world, and SPV is considered as leading additional power-generating capacity in 2016 across the world. The annual rate is increased by 50% to 75 GWdc, i.e. equivalent to more than 31000 SPV panels installation every hour. It results in a global installed capacity of SPV is about 303 GWdc. China leads in additional SPV power generating capacity, and it accounts for 85%. Many of the countries are contributing to global growth, but some countries see SPV as a cost-competitive energy source for electric power generation. In most of the locations, the SPV energy market is driven by government policies. However, falling capital costs and improvement in capacity are helping the SPV market to be a competitive source with traditional power sources. The price fall and rise in demand attract the new industry including oil-gas companies and electric utility companies. As of now, 17 countries had sufficient SPV capacity to meet 2% of their electric power demand, and few countries had higher shares including Germany (6.4%), Greece (7.2%), Italy (7.3%), and Honduras (9.8%) during 2016 (Source: www.iea.org). From Figure 1, China leads in installed capacity of SPV, and wind power around the world. The installation of SPV is raising in China, and its capacity is about 45% of the total capacity. Apart from China, Asia‘s most renewable power generation is hydropower but the other renewable sources especially V‘s share is relatively reduced.

The most profitable application for SPV is aerospace. Recent developments in new materials, efforts on device concepts and the processes, and fabrication technologies brought down the cost of the PV panel, and it helps to extend the PV applications. As per the previous discussions, many countries have introduced energy policy to support the PV power generation and aimed to increase PV growth. Due to the government's incentives, the cost of the SPV panels has fallen from US$76 per Wp (watts at the output peak) in 1977 to US$0.3 per Wp in 2016 (Source: www.bnef.com; pv.energytrend.com). The global price of PV module is shown in Figure 2.

The installed PV capacity around the world has multiplied by 220 in eighteen years from 1.8 GW in 2000 to 397 GW in 2017, a growth rate of 56% per year. Figure 1.3 gives the details on the installed solar PV capacity of the top 10 countries and the additional PV power generating capacity in the year 2017 as shown in Figure 3. The development in the PV power generation depends on strategic and technical developments to reduce the cost of the PV modules and increase the reliability (Source: resourceirena.irena.org).

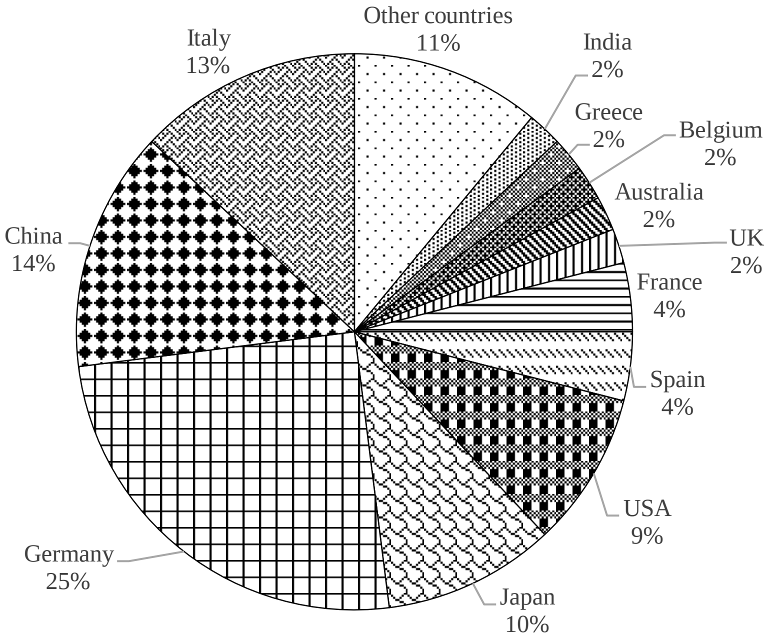

Figure 1. Cumulative capacities at the end 2013 top solar charts from Huge.

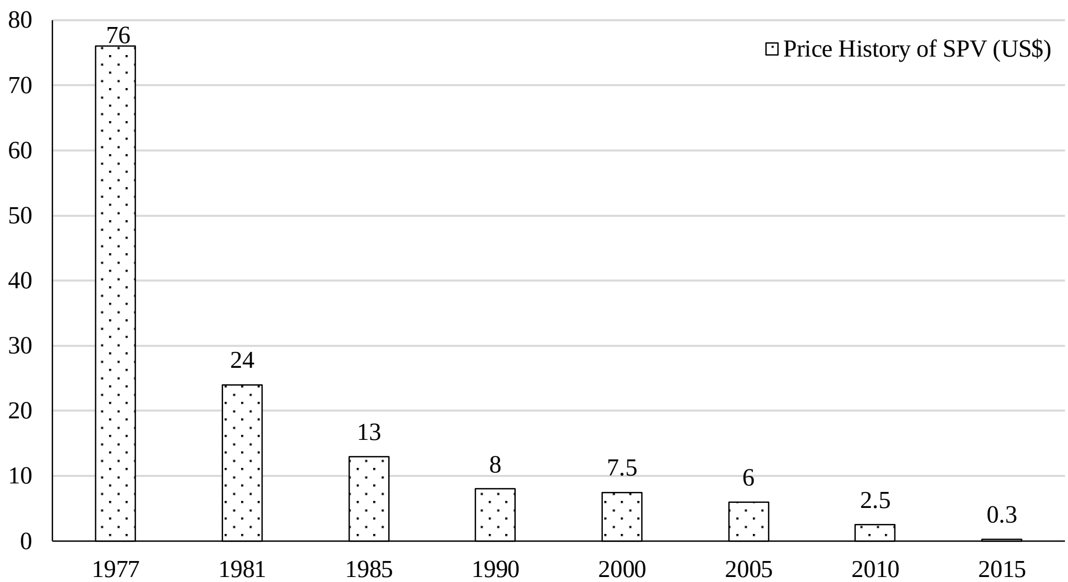

Figure 2. Solar PV price history.
Source: Bloomberg New Energy Finance & pv.energytrend.com.

LITERATURE REVIEW

For highly productive systems, the convergence speed should be low which results in frequent tuning to locate the MPP and reduces the power losses with high efficiency. Detecting the multiple local optimal points when the PV modules subjected to various insolation level is another significant parameter in detecting MPP. Under partial shading of the PV modules, the power loss is around 70% due to incorrect tracking of real MPP (Jung et al. [1]).

Enslin et al A well-designed renewable remote energy system that makes use of the Maximum Power Point Tracking (MPPT) principle can increase cost-effectiveness, dependability, and the standard of living in isolated locations.

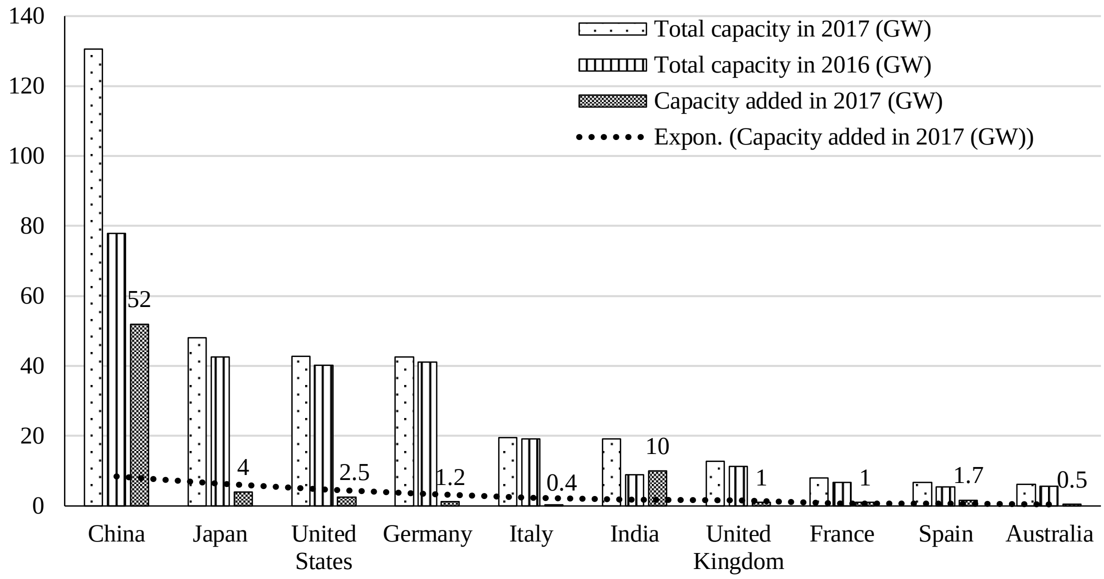

Figure 3. Global solar PV capacity.
Source: Data solar PV capacity

It has become possible to realise a highly efficient power electronic converter that can change the output voltage of a wind generator or solar panel to the necessary DC battery bus voltage. For relatively modest systems, maximum power point tracking is accomplished by optimising the output current in a battery charging regulator by the use of a low-cost, hill-climbing algorithm based on a microcontroller [2].

Espinoza introduced a unified method for producing pulsewidth-modulated patterns that offer fundamental current control and unrestricted selective harmonic elimination for three-phase current-source rectifiers and inverters (CSR/Is) [3].

Hussein et al. developed a novel topology for a seven-level asymmetrical cascaded H-bridge multilevel inverter with a fuzzy logic controller in order to lower Total Harmonic Distortion (THD) and enhance the inverter's overall performance. The suggested concept works well in solar photovoltaic applications. Just six IGBT switches with three distinct PV module voltage ratings (1:2:4) are utilised in this configuration. Switching losses, voltage stress on individual switches, and overall di/dt ratings are reduced when there are fewer semiconductor switches [4].

Chapman & Esram [5]; Saied et al. [6]; Sutikno et al. [7]; Tan & Kamarzaman [8] discussed various MPPT methods for the PV systems such as IC & PO, fractional open/short circuit voltage/current methods, advanced MPPT techniques (based on differential evolution, neural network (NN), particle swarm optimization (PSO), and fuzzy logic (FL)). The 44 MPPT methods for the PV panels under PSC are reported. Saied et al. [6] presented a review on 62 MPPT techniques with the theoretical results. From the detailed review, concluded that the common MPPT techniques are IC, PO and FL controller. The most familiar MPPT method is PO, and it has several advantages such as simple structure, low cost, smooth implementation, and fewer parameters measurement. The MPPT controller alters the PV output power with a tiny step in each cycle, and this step size kept fixed. The control parameters are PV voltage and PV current, and this is called perturbation. It depends on the power derivative concerning zero voltage at MPP. However, this method fails to locate the MPP under the fast-changing environmental condition and its convergence speed is high

Haque & Lyden [9] presents general MPPT methods such as modern MPPTs, conventional MPPTs, and power electronic converter-based techniques.

Chen et al. [10] presented The solar irradiance and temperature sensors are costly, and these sensors are rarely used in MPPT techniques. The definition of convergence speed is nothing but the time taken to reach the MPP (Leva & Faranda [11]). Depends on the various applications, the selection of the MPPT technique varies. The controller has to track the MPP continuously with less convergence time. However, it should not prefer periodic tuning on the controller (Mohamed et al. [12]). Direct and indirect methods are the two common techniques to implement the MPPT control over the system. The PV voltage and the current are physically measured by using the sensors in the direct method, whereas, indirect methods use the parameters including P-V characteristics of the PV panels or the mathematical model derived from the manufacturer datasheet to validate the MPP. Thus, the optimal point of the PV indirect methods is independent of the temperature and irradiance (Mohamed et al. [12]; Agarwa& Jain [13]) (Kerekes et al. [14]). The IC method is depending on the sum of the instantaneous conductance of the PV module, and the value of the IC is zero at MPP 46 condition. The value of the IC decides that the controller has located the point at PV delivers the maximum power and stopover perturbing the optimal point of the PV panels. The IC technique is an advanced version of the PO method, and it can track the MPP under rapidly changing in environmental conditions. Its tracking efficiency is higher than the PO method but complexity is more, and it results in high computation time Due to the familiarity and ease of hardware implementation, the PO method and IC method is considered in this research. This thesis objective is to design new topology for front-end dc-dc converter and backend inverter for the microinverter applications. So, the focus on MPPT technique is less, and the conventional and more popular MPPT techniques such as PO and IC are considered for testing the performance of the dc-dc converter and to determine the overall efficiency of the microinverter. Moreover, these techniques help to design a cost-effective system with higher efficiency (Chapman and Esram [5]; Mekhilef and Zainudin [15]; Chen [10]).

DISCUSSION

The MPPT methods are classified based on hardware, sensors, convergence speed, local optimal point, cost of the system and applications. The sensors play a vital role in MPPT techniques, and a high number of sensors affects the performance, and it is difficult for the designers to select the particular MPPT technique. The MPPT controller requires more accurate voltage and current sensors. The voltage sensing is easier than the current sensing. Due to the galvanic isolation and higher voltage gain, IS boost dc-dc converters have been studied and used widely in practical applications such as SPV energy systems, electric vehicles, fuel cell energy systems, telecommunications, DC power transmission systems etc. The NIS converters not provided with isolation; there are various topologies such as SI, SC, voltage multiplier (VM) cells are present to boost the dc voltage in transformerless structure with good efficiency with large power density but, the NIS converters do not meet the safety requirement due to non-galvanic isolation. To address this safety issue, some converters with isolation features discussed in this literature. The isolation between the grid and the converter provided with the help of transformers in isolated dc-dc converters. The 47 quality of power and the efficiency of the energy conditioning are depending on the transformers. The converter output current injected into the grid due to the nonappearance of the transformers, and it disturbs the grid distribution transformer. The tracking efficiency of the MPPT techniques is presented in where Pout represents the output power of the PV module, and Pmax represents the maximum PV power. As per the statement from for medium and large-scale systems, the tracking is essential to extract the maximum power. The various MPPT techniques help the users to select the system for the unique applications.

CONCLUSIONS

- In the context of this research project, we are addressing the issue of network power quality when inverter systems are connected to nonlinear loads.
- In the power system, nonlinear loads are a major source of harmonics. Additionally, inverter systems feature nonlinearity characteristics due to their electronic components.
- Inverter systems connected to nonlinear loads cause harmonic distortion-related problems and generate non-sinusoidal currents in the system, which reduces power quality in the system.

- We have specifically designed this study report to investigate the application of different controllers in this system.Initially, we completely focused on gaining knowledge about the basics of inverter and simulation of the inverter circuit and used a PI controller so as to minimize THD in the circuit.

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