

Perlustration On Multifarious Converters For Renewable Energy Source

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Abstract

Escalation in the use of renewable energy sources in this modernistic world is more and more elevated due to the increase in demand for energy and exiguous-ness of non renewable energy sources. Wind and solar energies are thriving among all renewable energy systems. Harvesting maximum energy from the conventional energy system, converters and controllers play a vital role. Implementation of fundamental converters with PV array has stability, boost ability as well as ripple issues. A converter with wind turbine has harmonics, reactive power and unbalanced compensation capability issues. For renewable energy systems researches on new power converters are inevitable. It is achieved by magnetic storage device such as inductor, electric field storage element such as capacitor in addition with switching elements and diodes in various configurations. It may be perplexing and difficult to follow or habituate for different applications. In order to make a delineation of the general law and schema of various power converters, this paper effectively reviews different topologies and assort according to the circuit pursuance

Key Words: Converter topology, MPPT- Maximum power point tracking, PWM- Pulse width Modulation.

1 Introduction

Innumerable DC/DC converters are developed for certain applications. Classifications are based on functions they perform. They may step up or step down the voltage or perform both. Some of the converters available are, Buck converter, Boost converter and Buck-Boost converter, and zero current switching (ZCS) and zero voltage switching (ZVS) converters, ZETA, SEPIC, CUK. There was no definite classification before 2001. After that they were classified into six generation converters. The fundamental circuits, developed circuits, transformer, voltage lift, super lift technique belong to first generation. Under fundamental circuits are buck, boost and buck boost. Positive LUO, negative LUO, double output LUO, CUK, SEPIC, tapped inductor converter are developed converters. The transformer includes forward, fly-back, push pull, half bridge, ZETA converter. Voltage lift technique includes positive LUO, negative LUO, double output LUO, modified output LUO, self lift converter. Super lift technique includes positive output super lift LUO, negative output super lift LUO, positive output cascade boost, negative output cascade boost. The multi quadrant converters belong to second generation. The third generation classification includes switched capacitor converter and switched inductor converter. Soft switching converters is of the fourth generation. Synchronous rectifier converters and MER converters belong to 5th and 6th generation respectively.

Energy technology is familiar among the people in this decade. When compared to other sources available solar energy has zero emission that is pollution free. By recycling and proper disposal of PV cells extremely clean and abundant supply of energy can be obtained, till sunlight is available. Solar and Wind can be implemented for stand alone as well as for grid applications. The energy obtained from solar panel can be utilized locally, transported and stored. Based on energy requirements a PV system can be constructed. If there is a change in energy usage additional modules can be added to meet the change in demand. PV system can be enlarged or moved according to the needs. If the efficiency of PV system increases cost also increases. It is its main drawback. By means of tracking maximum power, employing converter with high gain efficiency harvesting energy can be increased.

2 Converter topology for PV application

It is necessary to boost and regulate output voltage since the source may or may not be controlled and the load may be or may not be constant. DC-DC converter utilized for regulating is more efficient than linear regulators. PV systems depend on environmental conditions because of which its input vary as a result the outcomes will also have variation. In spite of all these variations maximum energy is harvested by numerous dc-dc converter topologies. These topologies are discussed in [1]-[25]

In 1980s before the implementation of MPPT algorithm to track power efficiently from PV a different topology employed is use of bidirectional converter and a storage device along with conventional converter. Bidirectional DC-DC converter here acts as stabilizer. When PV extracted power meets the load demand excess energy is stored in the battery. If not PV extracted power along with battery stored energy is fed to the load [1]. The energy harvested from PV panel can be enhanced by MPPT. MPPT usually connected externally instead it can be integrated in PV panel. The converter is employed with soft switching technique. Soft switching converter along with integrated MPPT has higher conversion efficiency at low cost. The cost of PV generation system cost would reduce if this method is integrated in PV panel rating of 75-100 W. This topology results in reduction of 25% of the panel area [2].

In photovoltaic (PV)-powered lighting system (PPLS) a bidirectional buck boost converter performs charging and discharging. Fluorescent lamps is driven by Class D resonant parallel loaded inverter. By inverted T type synchronous switching scheme the number of switches is reduced. Fuzzy logic controller controls charging and discharging to regulate current and MPPT control algorithm helps in harvesting maximum power from PV in PPLS [3].

Increase in voltage gain is achieved by high value of duty ratio or by large amount of circulating energy. Decrease in converter efficiency is because of losses in the leakage inductors. This loss can be overcome by replacing active switches. It is replaced by coupled windings and diodes to achieve high efficiency. It is an active clamp with additional diode and one coupled winding which recovers leakage energy. Voltage stress on the switches is reduced and the

circulating current level is low. [4]. Super lift techniques employed to increase dc voltage in arithmetic progression .By adding inductors and capacitors and with less number of switches high voltage gain is obtained. Recent trend is to employ this technique in PV system to increase the conversion efficiency [5]. Each PV panel has converter connected to it .They have the following advantages. They are maximum power can be tracked from individual panel that is the flexibility in the layout of the panel ,replacement and is sensitive to shading, installation becomes safe, maintenance is easy .Better protection of PV source and reliability, when converter or source fails. Converters that can be cascaded for PV systems are Buck, Boost, CUK, Buck Boost. High voltage is achieved by means of series connected dc-dc converter for each PV panel. It was examined that buck converter can deliver power in any range, but the disadvantage is that requires more panels. Boost converter require fewer panels but cannot deliver all the power. For better efficiency and flexible voltage range best topologies are Buck Boost and CUK [6].

The different sources such as PV array, wind turbine, fuel cell etc can also feed dc-dc converters. The combination of two or more different sources can act as an input for DC-DC converter. Current fed topology with two separate control loop regulates the converter for high voltage applications. Configuration simplicity, less number of components, lower cost and high efficiency are the advantages of this converter. Prototype of this converter is fed with two different power sources. The feasibility of the system was verified by means of simulation and experimentation and the result was found satisfactory [7]. For PV shows non linearity, voltage based power tracking along with the coupled inductor increases the efficiency, reduces the magnetic core requirement. For tracking the switch mode converter is employed. It partly decides the response of the system. For ripple free array current a coupled inductor SEPIC converter is employed in spite of other converter topologies [8]. The life span of the battery can be extended by means of proper selection of switching scheme. To regulate the current ripple, optimize the switching losses, hysteretic sliding mode control is implemented. This method shows an improvement of 7% increase in the life of the battery [9].

By using flying capacitor technology with converter reduces the

high pulse current and EMI problems. It is implemented for higher power applications. Proto-type developed for full load shows an efficiency of 96% [10]. The increase in the value of voltage gain is due to the coupled inductor based converter. Active sun tracking scheme implemented is based on open circuit voltage to track maximum power. Adaptive Total Sliding Mode Control (ATSMC) mechanism is employed to control output voltage. Implementing the above said the increase in energy conversion is 96.5% higher than conventional converters. Harmonics also reduced. Its value satisfies the industrial application standard [11]. PV systems also feeds Phase shift full bridge converter (PFSB) along with voltage doubler and decoupling inductor. The voltage doublers help in achieving higher voltage gain. The current oscillation due to voltage doubler is avoided by the external inductor. The inductor imposed on the circuit provide wide zero voltage switching ranges. The integration of external inductor and transformer increase the power density. PFSB is experimented for 100W prototype converter and its efficiency is about 93% at rated condition. PV system employing PFSB requires high efficiency and power density is satisfied by voltage doubler and external inductor [12].

PV module characteristics for ISOS reduce the power rating with increase in efficiency for ZVS full bridge. Input voltage controller achieves the equal sharing of input and output voltage among the module. 25 kW proto type is developed to verify this topology. Experimentally it was verified that this topology shows rise in efficiency for large variation in PV cell voltage and load range [13]. More efficiency than the boost converter is the series connection of fly back converter output with PV panel. It reduces the cost, increases efficiency. The power capacity required for the converter is 25% less than the rated PV system. The efficiency is found to be 95-98% [14]. Multilevel Boost Converter (MBC) with switched capacitor function performs better without extreme duty cycle. The advantage of this method is that more levels can be added without change in the primary circuit. MBC has one driven switch. Multilevel inverter principle paved the path for one single switch. MBC proto-type was developed. The experimental results prove that additional levels can be added without making changes in the primary circuit [15].

Reliability, cost and efficient interface capability are the param-

eters which decide the integration of PV system. The good performance is provided by low volt-age full bridge isolated boost converter. It takes part in reducing the disadvantage namely switching loss [16]. Switched capacitor in parallel with buck boost con-verter and proper selection of tank design parameters helps in achieving high effi-ciency without additional switches. The prototype is developed and tested. The con-verter efficiency when tested is 92.5% [17]. The oscillations of voltage in the system are overcome by electrolytic capacitor but it reduces the reliability. Instead of feed-back, feed forward configuration can be introduced to compensate voltage oscilla-tions. The equations for compensation justify that there is no dependency on the circuit parameters of the converter [18].

High voltage is created using series string of converters which is then connected to DC-AC inverter. In case of in homogeneous irradiation full power is not delivered to the load .There is a continuous flow of series current under normal climatic conditions. Under shaded conditions string current diverter diverts the flow of current by decoupling the converter from that particular string. The sensor less detection of current is carried out. MPPT algorithm is effectively applied for shading conditions. Thus under both conditions of irradianations that is homogenous and in homogenous NDSCD performance is good with an efficiency rate of 15.41% [19]. Interleaved active clamp mode with coupled inductor is a modified form of boost converter. The ability of transferring power, increase in volt-age ratio is improved by this topology. Soft switching is provided by active clamp circuit. Synchronous switch-ing technique is integrated with the converter switches. Active clamp circuit reduces the system complexity, components in the circuit which ultimately reduces the cost and the volume occupied by the system. Prototype is built and its efficiency is eval-uated under full load conditions. The efficiency was found to be 91% .This out-come verifies the feasibility of the active clamp circuit [20]. For large variation in input range of PV system, a hybrid type of series resonant PWM boost converter is employed. It has bidirectional ac switching. Switching schemes are ZVS and ZCS. These features are verified for 300 W prototype converter [21].

In multilevel cascaded dc-dc converter 3 PV generator is coupled to a half bridge buck cell. Each converter has independent

control such that maximum power is tracked under different irradiation and temperature level. Internal Mode Control (IMC) is used for tuning the controllers. In order to mitigate the current ripple switch-ing modulation strategy employed here is shift switching technique. Possibilities of connecting PV arrays are either in series or parallel. In case of series connection buck converter is preferred when compared to that of boost converter because it allows bi directional power flow .It also allows interfacing with the batteries, super capacitors to cascaded systems [22]. In recent years energy source integration to the grid is gain-ing importance. The continuous input current in dc -dc converter reduces the bulky capacitor at the input side. This method if implemented reduces the cost, increases the reliability since these capacitors have short life span. The mathematical and small signal models are derived for SEPIC and CUK and their performance are compared. The accurate modeling established predicts maximum obtainable gains that can be obtained from set of parameters before implementing it for higher applications [23].

For high output voltage, converter consists of voltage multiplier cell and boost converter. One switch achieves the high voltage where the efficiency of conversion is 20 times more. It is achieved at duty cycle less than the extreme values. Thus high voltage gain is achieved by means of conventional boost converter and voltage multiplier. This converter topology is verified for 20 V input, 500 W,400 V output and its performance was validated with the simulation results [24]. SEPIC is provide with a voltage doubler circuit. The voltage doubler provides increase in voltage gain. The voltage stress across the semiconductor devices also reduced. A single phase full bridge inverter is fed from this high step up dc-dc converter. The output of the inverter can be fed to AC grid applications. The efficiency of the energy conversion in this converter is increased by high static gain, fast dynamic response, and reduced voltage stress across the switches, low switching losses. The prototype was developed for 250 W/300 V dc output with 30 V PV input. This converter efficiency was found to be 92.9% at full load conditions with low voltage stress [25].

3 Inverter/converter topology for grid connected PV

Small residential to large utility-scale solar power stations are connected to grid. The different topologies available are discussed from [26]-[50]. High frequency Fly back-type utility interactive inverter circuit can be implemented because it increases the life span of the inverter, lightweight, occupies less space and manufacturing cost is low. The pulsation caused by the single phase power generation is decoupled by an additional circuit. This thin film capacitance of small capacitance value replaces electrolytic capacitors prevents shortfall of life of the inverter. The number of parallel connected inverters is equal to the number of PV modules. Lower power dc-ac utility interactive inverter of each module overcomes the variation in power generated by PV, when there is a variation caused by shadows [26].

Single stage grid connected PV system is Z source inverters integrated with grid tracks the maximum power and also facilitate the current to the grid. Integral compensation of sliding mode control guarantees the robustness of the system. [27]. Dual series resonant rectifier with active clamp increases the energy conversion value, eliminates the use of sensor, the value of ripple present in the current is reduced. Prototype was developed for PV voltage range of 30-60 V with 1 kW power rating. The prototype showed high performance. Efficiency value is in the range of 92.5-94%, value of PV ripple current is 3.5%, power factor is close to unity [28].

In renewable energy systems energy quality is improved when a storage device is charged by Class E buck boost resonant bidirectional converter on either side of the isolating transformer. In addition high efficiency and good dynamic properties are achieved by soft switching the converter transistors in ZVS condition. This topology has low size, low weight with high frequency ZVS switching process. Because of current sourced converter this system is environment friendly [29]. PWM technique uses 2 reference signals and one carrier signal to generate PWM switching signal to 1 phase five level photovoltaic inverter. Experimentally verified that harmonics of this topology is much less than 3 level inverter. To optimize the performance of the inverter PI control algorithm is implemented [30].

High frequency transformer feed the full bridge inverter which generates controlled output voltage with ZVS operation for both input and output side. The leakage inductance of the transformer eliminates the need of snubber circuit and over voltage across the device. Tracking the maximum power by P& O method. This converter has high efficiency, reliability and good integration level. The consistency of the system is confirmed by experimental and simulation studies [31].

In this method the number of conversion stages are minimum, switching losses are low and the switches are operated at high frequency [32]. Dissemblance of electrical parameters, fragmentary shadows grieve the modules in building integrated PV. This results in decrease in efficiency and reliability. A centralized inverter is a solution for PV dc building module (PVDCBM) The power line carrier communication transmits the information between PVDCBM and inverter. The controller in PVDCBM performs maximum power tracking, regulating voltage. But the disadvantage of this method is reliability problem caused by change in the ambient temperature. Converter efficiency is lower than the single stage PV power system. Several topologies for PVDCBM based BIPV system are available. Different topologies of converters for PVDCBM are compared and evaluated. Out of these topologies best one is found to be active current fed half bridge converter. PVDCBM based BIPV is validated and its performance is found satisfactory from the experimental results of the prototype [33]. Boost type active clamping circuit and voltage doubler rectifier reduces the switching losses, achieves zero current switching and is applicable for high voltage applications. This converter performance was evaluated for the power rating of 260 W PV MIC system and the value obtained as output is 350 V from 36 V low PV module [34].

High voltage gain topology have many switches for achieving high efficiency. The number of switches is reduced in the topology of single switch isolated dc-dc converter compared to traditional isolated bridge converter. Single switch isolated converter topology was implemented for real time PV system. The outcomes are validated with the theoretical and simulation studies [35]. For grid connected photo-voltaic application a family of inductor less forward fly back converters can be implemented. Usually in inductor less converter the voltage gain cannot be controlled. But in this

method it is overcome by utilizing dual constant on time modulation. The switching losses are effectively reduced in inductor less forward converter by operating with minimum off time and in a piece linear. The severity of circulating energy is reduced [36].

A control method in which the step size of MPPT is varied is incorporated for boost half bridge converter to track maximum power. The repetitive current controller regulates the current flowing to the grid. For single phase grid connected PV systems boost half bridge converter is integrated with full bridge inverter. The two converters are isolated by a transformer. By using two active switches the conventional boost converter is integrated with half bridge converter. This circuit is simple and of low cost. It is highly reliable and efficient under heavy and light load conditions. The stability is obtained by MPPT and repetitive current controller. THD of low value that is about 0.9-2.87% and power factor almost higher than 0.99 is guaranteed by this method [37].

Dual active clamping circuit with resonant voltage doubler rectifier employing complementary switching sequence ensures fast dynamic response. For fast output voltage control PI controller is modified. In this topology the switching losses are less, voltage stress on the switches are reduced, output voltage is regulated fast for output load variation. Prototype for a power rating of 200 W PV model is developed. The efficiency value achieved by this converter is 97.9% [38]. The problems posed by large PV module strings are dissemblance and fragmentary shading effects, safety issues as well parasitic capacitance effect. This led to low PV voltage source employing high converter gain high efficiency dc-dc converter. Instead of MPPT Required Power Tracking (RPT) is implemented. RPT tracks power as per the load requirement. RPT does not allow over charge or deep drain of discharge as a result life of the battery extends. The system efficiency is found to be 94%. Partial shading and capacitance effects are overcome converters with high gain. The control strategy need not be changed when replaced with other available sources. A reference frame transformation helps in achieving better efficiency of the inverter. Inverter output is regulated by SPWM. Regulation of dc link voltage is carried out based on active power demand. The disadvantages of this method are increase in the number of sensors, complexity in designing high gain dc-dc converters [39]. Interleaved LUO converter combines the mer-

its of interleaved and switched capacitor topology. This topology can be implemented for series or parallel connected PV module. The disadvantage of this topology is justified by reducing the component rating of the Interleaved SL LUO to half of the super lift LUO [40].

Quasi Z source series resonant can be implemented to operate the PV module so that best possible energy is harvested. This topology operates two switching schemes that is ZVS and ZCS to achieve high efficiency. The converter prototype was developed and tested to ensure ripple free 400 V output voltage. The maximum efficiency value obtained at nominal load is 97.45% nominal mode for power rating value of 250 W [41]. Cascaded multilevel inverter with current fed dual active bridge improves the system reliability. This topology replaces thin film capacitor instead of electrolytic capacitor. Minimization of peak current stress, ripple free power is done by using dual loop control. Incremental Conductance MPPT method is employed for PV system. 5 kW PV converter module was developed and tested for power mitigation control and MPPT method. Efficiency for PV system was realized above 99.5% [42].

Single stage conversion along with proper power tracking mechanism provides better utilization, high efficiency at low cost and compact size [43]. Generation of two 90 shifted output voltages by the multilevel inverter feed the grid. For grid connected three phase balanced system Le-Blanc transformer was used. Its performance is found good for multi string based PV system [44]. For low input range say less than 5 kW, transformerless 3 level voltage source inverter, is a best solution for the PV system connected with the grid [45]. Evaluation for grid connected PV system is based on array scale, environmental conditions, system cost, inverter efficiency and reliability. The parallel operated inverters with dc link bus can have elevation of conversion efficiency. But the number of inverters should be limited in range. Maximum power can be obtained by better orientation of PV panels. There should always be a compromise between efficiency and cost. The inverters connected in parallel are assumed to have independent efficiency characteristics [46]. PV system performance is affected by inverter failure. The factors that causes short fall of performance are reliability, inverter configuration and repair time. The inverter configuration is optimized by Monte Carlo analysis [47].

The optimal number, type of the PV modules, DC/AC converters, PV modules optimal tilt angle, optimal arrangement of the PV modules within the available installation area and the optimal distribution of the PV modules among the DC/AC converters are the decision variables taken in to consideration in order to increase the life time period .By this method lifetime period is increased at reasonable cost. With available system devices which configuration combination gives the best performance is suggested [48]. Different topology of inverters for photovoltaic applications is discussed to convert low voltage PV source input to high voltage to feed the grid [49]. More inverters are less susceptible to non uniform radiations will perform better for partial shadings is not true in all cases. String inverters have more shading losses when compared to centralized inverter. It is needed to take into consideration inverters MPPT when determining the maxima that appear in the generators P-V curve under different inverter configurations [50]. The table I and II brief the classification of converters based on the performance.

4 Conclusion

Ersatz and elegant energy source available in many countries is solar. The use of PV modules has to be optimized becomes necessary due to growing demand. Due to the decrease in price and increase in efficiency of PV cells in PV market, the converter topology changes according to the standards and demand requirement. But converters faces issues such as decrement in its performance and efficiency, variation in power density, grid code compliance, reliability, warranties, and cost. In order to overcome these issues a large number of researchers have developed new topology based on application, efficiency, cost, size etc. Numerous converter configurations available are bidirectional boost converters, super lift converters, cascaded boost converters, conventional converter with voltage multiplier ,soft switching converters etc. They have high conversion efficiency, high voltage gain, reduced switching loss. Grid connected PV systems can have different configurations such as multi-level inverter, centralized inverter, isolated converter , non isolated converter ,boost half bridge micro inverter photovoltaic

system, quasi Z source series resonant converter etc. Their performance and feasibility are analyzed by different researches. MPPT technique is employed to different converter configurations to obtain maximum power. A clear view is provided for researchers, designers and engineers. It helps them to choose the most appropriate converter configuration for the desired application.

Table 1. Proposed converter topology based on performance for PV application

Performance	Converter Configuration
High efficiency	1. Boost type bidirectional dc-dc converter 2. Multiple input dc-dc 3. Coupled inductor SEPIC 4. QSW ZVS converter 5. DC-DC converter with flying capacitor technology 6. Passive regenerative snubber circuit with coupled inductor based converter for standalone PV system 7. PSFB converter with voltage doubler and decoupling integrated magnetic 8. Boost converter with voltage multiplier 9. SEPIC converter with voltage multiplier 10. Half-bridge buck cell for each PV generator 11. Hybrid series resonant and 12. PWM boost converter 13. Interleaved active clamp boost converter with coupled inductor 14. Cascaded PV modules with integrated converters and 15. Non dissipative string current divider 16. Switched capacitor buck-boost dc/dc parallel connected distributed photovoltaic system 17. Full bridge dc-dc converter 18. Module integrated dc-dc converter 19. Series module isolated full bridge dc/dc converter
Ripple free	1. Coupled inductor SEPIC 2. LUO converter lift techniques 3. Half-bridge buck cell for each PV generator
Reduced switching loss	1. Clamp-mode coupled-inductor Converters 2. QSW ZVS converter 3. Passive regenerative snubber circuit with coupled inductor based converter for standalone PV system 4. Full bridge dc-dc boost converter
High voltage gain	1. Boost converter with voltage multiplier 2. SEPIC converter with voltage

Table 2. Brief the configuration based on performance of power converter for grid and stand

Performance	Configuration (Grid stand alone)
High efficiency, less volume and Lightweight	1. Flyback-type utility interactive inverter circuit with PV module and power decoupling circuit 2. Class E buck/boost resonant bidirectional DC-DC converter 3. Interleaved and switched capacitor converter 4. Two dc-to-dc, buck-boost Converters operating in DCM
Ripple reduction	1. Z-source inverter with MPPT and SMC 2. Quasi-Z-source series resonant DC-DC converter 3. (CF-DAB) dc-dc converter with cascaded multilevel inverter (CMI) with MPPT tracking 4. Active-clamp step-up DC-DC converter with IC MPPT tracking inverter controller
Less total harmonic distortion	1. Transformer isolated boost-half-bridge DC-DC converter and a full-bridge pulse-width-modulated inverter. 2. Single phase 5 level photovoltaic inverter with digital PI control algorithm
Low switching loss	1. Photovoltaic (PV) micro inverter using a single-stage high-frequency ac link series resonant converter 2. Active-clamping circuit with voltage-doubler rectifier 3. Single-switch isolated DC-DC Converter with MPPT tracking, high frequency transformer and inverter 4. Inductorless forward-fly back converters

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