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Chapter

Survey on Photo-Voltaic Powered Interleaved Converter System

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Abstract

Renewable energy is the best solution to meet the growing demand for energy in the country. The solar energy is considered as the most promising energy by the researchers due to its abundant availability, eco-friendly nature, long lasting nature, wide range of application and above all it is a maintenance free system. The energy absorbed by the earth can satisfy 15000 times of today's total energy demand and its hundred times more than that our conventional energy like coal and other fossil fuels. Though, there are overwhelming advantages in solar energy, It has few drawbacks as well such as its low conversion ratio, inconsistent supply of energy due to variation in the sun light, less efficiency due to ripples in the converter, time dependent and, above all, high capitation cost. These aforementioned flaws have been addressed by the researchers in order to extract maximum energy and attain hundred percentage benefits of this heavenly resource. So, this chapter presents a comprehensive investigation based on photo voltaic (PV) system requirements with the following constraints such as system efficiency, system gain, dynamic response, switching losses are investigated. The overview exhibits and identifies the requirements of a best PV power generation system.

Keywords: solar, renewable energy, converters

1. A survey on soft switching technique

The efficiency of our conventional boost converters is mainly affected by the power loss during switching. The hard switching performed by the switches actually causes major power lose and hard-switching of the semiconductor switches, generates voltage and current stress during turn-on and turn-off process. In order to overcome the losses during the switching stress, plenty of methods have been derived. Among these methods, however, soft-switching is considered to be the most popular and most efficient method. The soft switching technique is introduced in early 90s and soft switching means smooth turn on and turn off of switches.

During soft switching, zero voltage switching (ZVS) and zero current switching (ZCS) is possible during turn-on and turn off of the power switches. Interleaved converters have showed a significance improvement in the efficiency when compared to the conventional boost converter which is evident from our previous research work. Some of the soft switching techniques adopted till now are summarized briefly in **Table 1**. This section discusses and reviews the performance of few soft switching topologies that were introduced in the recent past.

From the above literature, it is evident that resonant soft switching technique with power conditioning system could be considered as the best due to its reduced switching losses and its ability to attain high efficiency with no additional switches for soft switching. The objective of high efficiency and better performance is achieved by connecting PV power conditioning system (PVPCS), MPPT using PV simulator and current balancing control technique. Most of the above-mentioned work deals with soft switching with an external circuit to achieve ZVS and ZCS condition of the switches for boost, buck and also for buck-boost. Since switches experience less voltage stress across them, the conduction loss is reduced to a great extent which obviously improves the efficiency.

Though, lossless switching have obtained improved efficiency care should be taken to reduce the converter size since extra external device are used for soft switching and also make the converter cost effective. Interleaved converters have filled this gap of over size of converters by avoiding external device rather, it designed and emphasized in such a way that two or more converters are put together to obtain improved efficiency and in turn voltage gain.

Cha et al. [1] proposed a solar powered high efficiency soft switching boost converter. Soft switching is achieved by adding an additional switch of 30 kHz switching frequency IGBT, a couple of diodes and single capacitor to the conventional boost converter. By adopting this method, the size of system is reduced.

Wu et al. [2] eliminated hard switching by adopting active clamping technique in 190 kHz switching frequency MOSFET. Where, ZCS cell is included with the conventional converter of 500 W, with 150 V DC input voltage. It consists of an auxiliary inductor and a clamping diode. The output of 350 V DC voltages is obtained.

Das et al. [3] achieved steep conversion ratio in the conventional converter of 200 W and 66 kHz switching frequency with the help of coupled inductor and eliminated switching losses by adding auxiliary circuit consists of a switch and passive elements. The converter can be operated in both buck and boost mode with input voltage of 30 V DC and 200 V DC voltage.

Park et al. [4] improved efficiency of our conventional converters of 700 W by eliminating the losses by soft switching. The converter input voltage is 230 V DC and output voltage is 380 V DC and has switching frequency of 30 kHz. A simple auxiliary resonant circuit (SARC) adopts ZCS during turn on and ZVS during turn off. SARC consist of two diodes, an inductor and a capacitor. It is easy control since both the switches are controlled by PWM signal. MPPT controller is applied to the circuit.

Lee et al. [5] used soft switching technique and interleaving technique in a buck converter to improve the step-down conversion ratio where the efficiency of the converter in high with an input of 200 V DC and output of 24 V DC with a switching frequency ranges from 65 kHz to 300 kHz. Here, the active switches connected in series and a capacitor is connected in the power path. The two active switches are connected in series with a coupled capacitor in the power path to yield higher conversion ratio. Since switches are connected in series the voltage and current stress across the switches are less and easy to control. High switching frequency, less voltage stress and reduced switching losses are achieved. Capacitive discharging is lowered. High conversion ratio and smaller output current ripple is obtained. An output voltage ripple of 250 mV is witnessed.

Amorndechaphon et al. [8] connected an active resonant snubber with a DC-DC boost converter in grid connected PV system in order to reduce the switching losses and switching stress. Circuit components for soft commutation are derived from equation of each operating stage. The proposed active resonant snubber experiences reduced switching losses as well as stress.

Lee et al. [9] handled losses in a conventional boost converter of 150–340 V DC voltage due di/dt, dv/dt in switch with 50 kHz switching frequency and EMI with

Power stage	Methodology	Additional components	Achieved objective	Reference
Boost	Additional switch of 30 kHz (IGBT)	Switch, inductor, capacitor couple of diode	High efficiency, reduced system size	Gil [1]
Non-isolated DC-DC boost	Active clamp ZCS cell (MOSFET)	Clamping diode	Circulating loss is minimized, reduced voltage stress in diodes, ZCV in all switches, high efficiency	Wu et al. [2]
Bidirectional DC/DC PWM buck-boost	Single common auxiliary circuit	Coupled inductors, single active switch passive elements	Step voltage conversion ratio	Das et al. [3]
Boost	Simple auxiliary resonant circuit	Auxiliary switch, diode, resonant inductor, resonant capacitor	Reduced switching losses, reduced voltage and current stress of the switching devices, easy control	Sang-Hoon Park et al. [4]
Boost	Current transition PWM	Additional cell in main switch, resonant inductor	Reduced di/dt & dv/dt, EMI is reduced, current stress is reduced efficiency improved	Lee et al. [5]
Boost	Zero voltage switching resonant	DC-link in parallel	Voltage stress in switch is minimized, sub-harmonic problem due to DPWM is eliminated	Lee et al. (2001)
Boost	Resonant soft switching technique, power conditioning system, Interleaving	Not required	Reduced switching losses, high efficiency no additional switches are needed for soft switching	Doo-Yong-Jong (1991)
Buck-boost	Zero-voltage switching, zero current switching interleaving technique	Resonant inductor, resonant capacitor, two parasitic capacitors and an auxiliary switch	Voltage and current stress in switches are reduced, input and output current ripples are reduced, size and cost is reduced	Doo-Yong Jung et al. (2001)
Fly back	Single capacitor snubber	Two turnoff snubbers (with inductor, capacitor, diode)	Smooth turnoff of switch, with reduced system complexity	Chen et al. [6]
Fly back	Dual series resonant active clamp technique	Clamp capacitor, auxiliary switch	Switching losses and reverse recovery losses is reduced, high efficiency is obtained	Tseng et al. [7]

Table 1.
Literature summary of soft switching technique.

ZCT-PWM. An additional cell is connected across the main switch reduced di/dt obtained by resonant inductor by soft turn on of main switch.

Doo-Yong Jung et al. [10] connected a photovoltaic power conditioning system to a conventional 1.2 KW ILBC for PV power generation application. The author worked as an improvement in ILBC mentioned in literature in Caris et al. [11] by connecting PVPCS (PV power conditioning system). Interleaved resonant soft switching method is implemented to reduce switching losses. MPPT using PV simulator and current balancing control is done. The work achieved 97.28% efficiency.

Chen et al. [6] three stage interleaving topologies in boost converter handles both voltage and current stress across the switches also get rid of the input and-voutput current ripples in the converter. The 600 W converter works in a couple of operational mode depending on the duty cycle with a switching frequency of 50 kHz and 250 V DC input and 400 W DC output voltage.

Tseng et al. [7] proposed an isolated interleaved buck converter (ILBC) with lossless turn off switches of 50 kHz using a snubber circuit. The snubber is single capacitive turn off snubber connected to 150 V input voltage and 100 V DC output voltage respectively. Work results in less number of components and complexity.

Lee et al. [12] proposed a 400 W fly back converter which is designed in such a way that the series resonance help in PWM, dual series circuit does the ZCS turn off of the diode, active clamping is responsible for magnetizing inductance and ZVS turn on. Thus, high efficiency is obtained by reducing the voltage stress across switch with 100 kHz switching frequency hence reducing switching losses and reverse recovery losses.

Table 1 summarizes the few soft switching topologies discussed in the above Section 1.

Below are the few advantages of this technique that have been witnessed during this literature,

- The semiconductor switches are handled in a smooth fashion during its operation to heavily bring down the switching stress.
- In addition, the switching losses (i.e.) due to di/dt and dv/dt are eradicated to a great extent.
- Obviously, the improved system efficiency brings down the cost of the converter system.
- It is also understood that by soft switching, EMI problems and
- Sub-harmonic problems have also been treated by the authors of the literature.

Therefore, all benefits put together produce a good conversion efficiency to the converter.

It is understood from the above literature that the soft switching is done by introduction of an external or auxiliary circuit in parallel to the main switch to make the turn on and turn off in a smooth fashion without power loss. Therefore, a good conversion efficiency has been obtained for the converter.

2. Review on interleaving technique topologies

Ultimately to extract maximum energy from the solar panel a converter is connected between the panel and the load. If high step converter is connected to the panel then the efficiency will be high. This includes ripple reduction with different conversion stages for different load conditions with different filters. A single-phase boost converter switches due to its extreme duty cycle faced high conduction losses and reverse recovery problem. The voltage stress in the semiconductor switches played a major role in the reduction of efficiency. So, it is evident that efficiency and the cost of the converter are proportional to each other. In addition to that they also suffer high current ripple which does not greatly support MPPT algorithms. Interleaved converters have showed a significance improvement rather than the conventional boost converter which is justified by our previous work. With all the above statements, it has been concluded that the system efficiency is improved due to the fact that interleaving technique reduces the ripple current. The researchers yet have handled many various topologies and few of them are listed below.

Numerous interleaving topologies have been evolved by the researchers of the previous decade, many such topologies have been investigated in this section and their methodologies are summarized in **Table 1** with some cited reference.

Garcia et al. [13] proposed Interleaved double dual boost converter IDDB of 200 KW power and 60 V DC and 360 V DC input and output voltage respectively. It is a non-isolated step up DC-DC converter which gains high voltage and suits electric vehicle, renewable energy, high power application. Six phase IDDB is verified approximately.

Tseng and Huang [14] proposed interleaved converters of 1000 W output power to obtain high step up gain without operating at extreme duty ratio. High step up converter suitable for renewable energy system with a voltage multiplier module. Proposed converter has reduced current stress, reduced input current ripple, and reduced conduction loss, extended life time of the source and improved efficiency. The converter has an Input voltage of 40 V, output of 380 V and efficiency of 97.1% is obtained.

Lai et al. [15] included a forward energy delivering circuit and a voltage doubling circuit with the conventional ILBC to achieve step up ratio in turn high efficiency which is applied to micro grid. Here, interleaving technique is implemented for a high step up converter. Closed loop control of 450 W, 2 paralleled modules with 24 V input and 200 V output is implemented. Module efficiency up to 95.8%. Steady-state analysis has been done.

Kejin et al. (2016) proposed a novel bi-directional three-phase DC/DC converter for high-power application. The proposed converter yields high conversion ratio than other conventional converters. The current and voltage stress of the power switches has been taken care to yield high efficiency.

Akın [16] compared conventional boost converters and interleaved PFC boost converters. They are compared by their power factor (PF), total current harmonic distortion (THD) and total efficiency. ILBC shows an improved efficiency than conventional. Conventional boost converter has 97.8% efficiency and 4.88% THD PF ILBC 98% efficiency and 1.93% THD values.

Table 2 summarizes the few interleaving topologies discussed in the above Section 2.

Thus, from the literature on interleaving techniques we can conclude that interleaving technique is

- The best solution to get rid of input and output current ripple as well as input and output voltage ripple.
- Due to reduced switching loss, conduction loss and voltage stress in the converter switches the system efficiency is greatly improved.
- Since the extreme duty cycle of the semiconductor switches have been minimized, the life time of the switches are increased and in turn resulted in reduced maintenance cost of the converter.

Power stage	Methodology	Achieved objective	Reference
Buck	Two active switches in series, coupling capacitor in power path	Low switching losses, improved step-down conversion ratio, reduced output current ripple	Lee et al. [5]
Non-isolated boost	Interleaved double dual boost (IDDB)	High voltage gain, suitable for high power applications	Garcia et al. [13]
Cuk and boost	Comparison	Cuk-design complexity, boost-high power application, improved switching frequency reduced ripple	Newton (2010)
Boost	High step up gain without operating at extreme duty ratio with voltage multiplier module	Reduced current stress, reduced input current ripple, reduced conduction loss, extended life time of the source and improved efficiency of 97.1% achieved	Tseng and Huang [14]
Boost, interleaved power factor correction boost (PFC ILBC)	Comparison	PFC ILBC-improved power factor (PF), reduced total current harmonic distortion (THD) of nearly 3%, improved efficiency of 0.2% than conventional converter	Akın [16]
Boost	Interleaving, adding forward energy delivering circuit and a voltage doubling circuit to ILBC	High step up ratio in turn high efficiency of 95.8% and also applied to Micro grid	Lai et al. [15]
Boost	Adding coupled inductor to ILBC	Reduces the current stress, current ripple and conduction losses	Tseng and Huang [14]
Boost	Bi-directional three-phase	High conversion ratio, current and voltage stress in switches are reduced	Jin and Liu [17]

Table 2.
Literature summary of interleaving technique.

- Interleaved converters are superior due to its simple structure and low complexity.
- From the above literature, it is also evident that they can serve for wide range of applications.

Though many techniques have been evolved and implemented in the boost converter still lag exists in the research in extracting 100% energy from the solar cell. Interleaving technique being one of the best solutions to get ripple free boosted voltage which results in improved efficiency. But, above all care should be taken in load matching of the converters.

3. Review on special converters

In literature, researchers have compared SEPIC converter, ZETA, Cuk converters with ILBC. SEPIC converter means single ended primary inductance converter and ZETA converter.

Newton [18] applied interleaving concept to the Cuk converter and analysis of system advantages over ILBC is compared. Cuk converter provides isolation without addition of extra active devices. Isolation gives different input and output facility.

Rech et al. (2001) compared different hybrid converters and new hybrid converter is proposed for high power application. The number of level of power conversion is reduced and THD is also reduced.

Yan Li et al. (2014) suggested buck-boost mode is preferred in applications where the input current needs to continuous and the output with less ripples. This gives a long-extended battery life. Non-isolated push pull converters (NIPPC's) are compared. Advantages of NIPPC's are less current stress, high efficiency and good EMC performance. Different types of configuration of push pull converters with single and coupled inductors are compared.

Kosai et al. [19] proposed a silicon carbide (SiC) Power semiconductor technology results in SiC rectifiers and controlled semiconductor devices (JFET and MOSFET), where the power converters can be operated in 200°C.

Qahouq et al. [20] proposed that by using only a single output voltage value, the controller can track the MPP of every solar panel with improved tracking speed, cost effective and also reduced system size. This technique works efficiently on non-uniform loads and mismatching conditions due to partial shading with single voltage sensor.

Darwish et al. [21] discusses about the inherent non-linearity of Cuk converter which is the reason for distortion of output voltage and current. A three phase Cuk converter is proposed. The buck-boost nature of the converter provides flexibility for standalone and grid connected applications.

Hong-Tzer et al. [22] introduced a single phase Cuk bridgeless AC-DC power factor correction rectifier which produces positive output voltage. This converter converts negative output voltage to positive value unlike other traditional topologies. The efficiency is improved by reducing the conduction loss of the power switches and also the power factor is maintained at 0.99 all input and output conditions.

Yifannyu et al. (2016) optimized the power imbalance problem in PV system by zero injection sequence injection method. They also introduced and applied the above-mentioned method in a multilevel-cascaded h-bridge converter to test the feasibility and effectiveness of the introduced method.

Forest et al. [23] is implemented isolating intercell transformer (ICT) in an interleaved converter. Two ways are implemented with coupled inductor or transformer. One is bidirectional converter buck or boost, another is bidirectional converter buck-boost. Advantages of this concept are removal of discrete inductors due which magnetic loss is less, high step up ratio and minimization of switching losses.

Khan et al. [24] proposed a synchronous buck converter with high conversion ratio and reduced system size. Gallium nitride (GaN) field-effect transistors are used in the converter. MPPT is implemented for all irradiation conditions where, maximum power extraction is achieved.

Kaouane et al. [25] obtained maximum energy transfer from generator to load side then other conventional converters by designing a SEPIC converter. High efficiency is obtained also during discontinuous conduction mode using PWM controlled switches.

Table 3 summarizes the few special converters involved in PV Power Generation discussed in the above Section 3.

ILBC yields better efficiency with simple design structure which serves for wide range of applications. Moreover, it is evident that it suffered with less ripples when compared the rest of the two converters with increased switching frequency. And also, they are compact in size though additional components are required for the control of switches. Finally, this section dealt with some other type of special

Converter	Methodology	Summary	Results	Reference
Cuk converter	Comparison of Cuk and ILBC	Isolation gives different input and output facility	Cuk converter provides isolation without addition of extra active devices	Singh et al. (2005)
Hybrid converters	Comparison different hybrid converters and new hybrid converter	Applied in high power application	Number of level is reduced and THD is reduced	Rech et al. [26]
Non-isolated push pull converters (NIPPC's)	Push pull converters with single and coupled inductors are compared	Buck-boost mode is preferred in applications where the input current needs to continuous and the output with less ripples	Long extended battery life, less current stress, high efficiency and good EMC performance	Yan Li et al. (2014)
MPPT controller	Single output voltage value, the controller can track the MPP	Woks efficiently in non-uniform loads and mismatching conditions due to partial shading with single voltage sensor	Improved tracking speed, cost effective and Reduced system size	Jaber Abu Qahouq et al. [20]
Cuk converter	Buck-boost nature	To overcome inherent non-linearity in turn distortion of output voltage and current	Provides flexibility for standalone and grid connected applications	Yang et al. [22]
Single phase Cuk	bridgeless AC-DC rectifier	Converts negative output voltage to positive value unlike	Improved efficiency reduced conduction losses, power factor is maintained at 0.99 all input and output conditions	Yu et al. [27]
Multilevel-cascaded h-bridge converter	Zero injection sequence injection method	To optimize the power imbalance problem in PV system	Reduced switching loss, high conversion efficiency, simple structure	Khan et al. [24]
Synchronous buck converter	Gallium nitride (GaN) field-effect transistors are used in the converter	For all irradiation conditions where, maximum power extraction is achieved	High conversion ratio and reduced system size	Kaouane et al. [25]
SEPIC converter	DCM mode using PWM controlled switches	—	Maximum energy transferred from generator to load side, High efficiency	Simonetti et al
Interleaved converter	Isolating intercell transformer (ICT)	Two ways are implemented with coupled inductor or transformer (buck or boost, bidirectional buck-boost)	Removal of discrete inductors due which magnetic loss is less, high step up ratio and minimization of switching losses	Forest François et al. [23]

Table 3.
Literature summary special converters involved in PV power generation.

converters like Cuk, SEPIC, etc. Here some work on comparison of ILBC's with SEPIC and ZETA converter, pros and cons between them, some new techniques implemented in special converters are also discussed. **Table 3** summarized the aforementioned features.

4. Review on MPPT technique

As we know PV panel is a non-linear device and in order to be able to extract maximum output power despite changing insolation due to partial shading and changing temperature due to weather conditions, maximum power point tracking (MPPT) is required. However, MPPT works based on maximum power transfer theorem which goes like this, whenever source impedance is equal to the load impedance maximum power is delivered to the load. This can be done by adjusting the duty cycle of a DC-DC converter between the source and the load. The researchers have approached various control techniques to achieve this that is listed in **Table 4**.

Doo-Yong-Jong et al. (2012) imposed MPPT to half bridge PV DC-DC boost converter and full bridge inverter applied to grid which adopts variable step-size algorithm. Grid current control is done with 4th order linear IIR filter controller.

Schuck and Pilawa-Podgurski [28] attended the problem faced by PV input interleaved converter with MPPT to work in asymmetric fashion due the difference in load and source combinations. The author proposes a control technique based on and harmonic elimination and ripple reduction under asymmetric source-load conditions.

Femia et al. [29] proposed distributed MPPT rather than the conventional MPPT to overcome the problem of model mismatch and partial shading in PV modules. Though the author showed improvement in the efficiency is a research gap of complexity in the design.

Qin et al. [30] formed an algorithm to extract maximum power from PV modules with differential power processing converters. Fast tracking is achieved with less number of perturbations for long strings.

Park et al. [4] designed a MPPT controller to track maximum power from PV module during fast transient changes due to environmental conditions with good tracking speed and accuracy. The author analyzed different dynamic PV panel data with high number of samples than before which includes different whether conditions.

Pilawa-Podgurski and Perreault [31] proposed an MPPT power converter with digital control technique for Synchronous buck converter. Obtains local and global MPPT in parallel connected PV modules. Direct integration is done hence economical.

Qin and Pilawa-Podgurski [32] proposed a differential power processing architecture. MPPT with minimum communication and no local sensing is ensured. Partial shading condition is considered. The system ensures extraction of more energy which is employed low voltage buck-boost converter. Control method achieves global and local MPPT operation.

Alexander et al. [33] analyzed different MPPT algorithms. Presence of noise in MPPT algorithm leads to deviation MPP steady state. Parameters like slowing tracking and noise are considered which affect the overall efficiency of the system. Optimizations of these system parameters are determined.

Sundareswaran et al. [34] formed artificial bee colony (ABC) algorithm for MPP global maximum power point (GMPP) which enables maximum utilization of solar

System	Problem	Methodology	Objective achieved	Reference
Boost, half-bridge connected to grid	Unbalance in grid current	Repetitive current control method-current controller (repetitive)-based on fourth order linear phase IIR filter. Variable step-size technique	Minimal devices are used, regulates the grid current	Doo-Yong-Jong et al. (2012)
Asymmetric Interleaved Multiphase	Asymmetric conditions due to difference in source and load conditions	Harmonic elimination control technique	Reduced Ripples, works in a symmetric condition, first harmonic ripple component is reduced by 14.8 dB	Schuck and Pilawa-Podgurski [28]
Interleaved	Effect of model mismatch and partial shading in PV module	Distributed MPPT	Improved efficiency, reliable	Femia et al. [29]
Series connected	To maximize the power extraction from series connected PV module	Differential power processing algorithm	Fast tracking without extra hardware, reduced no. of perturbations in each step, suitable for long sub module strings	Qin et al. [30]
DC-DC, DC-AC	Rapid transient changes in PV output power	MPPT controller design considering field measurements of transient effects	Improved tracking speed and accuracy—captures dynamic PV panel data of high temporal resolution	Park et al. [4]
Synchronous buck converter	To increase of the energy captured during partial shading conditions. To reduce the overall cost	Sub module integrated digital control technique	Ensures both local and global MPPT, direct integration is done hence economical	Pilawa-Podgurski and Perreault [31]
Buck-boost converter	extraction of more energy from PV applications	Differential power processing architecture (MPPT with minimum communication and no local sensing)	Global and local MPPT is obtained	Qin and Pilawa-Podgurski [32]
PV power generation	MPPT under partial shading conditions	ABC algorithm	Ensures fast tracking characteristics, improved energy saving capability, improved revenue generation	Alexander et al. [33]

System	Problem	Methodology	Objective achieved	Reference
Bidirectional DC-DC converter	MPPT for standalone power generation	Parallel MPPT technique	Reduced loss in power converter, improved efficiency, reduced number of power processing stages	Sundareswaran et al. [34]
Standalone hybrid system (solar and wind)	To achieve fast, better transient response and pitch angle of wind turbine	Neural-Network-Based MPPT control, radial basis function network (RBFN), Elman Neural Network (ENN)	Fast and improved transient response	Subudhi and Pradhan [35]
PV system	To minimize the settling time.	FPGA platform to obtain real time weather conditions, optimization of perturbation period in P&O algorithm, the settling time is calculated by dual kalman filter	Settling time is minimized	Roger Gules et al. (2008)
Buck converter	To improve solar energy conversion efficiency	Fuzzy-PID controller	Achieving high MPP under various environmental conditions	Whei-Min Lin Member et al. (2011)
PV system	To obtain maximum power transfer to load	Two phase tracking INC MPPT	Maximum power transfer	Jiang et al. [36]
PV system	To attain GMPP	GMPPT technique with a simulated annealing (SA)	Less design complexity, less number of parameters per iteration in P&O algorithm	Sarah and Haque [37]
Grid connected PV system	To identify maximum power point (MPP) rapidly	Modern predictive control (MPC)	Dynamic response of the system is improved	Shadmand et al. [38]
PV system	Uncertainty due to rapidly changing weather condition and variable load condition	Double integral sliding mode controller (DISMC) MPPT system	Easy to control where, switching frequency is kept constant	Raseswari et al. [39]
PV system	To avoid steady-state oscillation, to improve tracking efficiency	Gray wolf optimization method for MPPT tracking	Better transient response	Seyed Mahmoudian et al.

Table 4.
MPPT techniques imposed in solar powered converters.

energy under varying atmospheric conditions. Two different PV configurations under different shading patterns are tested. This ensures fast tracking characteristics, improves energy saving capability, increased revenue generation when compared with other energy MPPT techniques.

Subudhi and Pradhan [35] reviewed MPPT techniques developed until January 2012. Analysis based number of control variables, types of control strategy, types of circuitry for PV systems and application based on practical and commercial. Nearly 26 variety of MPPT technique has been compared.

Gules et al. [40] proposed a bidirectional DC-DC Converter with parallel MPPT for standalone power generation. The power converter works as multifunctional MPPT circuit, battery charger, battery regulator and as step up converter. Parallel MPPT helps in reducing losses in the power converter in turns improves efficiency also reduces the number of power processing stages. Same series connected MPPT algorithms can be used.

Lin et al. [41] constructed a standalone hybrid system consists of solar power, wind power, diesel engine and intelligent power controller. Radial basis function network (RBFN) is used to achieve fast and transient response and pitch angle of wind turbine and Elman Neural Network (ENN) is used to achieve MPPT.

Jiang et al. [36] proposed a grid connected boost half bridge PV micro inverter system which uses only minimal device. Dynamic response is improved when load and solar irradiance were changed rapidly. Variable step size MPPT is adopted.

Ricco et al. [42] used FPGA platform to MPPT algorithms acquire its parameters to the real-time weather conditions. The settling time is minimized. The proposed controller presents optimizing the perturbation period of the P&O algorithm the settling time can be calculated by a dual kalman filter.

Dounis et al. [43] proposed that Maximum power point tracking (MPPT) with Fuzzy-PID controller to regulate to output power of PV system for a DC/DC buck converter. The proposed system improves the solar energy conversion efficiency. Fuzzy-PID is highly effective in achieving high MPP under various environmental conditions.

Hsieh et al. [44] proposed two phase tracking INC MPPT which either constant-frequency with variable-duty cycle (CFVD) or variable-frequency with constant duty control(VFCD) to perform with reference to a commonly known threshold-tracking zone (TTZ) thus obtained maximum the power transfer to load at MPP.

Wang et al. [45] identified that the mismatches the PV system affects the major portion of energy production. Then, proposed a MPPT system which is simple with unified output.

Lyden et al. (2015) proposed that the global maximum power point tracking (GMPPT) technique with a simulated annealing (SA) for PV energy system which experiences the partial shading condition (PSC). This attains GMPP or near GMPP. Less design complexity when compared to P&O technique and less number of parameters per iteration to iteration. Shadmand et al. [38] proposed a MPPT technique called as modern predictive control (MPC) for a grid connected PV system. The technique identifies the Maximum Power Point (MPP) rapidly than other earlier techniques. The dynamic response of the system is improved than other conventional techniques.

Pradhan and Subudhi [39] handled the uncertainty problem due to rapidly changing weather condition and variable load condition in a PV system by implementing double integral sliding model controller (DISMC) MPPT system. The system is easy to control where, switching frequency is kept constant. Mohanty et al. [46] used Gray wolf optimization method for MPPT tracking. The limitations such as steady-state oscillation, lower tracking efficiency and transient condition has been fixed in this method. Where, our other traditional methods such as P&O, improved P&O failed to do so.

Table 4 summarizes the few MPPT techniques imposed in solar powered converters discussed in the above Section 4.

It is clearly evident from the above literature review that various problems have been attended and solved by implementing MPPT controller to a system. To summarize some of the key problems addressed,

- Uncertainty due to partial shading and changing weather conditions.
- Asymmetric source-load mismatch, model mismatch especially in interleaved converters.
- Rapid transient changes in PV power generation system.
- Steady state oscillations are avoided by minimizing the settling time.
- Unbalanced grid current is handled.

The MPPT techniques used by the researchers in the previous decades have been discussed in the above section. The Problem, objectives, various techniques and advantages of MPPT imposed PV system are summarized and discussed in **Table 4**. The MPPT applied PV power generation system have witnessed the following advantages, which is understood from the literature.

- High conversion efficiency because of maximum power extraction especially in series connected models.
- Reduced ripples and harmonic distortions in the system.
- Fast maximum power tracking in turn better tracking efficiency.

Supports wide range of applications, which includes stand-alone power generation and also in pitch angle control for wind turbines.

5. Review on controller for ILBC

Since the boost converters are nonlinear in nature, the controller maintains the stability during the source-load variation. In order to balance the fast-transient response, it is vital to select an appropriate controller to overcome over shoot damping and achieve the steady state response. Different types of controllers used by the researchers so far till 2016 have been discussed here. The extended summary is displayed in **Table 5**.

Zdravko et al. [51] proposed a sensor less multiphase average current controller which a self-tuning current estimator. The average inductor current is calculated with the duty cycle, input and output currents, based on these parameters the active phase gets automatically changed.

Cheng et al. [47] introduced Hybrid ripple concept for ripple-based control which may suffer from large jitter issues and instability. It is achieved by feed backing both inductor current ripple and compensated external ramp to the modulator. Reduce jitter and improved stability is achieved. Fast load transient performance with the proposed control scheme of controller is achieved. Research gap: system becomes more complicated with two different ramp compensations. Wang and Li [48] developed a RPC (ratio pre-setting controller) method to enhance current

Controller	Technique	Methodology	Summary	Results	Reference
Multiphase average current controller	Self-tuning current estimator	Average inductor current is calculated with the duty cycle, input and output currents	Using these parameters active phase gets automatically changed	Sensor less controller	ZdravkoLukić (2009)
Ripple-based control	Hybrid ripple concept	Feed backing both Inductor current ripple and compensated external ramp to the modulator	Research gap-system becomes more complicated with two different ramp compensations	Reduce jitter and improved stability.	Cheng [47]
Ratio pre-setting controller (RPC)	To enhance current sharing capability	The relationship between phase shift angle and the transformer current is arrived	Three types of three-phase bidirectional DC-DC converters are introduced and other two types are compared	Y-connection type converter evidence less current mismatch due to its current sharing capability	Wang and Li [48]
Power control system	Artificial Neural Network (ANN)	Output voltage is regulated which is received from the PV array from changing ambient temperature and irradiance	Battery as load	Fast settling time and low over shooting	Jiteurtragool et al. [49]
IC controller	IC is embedded with power MOS	Controls the converter as well as takes care of MPPT algorithm	4 Phase ILBC for PV distributed power conversion	Use less number of external components and less overall cost	Pulvirenti et al. [50]
State trajectory controller	State trajectory control	Based on boundary control	Method involves four switching states, and three state equations	Good dynamic response during starting and load change	Rafael Pena-Alzola (2015)

Table 5.
Literature summary of analysis of controllers and implemented applications for PV generation system.

sharing capability. Here, three types of three-phase bidirectional DC-DC converters are introduced and other two types are compared. Where, Y-connection type converter evidence less current mismatch due to its current sharing capability. The relationship between phase shift angle and the transformer current is arrived.

Jiteurtragool et al. [49] proposed a power control system for DC-DC converter using ANN. Output voltage is regulated which is received from the PV array from changing ambient temperature and irradiance. With battery as load hardware implemented with fast settling time and low over shooting. Pulvirenti et al. [50] proposes IC controller 4 Phase ILBC for PV distributed power conversion. The system uses less number of external components and less overall cost is assured. An IC is embedded with power MOS which controls the converter as well as takes care of MPPT algorithm. Sean and Williamson [52] compared various state space model for power amplifiers and concluded there is a considerable difference in the measured frequency response. Three different models are compared in this chapter. Rafael Pena-Alzola et al. (2015) handled instability problems in ILBC's during large bandwidth requirements by state trajectory control which is based on boundary control where, conventional controller failed to do so. The system provides a good dynamic response during starting and load change. The method involves four switching states, and three state equations.

Table 5 summarizes the few analysis of controllers and implemented applications for PV Generation system discussed in Section 5.

Implementation of controller is also being a best method to eliminate ripple. Not only for ripple reduction, the controller also helped to improve the systems overall performance by maintaining good dynamic response.

6. Ripple minimization technique

When input current is equal to the inductor current then the converter works in continuous conduction mode (CCM). But the drawback in this style of working is the diode reverse recovery current. When the inductor current does not match with input current then is said to be working in pulsating mode. In this mode, the input and inductor currents are equal only when it is switched ON. Boost converter works in CCM mode but buck converter works in pulsating mode. So, in pulsating mode of operation the inductor current turns zero when the switch is OFF. Coupled inductor can be a solution for this issue but then integrated magnetic components have caused EMI problems so coupling coefficient should be designed well in advance. So, pulsating type interleaving technique can be adopted to achieve current ripple reduction.

Kim [53] proposed reconfigurable solar converter (RSC) which helps in single stage power conversion. The proposed system is nothing but a single stage, 3 phase grid tie solar PV converter for DC-DC or DC-AC generation used for PV battery application. Numbers of conversion stages are minimized. Therefore, improved efficiency, reduced cost, weight and volume are ensured.

Garcia et al. [54] handled the tolerance in the inductance on the output current and the voltage ripple. The author concluded that Multiphase is advantageous for its filter less input and output. Where, in the other side tolerance in semiconductor switches is undesirable.

Caris et al. [11] proposed a method to calculate the phase-shifts to avoid harmonics generated due to the cell inductors in the interleaved converters. Interleaved topologies used to improve power converters to obtain higher power ratings, higher bandwidth and lower current ripple. On other hand, it suffers with cell inductor tolerance.

Yu Gu et al. (2013) proposed ILBC with RPN (ripple cancelation network). RPN is connected with a normal ILB, it consists of additional inductors, a couple of capacitors and coupled inductor. Input ripple current cancelation with minimum loss and 96% efficiency is achieved.

Caracas et al. [55] implemented solar water pump where, a 3-phase induction motor runs directly from the PV cell without the help of battery. This is a system based on resonant two inductor boost converters (current resonant converter) and full bridge 3 phase voltage source inverter. Also, non-isolated recovery snubber is added with the system in order to control hysteresis loss and duty cycle improvement in order to improve the efficiency. Advantage of resonant two inductor boost converters is high voltage gain and low input current ripple. Prolonged lifetime due to the absence of battery, use of induction motor is more efficient, maintenance free when compared with DC motor.

Peng [56] ILBC with self-balancing capability is designed. Smoother and less distorted power conversion is achieved. More than two level will be convincing to balance DC voltage level without additional circuits. Advantages of system are magnetic less, compact, high efficient, zero EMI, low cost power conversion.

Ramos-Paja et al. [57] analyzed the pre-filter optimal operatinvg conditions where the input ripple is mitigated for better conversion ratio of ILBC. The inductor losses are predicted in terms of efficiency and input current ripple then a pre-filter is designed accordingly.

Problem	Methodology	Results	Remarks	Reference
Load side ripple in parallel multiple in input source	Minimized by increasing the switching frequency	Research gap-increase in switching loss	Can be applied to smart grids	Kim et al. [53]
More number of conversion stage	Reconfigurable solar converter (RSC)	Single stage conversion	Improved efficiency, reduced cost, weight and volume are ensured	Garcia et al. [54]
Tolerance in the inductance on the output current and the voltage ripple	Digital control, multiphase	Filter less input and output	Research gap-undesirable side tolerance in semiconductor switches	Caris et al. [11]
Harmonics in multilevel converter	Calculated phase shift	Higher bandwidth, low current ripple		Gu and Zhang [60]
Input ripple current	Ripple cancelation network (RPN)	Minimum loss and 96% efficiency	Consists of additional inductors, a couple of capacitors and coupled inductor	Peng [56]
Power mismatch	ILBC with self-balancing capability	More smoother and less distorted power conversion	Magnetic less, compact, high efficient, zero EMI, low cost power conversion	Ramos-Paja et al. [57]
Input current ripple mitigation	Pre-filter optimal operating conditions, predicted inductor losses	Better conversion ratio in ILBC		Jiang et al. [59]

Table 6.
Literature summary of ripple minimization techniques in PV power generation.

Tseng et al. [58] included voltage multiplier for managing asymmetrical interleaving condition without changing the duty cycle extremely is proposed. Voltage multiplier is nothing but conventional converter with a coupled inductor. Reduces the current stress, current ripple and conduction losses.

Jiang and Wang [59] discussed about the current ripples in converters and proposed of three phase PWM converter. The author concluded bigger current ripples are generated by discontinuous PWM when compared to space vector PWM. This is mostly suitable for variable switching-frequency control for three phase PWM converters applications.

Table 6 summarizes the few ripple minimization techniques in PV power generation discussed in the above Section 6.

There is high frequency ripple caused by the switching frequency and the low frequency ripple caused by AC load. For the symmetrical 3-phase load, low frequency ripple is not experienced. Rather, the single-phase or unbalanced 3-phase, will experience a double line frequency ripple.

Mainly in interleaving converters source and load mismatch in various conversion stages have occurred. This is handled by the researchers in two ways either,

- By tunning the switching style or,
- By some unique ripple mitigation methods and fixed it with some additional integrated circuit.

In the above two methods the later suffers with switching stress and the former with increased volume of the system size. This method can be considered as bridge to fill the research gap when interleaving technique cannot be applied and considered as limitation. This section discusses about the ripple minimization techniques used so far and **Table 6** exhibits the summary of the same.

7. Power conditioning PV simulator and performance evaluation

Below are some set of references which carried few sophisticated tools for betterment of the PV system that involves

- Evaluation
- monitoring
- As well as rectification

Koran et al. [61] proposed high efficiency and fast transient response time that are essential for PV simulator. PV source simulator-evaluate the power conditioning system and MPPT algorithms, high efficiency photovoltaic source simulator both analog and digital based is proposed.

Kim et al. [62] compared several parameters like efficiency and power factor performance. Several topologies are compared, conventional average current mode control boost PFC, an interleaved boost PFC, a back-to-back bridgeless boost PFC, semi-bridgeless boost PFC, are assessed through loss analysis. Improved power factor correction (PFC) topologies suitable for a high density are identified.

Singh et al. [63] improved power quality by a control strategy for achieving maximum benefits for grid interfacing inverters. Perform a multi-function device by incorporating active power filter functionality. Power converter to inject power generated from RES to the grid.

Rosario et al. (2005) analyzed series—parallel L, Cp, Cs resonant inverter for effect of tolerance, to ensure circuit performance-with no feedback-good repeatability. The author concluded that the capacitor value affect the sensitivity values and done statistical study by Monte-Carlo method.

Roh et al. [64] proposed two phase interleaved critical conduction mode (CRM) power factor correction for boost converter. Variation tolerant phase shifter (VTPS) which ensures accurate 180-degree phase during interleaving operation. This VTPC circuit can be applied to any type of ILBC's.

Stanth et al. (2013) proposed a converter which is connected in parallel with the PV string to improve the energy captured during the shading or power mismatch. The parallel configuration is proposed to handle mismatch of power, its turns off if no mismatch. The converter handles only, mismatch in the adjacent string, turns off during no mismatch, low average power handling and low operational duty cycle these can be considered as research gap.

Oscar et al. [65] developed a multiphase converter with buck converter as base. Natural ZVS is achieved in buck converter the instantaneous inductor current itself will manage the current imbalance in the phases. Better current balance and ZVS in both transitions are achieved but with high current ripple. Higher conduction losses, high number of phase and high current ripple are found as research gap.

Liserre et al. [66] introduced generalized hybrid modulation (GHM) technique to overcome the drawback in the conventional method that these techniques succeed in canceling the sideband harmonics in multilevel voltage only when the DC-link voltages are equal. PSC-PWM technique proposed, a method to obtain the proper shifting angles to avoid the reduction in overall output voltage.

Shibin Qin Andrew et al. (2014) proposed a differential power processing (DPP) which combines micro inverter and DPP converter. The architecture configures DC-DC parallel with PV string. Power yield is improved by overcoming the mismatch in sub module. Since the converters are connected in parallel low power rating is sufficient. Low power losses are evident and suitable for sub module MPPT.

Tolbert et al. [67] introduced a procedure to find all sets of switching times (angles) for each converter in a multilevel converter to obtain desired output voltage. Here, 5th and 7th are eliminated by converting the transcendental equations that identifies the elimination of the harmonics into a set of polynomial equations.

Zhang and Yu [68] investigated on the feature of interleaved PWM DC-DC converter and analyzed their methodology. Practical design is presented such as ripple quantification, zero ripple necessary condition and sufficient condition, fault detection, and waveform shape prediction.

Sangswang and Nwankpa [69] quantified random noise in PWM switching DC-DC boost converter. The presence of noise creates uncertainty in switching time. Performance analysis for the parameters such as stochastic performance index, MPPT and critical energy are done.

Zhang et al. [70] connected pair of additional diode and capacitor/inductor are connected in X-shape to a conventional converter (diode assisted converter). Comparison based on silicon devices, passive components, EMI and efficiency are done. Input current ripple is reduced, improved power conversion and buck-boost capability are ensured.

Ray et al. [71] done a multimode analysis of the ILBC for switching duty cycle from 0 to 1, for both CCM and two DCM modes. This analysis helps designer to optimize the inductor value and coupling factor for different performance values. Also, could optimize the number of power stages for varying input and loads. DCM shows less switching losses.

Li and He [72] reviewed on challenges based on high step up, low cost, high efficiency converters are summarized. To extend the voltage gain, to avoid extreme duty cycle in order to reduce current ripple, to avoid power devices losses by soft switching and to avoid reverse recovery problem of diode are the problems summarized. Limitations of conventional boost converters are analyzed. Parallel connected and non-isolated high step up converters for its low cost and improved efficiency.

Lefevre and Mollov [73] discussed about the asymmetric voltage operation while handling multiphase boost converter. Conversion efficiency of 99% is achieved by introducing a flying-capacitor in the existing topology.

Nigsch et al. [74] proposed a bridgeless single stage PFC converter for efficient solution to fulfill the harmonic standards. Efficiency is improved by removing the input rectifier and providing galvanic isolation by allowing single switch active at a time. Around 95% of efficiency is obtained and single stage approach makes it a low cost high-power density PFC.

Xiong Li et al. (2016) proposed a space vector pulse-width modulation (SVPWM) to regenerate phase current using neutral-point current sensing, scheme. Complementary active vectors replace the zero and offset vectors. Hybrid switching pattern are used, to synthesize the reference voltage vector. Phase currents can be reconstructed using SVPWM scheme.

Yuan-Chuh et al. (2016) achieved desired generator performance by one-cycle voltage regulation (OCVR) for permanent-magnet synchronous generator (SPMSG). Design of voltage controller is simplified and computational time is less when compared to other conventional controllers.

Table 7 summarizes the few power conditioning in PV power generation discussed in the above Section 7.

The power quality monitoring has been done to enhance the system performance, the power quality improvement includes the following,

- Power factor correction
- Power mismatch in multiphase converters
- Fine-tunned control strategy for maximum benefits
- Optimized MPPT algorithms

These set of dynamic response tuning of the PV system are overviewed in this section and power quality issues are also discussed here. The power conditioning, power quality improvement and performance evaluation works of the previous decade has been discussed in the above section and the objective, evaluation parameters, summary of discussions are summarized in **Table 7**.

8. Inference

This research work has compared and identified an efficient and suitable converter extract solar energy from the PV panel in an effective way to obtain high conversion ratio among the conventional converters. The overview exhibited and identified the requirements of a best PV power generation system, where the

Objective	Evaluation parameter/ methodology	Summary	Remarks	Reference
PV source simulator	Efficiency and transient response	Both analog and digital based are proposed	Improved efficiency, fast transient response	Koran et al. [61]
Comparison, power factor correction	Loss analysis of converters—current mode control boost, interleaved boost, buck-boost and semi bridge boost	Efficiency and power factor correction		Kim et al. [62]
Power quality improvement	Performs as a multifunctional device by adding an active power filter	Control strategy to achieve maximum benefits from grid interfacing inverter	Inject power from RES to grid	Mukhtiar Singh et al. [63]
Output current sensitivity analysis	Effect of tolerance, performance without feedback	Capacitor values effect the sensitivity value	Good repeatability	Rosario et al. (2005)
Power factor correction	Variation tolerant phase shifting technique (VTPS), critical conduction mode technique (CRM)	Two phase interleaved converters	Accurate 180-degree phase shift and can be applied to any type of ILBC's	Roh et al. [64]
Improvement of dynamic response	Resonant switched capacitor converter	Converter imposed in parallel with PV string	Research gap-handles only adjacent string mismatch, turns off during mismatch, low average power handling and low operational duty cycle	Stanth et al. (2013)
Current imbalance in the phases	Current self-balance mechanism in CCM mode	Multiphase buck converter	Research gap-high conduction losses, more no of phases, high current ripple	Oscar et al. [65]
Sideband harmonics in multilevel voltage, multilevel phase shifting in non-equal DC link	Generalized hybrid modulation technique, carrier PWM technique	To obtain exact phase shifting angle	Reduction in overall output power is avoided	Liserre et al. [66]

Objective	Evaluation parameter/ methodology	Summary	Remarks	Reference
Mismatch in sub-module DC-DC parallel PV string	Differential power processing (DPP)	Combines micro inverter and DPP converter	Less power is only required since connected in parallel	Shibin Qin, Andrew et al. (2014)
Harmonic elimination	To find switching times (angles)	In multilevel converters where, non-equal DC source	5th and 7th harmonics are eliminated	Tolbert et al. [67]
Ripple quantification, zero ripple necessary condition	Analysis of interleaved DC-DC PWM converter	DC-DC converter	Ripple minimization, fault detection, wave shape prediction	Zhang and Yu [68]
Uncertainty switching time due to noise	Analysis of critical energy, stochastic performance index	PWM switching DC-DC boost converter		Anawach Sangswang and Nwankpa [69]
To optimize the number of power stages for varying input and loads	Multimode analysis of the ILBC for switching duty cycle	Multimode analysis of the ILBC	Helps to optimize the inductor value and coupling factor for different performance values	Ray et al. [71]
Asymmetric voltage operation	Flying capacitor is introduced	Multiphase boost converter	99% conversion efficiency	Li and He [72]
To fulfill harmonic standards	Removing the input rectifier and providing galvanic isolation by allowing single switch active at a time	Bridgeless single stage PFC converter	95% of efficiency is obtained, low cost high-power density PFC	Guillaume Lefevre et al. (2010)
To synthesize the reference voltage vector	Space vector pulse-width modulation (SVPWM)	—	—	Nigsch et al. [74]
Performance enhancement	One-cycle voltage regulation (OCVR)	Permanent-magnet synchronous generator (SPMSG)	Simplified design of voltage controller and less computational time	Li et al. [75]

Table 7.
Literature summary of power conditioning in PV power generation.

investigation involves the work till 2016. The above survey vigorously focussed on the analysis and requirements of an efficient PV power generation system. In order to yield the maximum energy from the PV panel which is highly nonlinear in nature, in spite of its heavy capitation cost and low conversion efficiency a well-developed PV power generation system is essential.

The boost converter which is intended between the PV panel and the load plays a major role in this process of extracting maximum energy. It should boost and regulate the voltage from the source, should have less switching losses semiconductor switches, reduced ripples, should act as an isolation between source and the load and finally needs to be free from EMI. These forth-coming conclusions are derived from the above bunch of literatures that can be considered while designing a PV power generation system.

- Si (crystalline) is considered as the best technology which produces nearly 24.7% of efficiency when compared with rest of the evolved solar cell technologies. Where, in this technology the electron-hole pair recombination seems to less than any other technology.

- Though, soft switching technique fetched a considerable improved status in conversion efficiency there are few limitations, therefore care should be taken to reduce the size and cost of the system due to extra external circuit for control of switches.

- Though, interleaving technique is best solution to get rid of input and output current ripple without the extra external circuit which is considered as the drawback of soft switching technique mentioned above, care should be taken for the source load mismatch.

- In order to overcome the above-mentioned limitation of source load mismatching in interleaved converters maximum power point tracking MPPT can be enabled to the system. With MPPT reduced ripples and harmonic distortions in the system high conversion efficiency is obtained. Care should be taken to choose the best MPPT technique.

- There is high frequency ripple caused by the switching frequency and low frequency ripple caused by AC load. For the symmetrical 3-phase load, no low frequency ripple occurs. For single-phase or unbalanced 3-phase, there will be a double line frequency ripple. In this survey, high frequency ripple caused by switching frequency is concentrated. This is handled by the researchers in two ways either by tuning the switching style or by some unique ripple mitigation methods and fixed it with some additional integrated circuit.

- Implementation of controller is also a best method to eliminate ripple. Not only for ripple reduction, the controller also helps to improve the systems overall performance by maintaining good dynamic response.

- ILBC is better than the other special purpose converters like ZETA and SEPIC in terms of its system efficiency, compact size, ripple reduction, design simplicity.

The survey mainly focused on the requirements to build an efficient PV system with extraction of maximum energy and better dynamic response. The general discussion on objectives, techniques and advantages of each sections were also exhibited. The detail requirements of different constraint are presented in a systematic way in order to facilitate the reader to find a better solution for their application and

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constraints. It is essential to enhance these methodologies used so far and provide sufficient guidelines for selection criteria to support the researchers of PV power generation to opt and design a best PV architecture.

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