A Review on DC-DC Converters with Photovoltaic System in DC Micro Grid

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Abstract. Photovoltaic system is the low-cost source of electrical power in high solar energy regions. The benefits of PV system are like nonpolluting and minimum maintenance. Solar energy changes as per irradiance and temperature and also one factor which reduces the power output is the partial shading in the cells. Henceforth, various algorithms are put forth to obtain the maximum power from the PV arrangement and dc-dc converters intend to regulate the supply. The concept of micro grid is emerging as an excellent solution for inter connecting renewable energy sources and loads. DC micro grid is a necessity in today’s world. There is wide increase in usage of DC systems in commercial, residential and industrial systems. DC micro grids are dominant in reliability, control and efficiency. Direct current architectures will be used in demand in the future electrical distribution systems. This paper reviews on all above concepts to be used in DC micro grid for future DC applications.

1. Introduction
Today, the world pays lot of consideration to renewable energy sources, as it is practically unlimited, clean and interdisciplinary research is always developed for the improvement of existing conversion technologies and new developments are carried out in this field. Photovoltaic (PV) constructions are the most familiar landscape. The power from the solar which is not depleting in nature is unpredictable and greatly fluctuating. One serious component of any PV is the effectiveness of its maximum power point tracker (MPPT). Various, MPPT methods have been presented by different authors and published in different reputed journals.

The concept of micro grid is emerging as an outstanding solution for inter connecting renewable energy sources loads. Power generation systems with applications in photovoltaic, step-up ratio of high voltage dc-dc converters are having increasing demand. Sources of microgrid are ecologically friendly and can integrate with renewable energy sources which include wind power, solar power, waste-to-energy, geothermal power and combined heat in power systems. The integration to any of the renewable DC generation with energy storage is easier and more efficient in DC power systems than in AC systems. As problems like harmonics, phase unbalances and synchronization does not occur, there is wide increase in the usage of DC systems in commercial, residential and industrial systems.

Extensive literature has been discussed on the ongoing technological progress which is mainly observed in high voltage dc-dc converter and also investigations on power optimization by various technologies are used to obtain low cost, higher efficiency, reliability, weight/volumetric dimensions and higher performance with advanced designs that are all in research platforms. Therefore, there is requirement of design of dc-dc converter PV architecture which has better prospectus with grid connected PV systems by adopting MPPT algorithm irrespective of climatological conditions.
This paper carries out extensive literature review on the earlier proposed techniques for MPPT, different dc-dc converters and grid system. It highlights some of the advantages and disadvantages and provides directions for future improvements.

2. REVIEW ON DC-DC CONVERTERS

The photovoltaic power system with middle power and PWM techniques at high and medium frequency with variable hysteresis modulation was carried out. DC bus at high-voltage was formed by the module combined with dc-dc buck boost converters which are connected in series, in this system. Phase current can be controlled by using PWM and changes its character and direction of the flow of power on the AC side of the module [1]. A new proposed circuit of dc-dc converter with input current of less ripple for which simple relations and modelling outcomes were provided.

The investigation about the optimization of power that can be attained for cascaded dc-dc converter in PV constructions was carried out. Perturb and observe method and Matlab/Simulink were the tools used. The systems of this kind confirms to have decent efficiency and low cost, when compared to parallel configurations, as in order to have higher boost ratio, individual choppers are not necessary [2]. To obtain global power optimization, supervisory algorithm was put forth, three-generator PV topology was used and block diagram of the considered cascaded PV architecture is as shown in figure.1 [2].

![Figure 1. Block diagram of cascaded PV architecture [2].](image-url)

The state of art on non-isolated converters and its characteristics in research work and the solution which best suits the applications with MPPT are discussed. According to the review of various converters, there is limitation in systems' performance when it comes to type of converter used. According to the paper, buck boost were most efficient for given price. Comparison of these converters with respect to input current, output voltage polarity, switch drive, cost and efficiency and the optimum operating performances of various converters are carried out [3].

Towards improving the system efficiency for PV application [4] studies the current-fed dual active bridge (CF-DAB) with improved operation and gives a design guideline for converter for PV system with wide input voltage variation applications. Under high input voltage and heavy load with reduced power loss and soft-switching region, proposed operating mode can be extended. Improvement can be done in efficiency with higher dc-link voltage. With complete operating choice using duty cycle and
Phase-shift control, a full study for CF-DAB converters was presented. An improved operating mode generating less power loss for wide input voltage range was developed to obtain high efficiency. In [5], an improved converter controller was designed using Current Mode Control (CMC) to maintain constant output, reduce the transient response time, good efficiency, stability and obtain low output voltage ripple and simulation was carried out using LT Spice. Voltage mode control was compared with the proposed control technique and voltage mode control had less performance than CMC. Thus for domestic solar PV applications, CMC is a suitable solution.

A detailed review on classification of converter topologies of isolated and non-isolated types with respect to comparative performance and various modulation strategies and information on various MPPT methods for converters in PV systems with future advances in dc-dc converters like module integrated, series resonance, integrated synchronous boost and soft switching current fed push-pull converters were studied in [6].

3. REVIEW ON LOSSES AND VOLTAGE STEP UP TECHNIQUES

Reference [7] proposed a converter of robust and simple solutions, without using transformers and by using cascading boost converters there are possibilities of getting higher voltage ratio and obtain overall good efficiency. For a line voltage of steep step-up, a circuit was suggested. Within a boost converter, switched-capacitor (SC) is integrated in the circuit. High voltage ratio can be achieved by SC with an increase of the supply voltage to higher voltage values. One advantage of the suggested circuit is its flexibility. Any higher voltage ratio could be obtained by increasing the capacitors.

A thorough review, introduction and framework which is systematic for high-step-up coupled inductor boost converters category wise was carried out. Boost converters with high-step-up coupled inductor represents an ideal converter for various applications with several advantages of high voltage gain, simple structure and low switch voltage stress. High-step-up coupled inductor boost converters were categorized in to five categories and were reviewed, which were derived from conventional boost converter. Reduction of the input current ripples, recycle leakage energy, and improving the step-up voltage gain are the future challenges that needs to be considered and the techniques to be used were discussed in [8].

Vast literatures gives details of increasing step-up ratio of the converter with voltage lift method can be increased by using basic quadratic boost converter. Voltage lift design is good for solar energy system and modern industrial applications. This design capabilities and potential values were illustrated by computer-based simulation results using LT Spice XVII and mathematical analysis. This design’s best duty cycle was in the range between 0.5 to 0.6 but there was higher power loss, at higher duty cycle and switching action in a circuit having inductors will not be perfect and as the inductors were increased, the power conveying efficiency decreased in [9]. One more paper gives the classification and review of several step-up methods in dc-dc converters which are based on voltage boosting techniques and their characteristics and its pros and cons were also discussed in detail. The overall review of various voltage boost techniques, different converters and circuits was carried out and this helps in fast selection between related alternatives for different applications and load requirements [10]. The power conversion system for next generation will utilize this advanced powerful power converter solutions. For industry and academic readers, this inclusive survey will be a beneficial resource.

A non isolated dc-dc converter is compared with Boost, SEPIC, modified SEPIC converters. The parameters considered here are supply voltage, output voltage, output power, efficiency and duty cycle. According to performance evaluation, output voltage and the proposed converter efficiency were better than traditional converters and was a good choice for RES applications. The settling time of the suggested converter with respect to steady state current and voltage was faster than the other converters which were compared in [11]. Matlab/Simulink was used for simulation purpose.

To obtain high voltage gain with ripple-free input current and also which is suitable for applications in renewable energy resources, a circuit having auxiliary active clamp was used to reduce the switch voltage spikes which was produced by leakage inductor of coupled inductors and it improves voltage gain. Voltage doubler structure clamps the diodes voltage stress which was located in the coupled inductor’s secondary winding. The observed voltage ripple of input and output were 4.8 V and 2.3 V respectively and the calculated input current ripple was 0.148 A and by using this method in active switches there was
less losses in the proposed converters [12]. To decrease voltage spike of the switch, active clamp circuit can be used which are mainly produced by leakage inductor of coupled inductor. Another technique of obtaining high step up voltage was explained in [13] by using a full bridge cascaded dc-dc converter and a voltage multiplier circuit like Cockcroft Walton Circuit (CWC) to obtain high voltage. The comparison of the proposed converter with CWC on voltage multiplier step up dc-dc converter and full bridge dc-dc converters is carried out. The results clearly specifies that the maximum efficiency and high voltage gain of 94.6 and 11.9 was obtained with ripple in input current being low and lower ripple in output voltage in Cockcroft Walton Circuit.

A dc-dc lift up converter, quadratic quadrupler boost converter having voltage gain to be high for photovoltaic built power generation particularly were used for micro grid. PSIM simulations shows that for 25 V input with approximately 0.35 MOSFET duty ratio, output voltage was 263 V and the coupled inductor having turn’s ratio of 1.9 had 10.5 gain. MOSFET voltage stress was 57 V, voltage stress on input diodes were 35 V and 18 V respectively with 40 V input voltage, maximum efficiency of 92.9 was achieved for suggested converter at 175 W power output and at this output power loss analysis was carried out. To decrease leakage inductance and switching devices voltage stress, coupled inductor with low value of the winding turn’s ratio was chosen in [14]. Future communications can have the proposed converter analysis with integration with internet of photovoltaic (IoPV) and soft-switching.

A quadratic boost converter of high voltage gain was designed through voltage-lift technique. In various industrial applications and also in PV and UPS systems, proposed boost converter can be used. To increase the voltage gain to almost greater by 4 times in quadratic boost circuit, voltage-lift cells were used in place of inductors. Voltage doubler cell was used which doubles voltage gain and improves the power switch voltage stress by decreasing it to half of the output voltage and conduction losses can be decreased by using power switches with low value of ON state resistance. The limitation is that efficiency analysis has not been considered on devices of the high voltage side and the switching losses analyses has not been done. PSIM for simulation was used in [15].

Non isolated interleaved dc-dc converter to obtain high voltage gain which can be used in RES applications with reduction of voltages stress, conduction losses and ripple in input current and recycling of leakage energy using voltage multiplier cell and two coupled inductors was introduced in [16] and the simulation using Piecewise Linear Electrical Circuit Simulation (PLECS) to obtain 800 V DC from 32 V at 0.68 duty ratio, 118 kHz switching frequency and prototype in hardware of 400 W with efficiency of 96.7 was carried out. The efficiency can be improved in the converter by more coppers which was highly recommended.

4. REVIEW ON MPPT TECHNIQUES

A thorough study of different MPPT methods like incremental conductance, perturb and observe (PO), fuzzy logic controller and hill climbing method was carried out considering duty ratio and PV output power parameters. The results indicated that fuzzy logic controller performance was best among hill climbing, incremental conductance and perturb and observe methods of MPPT techniques in both steady state and dynamic response by using PSIM and Simulink software in [17].

To deal with partially shaded conditions, the MPPT of a photovoltaic system and real power support with power quality improvement was done. When the suggested MPPT algorithm and conventional fibonacci search method was compared the proposed system had greater tracking speed and power tracking performance than conventional algorithm. For power generated from the PV system to be optimized power management system is also been offered along with battery system. Matlab/Simulink and MPPT technique and inverter control system are realized in dSPACE controller with a real time experimental prototype system are used. Based on two important aspects, proposed MPPT algorithm is done with PV array characteristic curve in partial shading and normal conditions along with a modified fibonacci search method [18]. In the grid having PV system, the power flow control between them and power quality improvement uses only single inverter hence this system is cost-effective and it operates both in grid-connected modes and standalone mode.

The review paper [19] gives details of various recent hybrid methods along with new MPPT algorithms. In the future, the references in PV arrangements in conditions of partial shading involves
lot of research works. MPPT methods has been grouped into essentially four important groups which are reviewed. The first group had MPPT optimization algorithm which are new algorithms, second group had MPPT algorithms in hybrid form, the third group had new modelling methods and fourth group had numerous converter topologies. The PV modelling methodology in partial shading condition by which power peaks can be identified easily. Different optimization algorithms were analyzed. In paper [20], shuffled frog leaping algorithm and particle swarm optimization (PSO) were incorporated for correct searching of the global point and a new proposed control technique with power tracking method and a PWM permutation system has been proposed, along with AC output voltages with multilevel DC link converter of 5 levels in different partial shading conditions. This system has buck-converter modules with two chained PV system and one dc-ac H-bridge for supplying an AC load is connected at the terminals and simulation studies were performed with the proposed MPPT scheme. Maximum power generation can be obtained by each of the modules in the PV system according its illumination level and considerably higher power output was observed in proposed method by using the new control method proposed and was compared with the PSO and PO methods. The waveform of output voltage performance was higher than the conventional PSO and PO methods in this paper. According to reference [21], in order to avoid the divergence of maximum power point, a MPPT algorithm with duty cycle finely-tuned dc-dc converter was proposed and with the help of simulation results and case studies, effectiveness of fast acting MPPT technique was demonstrated. With variation in radiation, the proposed MPPT algorithm along with incremental conductance method and perturb and observe method were discussed in this paper. To the variation of load and variation of solar irradiance, proposed algorithm shows better response than conventional algorithms with reduced power losses. According to simulation results, PV panels produced a voltage of 20 V, which was varying in nature by conventional MPPT algorithm but the current, voltage and power was in steady state in proposed algorithm.

Perturb and observe based MPPT controller and selecting the duty cycle faultlessly for controlling the output voltage using fuzzy logic based intelligence controller was proposed. It is depicted from the results that fuzzy logic controller is much faster than perturb and observe based MPPT controller with smoother signals, less variation and high efficiency. Simulation was carried out using Matlab/Simulink. Continuous current mode for high power conversion and for low power and stand by operation discontinuous conduction mode was adopted in [22].

Comparisons, reviews and analyses of nature-inspired and bio-inspired MPPT techniques with conventional techniques to optimize the output power during Partially Shaded Conditions (PSCs) in a PV was discussed. It presents the comparisons and reason of each global search of MPPT algorithms and reviews the enhancement of the performance of these methods when they are hybridized. Five evolutionary algorithms are being reviewed in this paper. The most generally used algorithm used for MPPT method is PSO. Algorithms on nature inspired that are based on MPPT methods are Artificial Bee Colony (ABC) algorithm, Differential Evolution (DE), Particle Swarm Optimization (PSO) algorithm, Ant Colony Optimization (ACO) algorithm, etc., are discussed in [23].

Details of analysis and the power generation patterns of PV system using smart converters were discussed. Simulation model of PV system with 5kW smart converter was made in Matlab/Simulink. In maximizing power delivery, a converter with PV system is advantageous when compared to string and central PV system. One of the problems faced by MPPT methods in converter with photovoltaic system is that it causes MPPT instability problem because of stiff voltage limit region hence this problem was solved by using R-based (Resistance-based) MPPT. One of the limitations of traditional MPPT methods is that when the system is successively going from MPPT region into a region of voltage limit then abrupt power drop will occur that leads to instability in the system which is a major issue of the system. When it comes to the sources, to simulate two PV panels, two simulators called Agilent Solar Simulators were used and each of the output of the simulator module was provided with solar magic, power optimizer which is coupled in sequence forming a converter string with two panels [24].

The paper [25], gives the total review papers published in last five years in google scholar with respect to various MPPT methods under different conditions with information on classification of soft computing and conventional techniques under non-uniform irradiance state. Conventional algorithms failed to attain GMPP in non-uniform solar irradiance and partial shading conditions, but soft computing methods having
complex algorithms were accurate and fast in tracking GMPP under these conditions. Recent and important techniques were discussed under non-uniform irradiance and partial shading conditions.

5. REVIEW ON GRID CONNECTED SYSTEM

The reference [26] discusses, still-open research issues and current state of art in the communications of smart grid like GSM, GPRS, 3G, WiMAX, PLC, ZigBee along with well considerate of the technologies, challenges and potential benefits in the research. The discussion of pilot projects, grid characteristics, architectures, key players, challenges in research and applications on information and communication technology issues, to give a complete summary on the topics are all the future works to be carried out. The QoS (Quality of Service) mechanism was introduced and standards are presented.

A control method was recommended for PV systems of 3 phase grid connected system with dc-dc converter. In order to supply alternating current of high quality in the grid, a 3 phase–2 level voltage source inverter was used and total efficiency increased as the transformer primary voltage increased. The PV arrays are interconnected to the grid by using power electronic devices like inverter and converter to analyze grid designed for 800 W photovoltaic system connected with 3 phase inverter systems [27]. Limitation is that, PV developers and simulation computer programmers should design more efficient PV systems to rise the output voltage of PV array and improvise the performance of MPPT.

To meet the high-power requirement and reduce the ripple at the supply current and hence a hybrid combination of three coupling inductors and three-phase interleaved boost converter was chosen. In real-time micro grid, before interfacing the converter, proper protection arrangements with proper isolation and standard safety precautions must be provided. Proposed converter uses gain extension technique for voltage stress on the switches to be reduced. In the micro grids, the striking choice of this converter were the modular structure, very low supply current ripple, low switch current and voltage stresses and at higher power level, higher voltage conversion ratio were very attractive features [28].

The paper [29] aims to obtain constant power flow between the load and sources by developing a new control technique. Elephant Herd Optimization (EHO) is used to attain the learning function of the Artificial Neuro Fuzzy Interface System (ANFIS) in Matlab/Simulink. Four cases of generated powers are compared with the existing method in this paper. In conventional controller when inverters are parallel-connected, there was imbalanced reactive power sharing which could cause line impedance mismatch in future work and this could be a serious problem in AC microgrid. To improvise the system response in the future another new strong controller should be designed.

A DC microgrid in islanding mode with PV module was presented with a new method to provide regulated voltage in DC bus of high quality irrespective of various problems in PV modules. Problems arising due to partial shading can be avoided by disconnecting the fault modules and providing flexibility by adding extra PV modules by using this approach method which was proved in a 200 W sample. The renewable energy sources and DC loads were connected to a DC microgrid of 200 V for the testing in distributed input series output configuration (DISO) which had the advantage of higher efficiency for more number of converters and allowed more sources to be connected, having voltage at output to be at high levels with less stress on converters has been published in [30]. In order to avoid miscoordination of fuses with other protective devices in a DC microgrid due to high penetration in renewable energy resources, a fuse saving scheme was proposed which can be used for conventional and digital protective devices with fault calculation, protection strategy and coordination of fuse and digital recloser switch settings was discussed in [31]. Matlab/Simulink was used by digital time domain simulation. The noise, cost and delay in given method was high due to dependency on communication link was high.

6. LATEST LITERATURE SURVEY

A combination of three coupled inductors with three phase interleaved boost converter was used to reduce ripple in input current and voltage spikes was reduced by active clamp circuits. To decrease leakage inductance and switching devices voltage stress, coupled inductor with low value of the winding turn’s ratio was chosen and future communications can have integration of converter with internet of photovoltaic (IoPV) and soft-switching. A current fed active bridge was used to improve efficiency with current
mode control for PV applications. In order to obtain high step up voltages, non-isolated interleaved converters, dc-dc lift converter, voltage boost and quadratic boost converters were used. Matlab/Simulink, PSIM, LTSpice and PLECS were software tools used for simulation purpose.

Information on various MPPT methods for converters in PV systems with future advances in dc-dc converters like module integrated, series resonance, integrated synchronous boost and soft switching current fed push-pull converters were studied. Advantages, disadvantages, comparison and applications of various conventional MPPT methods with recent nature inspired, soft computing, hybrid techniques and new proposed algorithms for power tracking methods have been discussed to track maximum power under various conditions like non-uniform solar irradiance, partial shading and load variations with the inference of hybrid and soft computing methods were accurate and fast in tracking GMPP.

To obtain constant power flow between the load and sources, supervisory algorithm was used with hybrid algorithm having Elephant Herd Optimization (EHO) with Artificial Neuro Fuzzy Interface System (ANFIS). In DC microgrid, distributed input series output configuration (DISO) was used in testing which has lot of advantages and in order to avoid miscoordination of fuses with other protective devices in a DC microgrid, a fuse saving scheme was proposed.

7. SUMMARY AND DISCUSSIONS
To meet the increasing response for power, solar energy has to be maximized which is of great interest in today’s world that can be accomplished by using dc-dc converters and MPPT methods. This review paper gives information on various categories of dc-dc converters with step up techniques and reduction in losses, MPPT methods to optimize power and grid connected system that are discussed in various publications. Many papers have proposed various MPPT algorithms for DC-DC converters to avoid the divergence of maximum power point. Various papers discuss about the still open research issues and current state in grid connected systems with recent new mechanisms introduced to improve the quality in grid system.

8. CONCLUSION
This paper gives an overview of dc-dc converters to obtain high step-up voltages with less losses, MPPT techniques to optimize power and grid connected systems to be used in micro grids for future AC and DC applications with renewable energy sources. A DC micro grid is required for advanced control system, when the fault occurs in the main grid it is an option to work in islanded mode and as small and intermittent energy storage elements are the primary requirements, DC micro grid brings the possibility of better efficient integration to any residential renewable energy source and energy storage systems. Extensive literature review on various methods for MPPT, grid connected system and different dc-dc converters are discussed in this paper. This data provides information for future research.

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