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A REVIEW ON POWER CONVERTERS WITH DIFFERENT CONTROL TECHNIQUES FOR PV APPLICATION

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Abstract: Nowadays, in most of the industrial applications, power converters are required because it is very essential to convert the fixed voltage dc source into variable voltage dc source for some applications and for some more applications, it is required to convert the variable voltage dc source into fixed voltage dc source based on the application. In this paper, different types of dc-dc converters are studied based on their applications. In recent days, dc-dc converters are implemented in photovoltaic applications like solar panel, wind energy integration, dc grid system, etc. In order to obtain the regulated output dc voltage, different control techniques are also studied. In this paper comparison of different control techniques have been done. In photovoltaic systems, dc-dc converters are required in order to link the low voltage PV panel and high voltage dc link. MPPT control technique is also employed in the photovoltaic system to extract the maximum power from the PV panel. In PV DC grid system, DC-DC converters are more essential as it converts the unregulated and unstable output power to regulated, stable output. By using dc-dc power converters, use of bulky and heavy low frequency step-up coupling transformer can be avoided.
Keywords: DC-DC converter, Photovoltaic applications, control techniques, MPPT techniques, DC grid system.

I. INTRODUCTION

In this paper mainly, dc-dc power converters are taken with different control techniques which is useful for photovoltaic applications. DC-DC converters are used to link the low voltage PV panel and high voltage DC link. There are different types of converters such as boost converter, buck converter, buck-boost converter, Cuk converter, Sepic converter, Zeta converter, etc. DC boost converters are commonly used in DC systems such as DC microgrid system and vehicle power systems. For output voltage to be well regulated, then the boost converters require a controller. Actually, there are plenty of controllers such as P, PI, PID, backstepping, sliding mode control, model predictive control, etc. let us consider the DC-DC converters in DC micro grid application. Micro grid includes the distributed generators which has many advantages. Most of the DGs such as PV, fuel cells and batteries. DC micro grids have less losses because it has no reactive power flow, absence of skin effect and transformers are interchangeable by DC-DC converter. These converters are connected in parallel to share a common DC bus. DC micro grids are enables equal current sharing per unit between converters and eliminates the voltage deviations. Master slave, the feeder flow and droop techniques are the methods to control the DC-DC converters in micro grids [1]. This paper mainly concentrates on different control techniques for boost converter which are useful for PV applications.

II. CLASSIFICATION

Generally, DC-DC converters are broadly classified into two types that is isolated and non-isolated converters. These non-isolated converters include buck, boost, buck-boost, cuk, zeta, sepic converters. Isolated converters are used in high power applications where the circuit is divided into two separate sections which makes the output isolated from the input electrically.

This can be achieved by using a transformer which in turn increases the size and cost of the converter. In non-isolated converter, transformers are not used as the output is not isolated from input. Classification of various power converters are shown in the Fig 1.

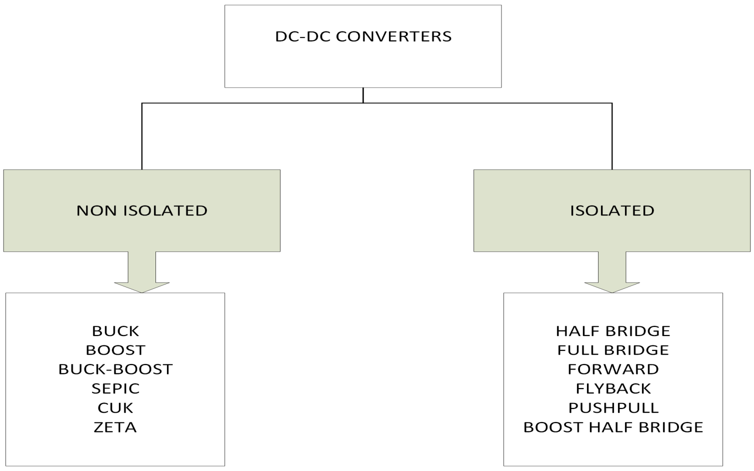

Fig 1. Classification of converters [2]

A. Buck Converter

The buck converter is nothing but step-down converter as the output voltage is less than that input voltage. This buck converter circuit along with sliding mode controller is used in order to track the maximum power point from the PV module. Figure shows the PV array connected to a DC -DC buck converter by varying the duty cycle of the buck converter, the power output from the PV module is controlled in order to identify the voltage at which output power can be maximized [3].Buck converter for maximum power point is as shown in fig 2.

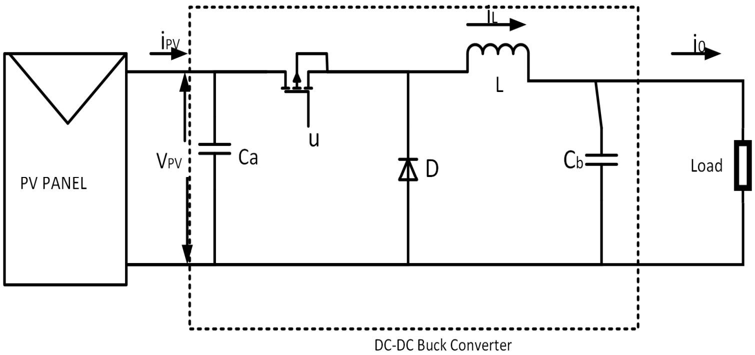

Fig 2. PV array in conjunction with buck converter [3]

B. Boost Converter

This soft switching boost converter is used to convert the photovoltaic panels output level due to soft switching cell adapted to the converter. Hence, it can be used in high efficiency and boosting factor application. Due to disadvantages of conventional boost converter, the ZVT boost converter is proposed in order to decrease the power losses and increase the power efficiency. The ZVT boost converter uses a snubber capacitor, inductor and two diodes as resonance circuit to achieve ZVT. The ZVT boost converter for PV applications is shown in the Fig 3.

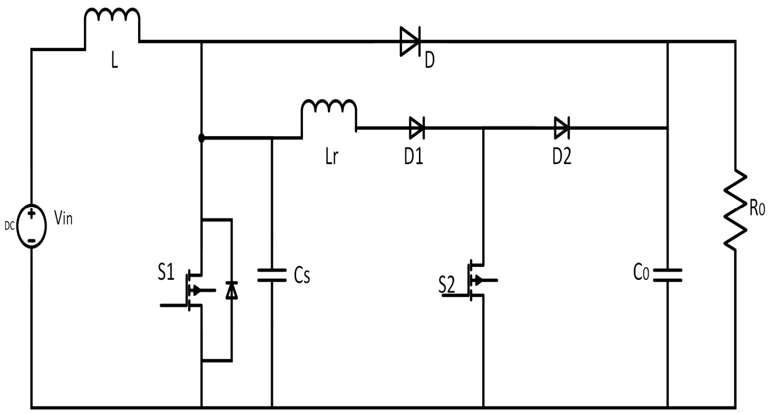

Fig 3. ZVT boost converter [4]

C. Buck-Boost Converter

In this buck- boost converter, the output voltage can be can either be higher or lower than the input voltage. Fuzzy logic-controlled buck-boost converter is proposed for battery load systems. In this, output voltage V0 is compared with the reference voltage Vref in order to generate a signal to determine the switching signal duty cycle [5].

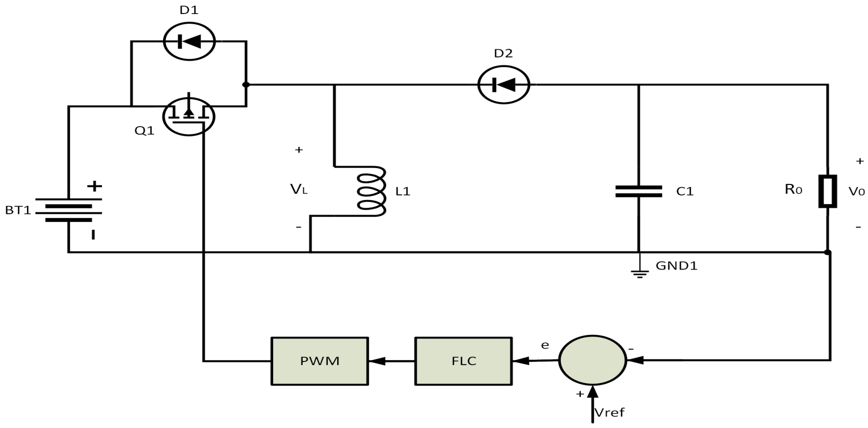

Fig 4. Fuzzy logic-controlled buck-boost converter [5]

D. Sepic Converter

Multilevel sepic converter is proposed with PV source for PV applications. Due to this multilevel sepic converter, high voltage gain can be achieved. Initially, when the transistor is closed, inductor LI one gets connected to input voltage Vin, hence current in L1 increases with a constant slope. Next when the transistor is opened, the Current in L1 charges capacitors C1 with a positive voltage [6]. The basic diagram of the multilevel SEPIC converter is shown in fig 5.

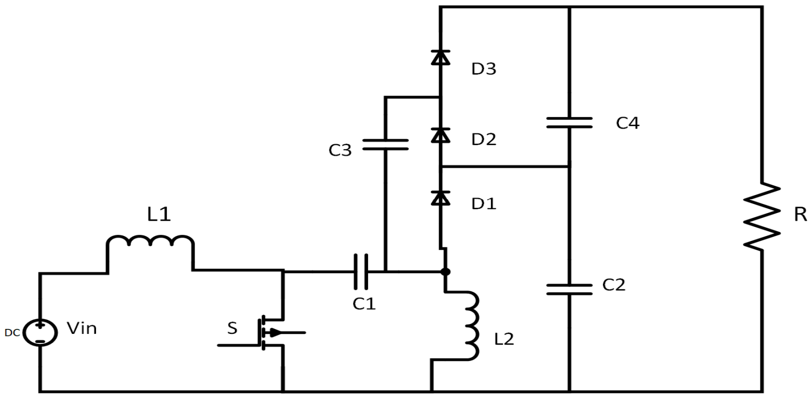

Fig 5. Multilevel SEPIC converter [6]

E. Cuk Converter

In Cuk converter, there is a polarity reversal on the output and this output can be other higher or lower than the input voltage. To prevent large harmonic content, there is inductor which acts as a filter on the input side. A soft switched CUK converter with active clamping action for MPPT of PV module is proposed. The major parasitic reactance like transistor output capacitance, track inductance is observed in this converter [7].

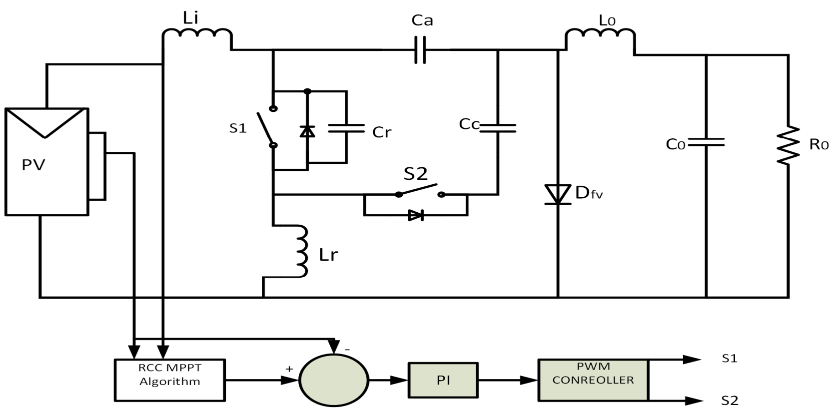

Fig 6. CUK converter with closed loop control [7]

F. FlyBack Converter

Fly back converter for MPPT, PV applications is proposed. The advantage of this converter is simple in structure, good power density. Acceptable energy conversion efficiency is obtained for this type of converter for power up to 150 watts [8]. The circuit of fly back converter is shown in fig 7.

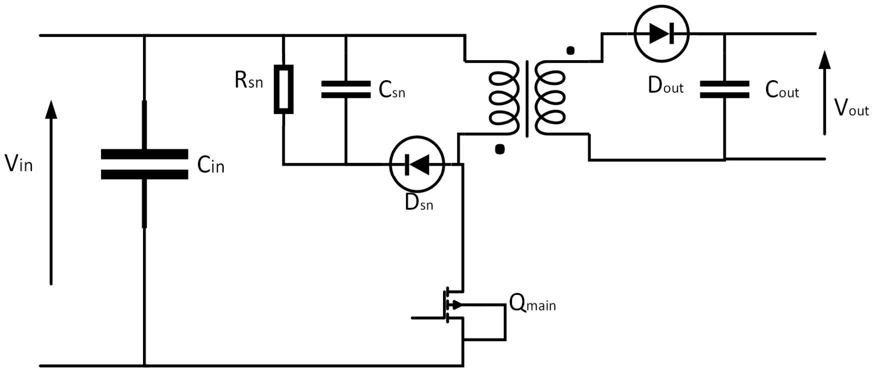

Fig 7. Fly back converter diagram [8]

G. Push-Pull Forward Converter

Push-pull forward converter is used for digital PV simulator. It is hybrid structure which includes both push-pull converter and forward converter. A transformer works in two directions so it has high utilization factor of the transformer core [9].Fig 8 shows the topological structure of the push-pull forward converter

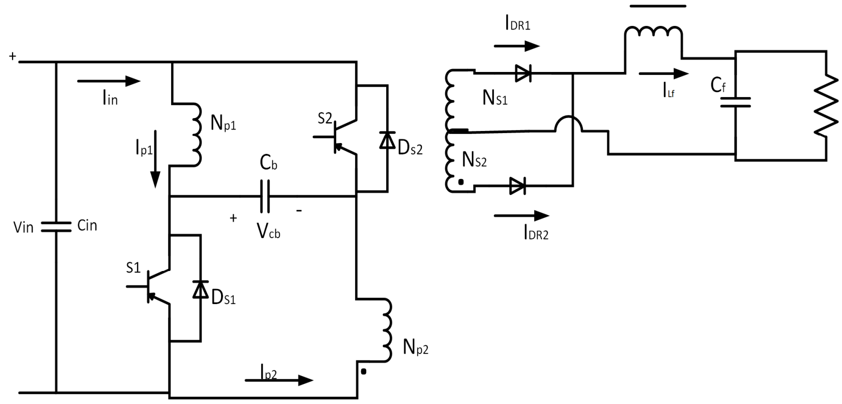

Fig 8. Push-pull forward converter topological structure [9]

III. DIFFERENT CONTROL TECHNIQUES FOR POWER CONVERTERS.

1. MODEL PREDICTIVE CONTROL

In this technique, a new high gain dc-dc converter is proposed. By using MPC-MPPT technique, it is possible to track the maximum power from the PV module at different environmental conditions. MPC-MPPT uses three sensors, two voltage sensors and one current sensor.

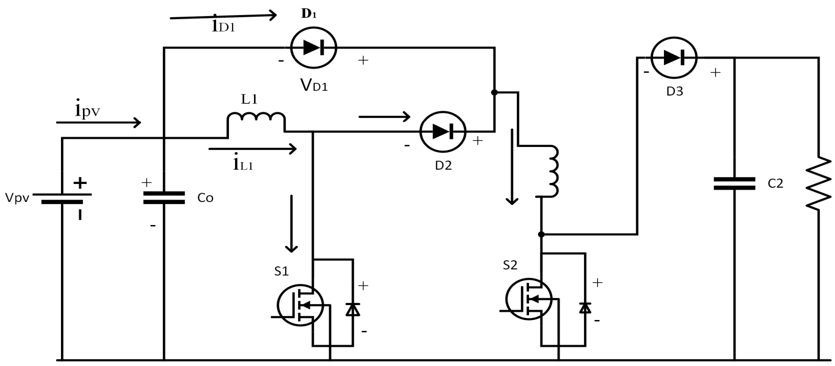

Fig 9. New high step up DC-DC converter [10]

In according to this technique, first new high gain step up transformer less DC-DC converter is proposed and secondly a novel model predictive control algorithm is proposed. This new high gain converter consists of two inductors, three diodes, one output capacitor and two power switches. In this technique based on switch status that is zero or one under continuous conduction mode (CCM), the converter operates into two modes that is mode I and mode II respectively [10].

In mode I, two switches are triggered by giving high pulses and they are turned on, diodes D0 and D2 are turned off and inductors L1 and L2 are charging from DC source. In mode II, two switches are triggered by giving low pulses and they are turned off, inductors L1 and L2 starts discharging to the output capacitors. Converters which are integrated with PV module applications are featured with high gain and high efficiency. By using this converter gives improved performance and efficiency around 93%. The configuration of the new high step up DC-DC converter is illustrated in Fig 9.

2. CONTROL BLOCK OF THE PROPOSED CONTROL SYSTEM

MPC-MPPT algorithm highlights PV current and voltage only, then an incremental conductance approach method is adapted to the generate the reference current that leads to maximum power operation. The MPC algorithm starts to regulate the converter to track the reference current. The proposed control block is depicted in Fig 10.MPC can be treated as finite set of non-linear models. Each model constitutes each state. MPC calculates prediction of every switching state and minimization process by using cost function, finally it gives minimum errors which can be applied to the circuit.

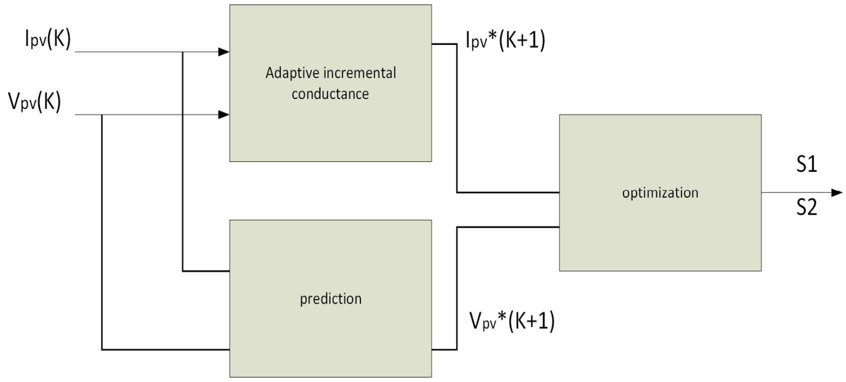

Fig 10. Control block of the proposed control system [10]

3. VOLTAGE MODE CONTROL TECHNIQUE

Voltage mode controller is preferred in order to obtain the regulated output voltage without using current sensor. This controller technique is implemented using classical frequency-domain technique. Controller gain is directly obtained by bode plot which has gain margin and phase margin.

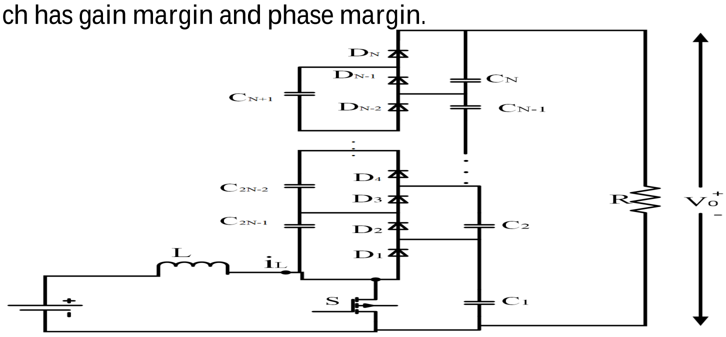

Fig 11. Circuit diagram of Multi-level boost converter [11]

This technique does not depend on load resistance R and it will not follow trial and error method to obtain the controllers gain [11].Here voltage mode controller is proposed for the regulation of multilevel DC-DC boost converter. This regulation can be obtained without using current sensors. Controller design is based on the classical frequency domain where the bode plot approach is directly applied to the controller in order to obtain the controller's gain through phase margin and gain margin. Fig11. Shows the topology of the multilevel boost converter.

4. SLIDING MODE CONTROL TECHNIQUE

Graphical approach is employed in the analysis of SM control reachability and existence conditions.

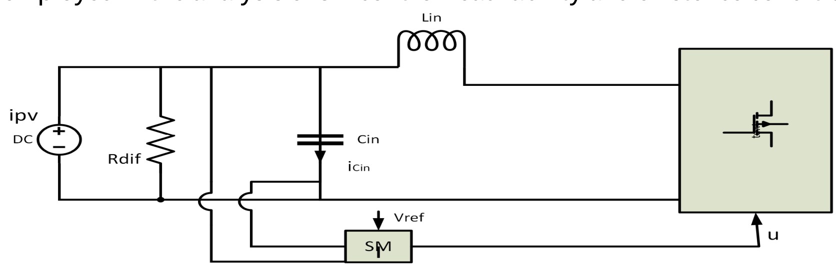

Fig 12. - Connection scheme of the PV linear model with SM control [12]

This method is useful method in determining the key relations among the parameters of converter and PV array and sliding surface. In this control technique, the PV sources model using Norton's equivalent circuit. To analyze the reachability and existence conditions, SM design consists of two steps in the first step hitting face, the controller drives the trajectory of the state variable toward this sliding surface regardless of the initial position [12]. The reachability conditions must be ensured the insurance the SM control existence condition employs then all of the trajectories in the vicinity of sliding surface.

5. PWM BASED SLIDING MODE CONTROL TECHNIQUE

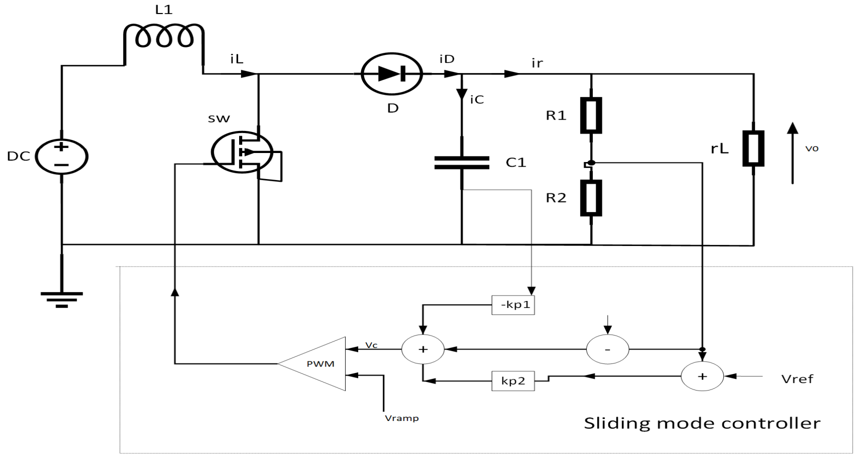

Fig 13. Control structure of PWM based SM controller [13]

In pulse width modulation, width of the pulse is determined based on the modulator signal information. For small signal-based system conventional PWM controller do not show large variations which faces the problem of proper execution so PWM-based sliding more controller overcome this problem of conventional perimeter converter controller and provides good regulation at all operating conditions. Sliding mode controller is another widely used controller for the dc-dc boost converter as it offers the simplicity of implementation and the robust performance against the load and line variations. However. the main drawback of traditional hysteresis modulation based sliding mode controller is that it leads to a variable switching frequency in its implementation. This leads to excessive switching losses inductor losses and electromagnetic interference generation if a pulse width modulation-based SMC is used to solve this problem, it might require two sensors for its implementation this may not be suitable for some applications where in there are power density constraints to accommodate the correct sensor [13].

6. FUZZY LOGIC CONTROL TECHNIQUE

PD based fuzzy controller is designed stability and small signal dynamic performance can be improved by this technique. The conventional fuzzy logic controller consists of fuzzification interface, linguistic operation, rule base inference mechanism and defuzzification interface [14].

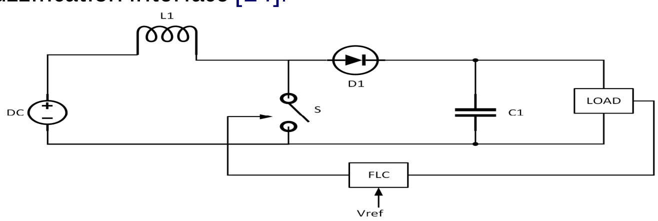

Fig 14. Fuzzy control technique for boost converter [14]

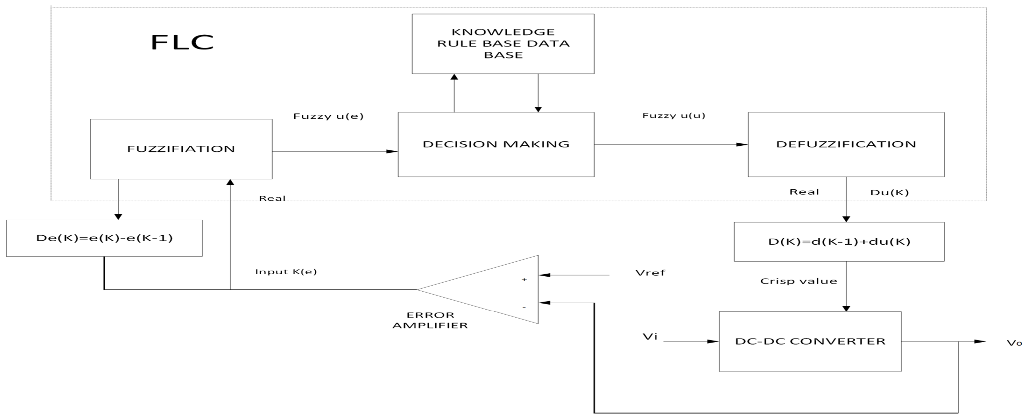

Fig 15. Conventional fuzzy logic controller [14]

IV. DIFFERENT TYPES OF MPPT ALGORITHMS

A) Perturbation and Observation (P&O)

In this algorithm, voltage perturbation is introduced in the system, this voltage perturbation causes the change in the power of the PV panel. If this change is in the positive direction then the perturbation is carried out in the same direction. By doing this once the peak power is reached then any small increase in the voltage makes the decrease in the power and hence reversing the perturbation.

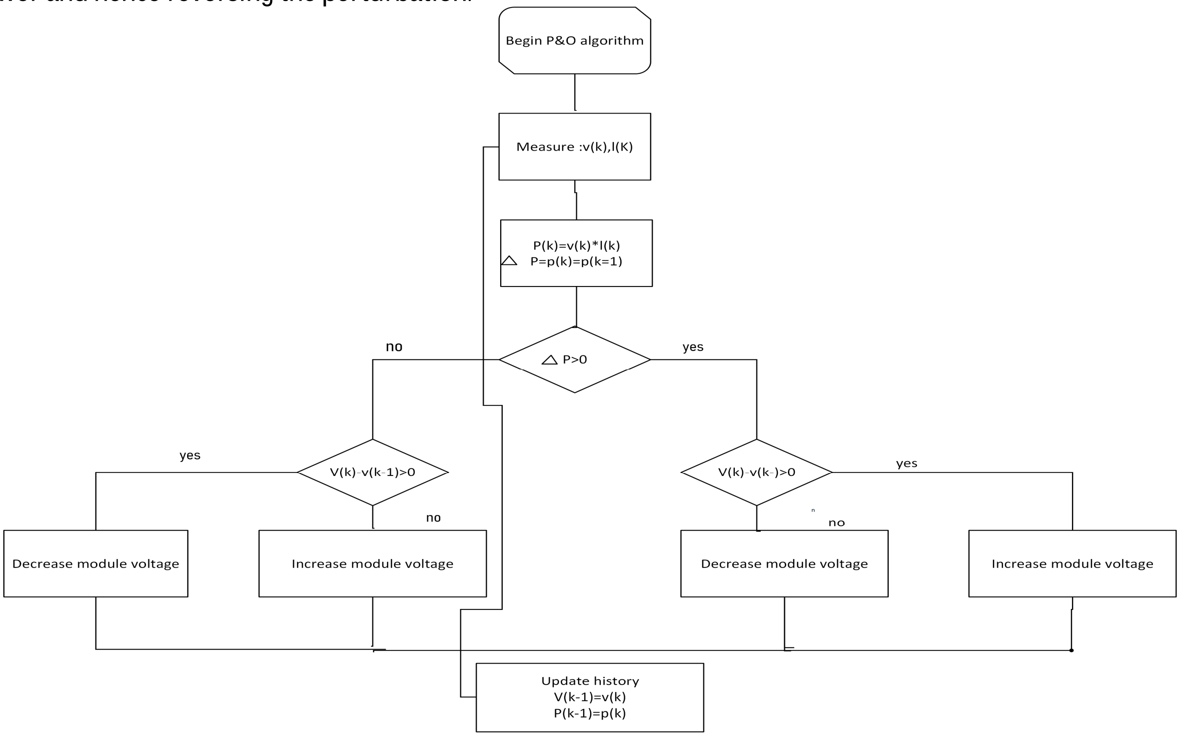

Fig 16:- P&O Controller algorithm[15]

B) INCREMENTAL CONDUCTANCE ALGORITHM

Maximum power point is tracked under first varying atmospheric conditions. Incremental conductance algorithm is used in order to overcome the problems of P and O algorithm. In this technique gradient values, I and V are determined by previous values of current and voltage. Atmospheric conditions also play very important role in the algorithm. No operation is performed by the algorithm if the MPPT continues to operate at maximum power point condition that is dV is equals to zero; with no change in the irradiation condition that is dI is equals to zero when the radiation is increased; that is dI is greater than zero it increases the maximum power point voltage [16].

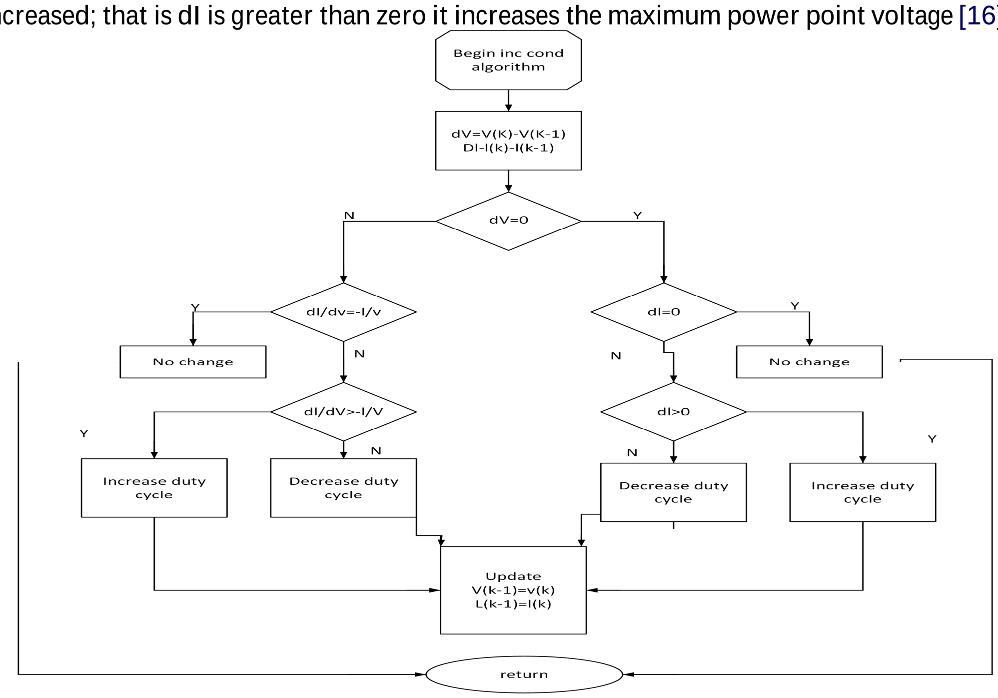

Fig 17:- Incremental conductance algorithm[16]

C) MULTIPLE MAXIMA SEARCH MPPT ALGORITHM

By analysing the different MPPT, multiple maximum search method MPPT algorithm is taken because it tracks the maximum power even under partially shaded condition. This algorithm works on dividing rectangles algorithm for searching the global extreme of a lipschitz function in an interval. A lipschitz function describes the relationship of power and voltage PV cells does propose the MPPT has better performance and fast-tracking speed particularly in the presence of multiple MPPs and Saturn high level changing of insolation [17].

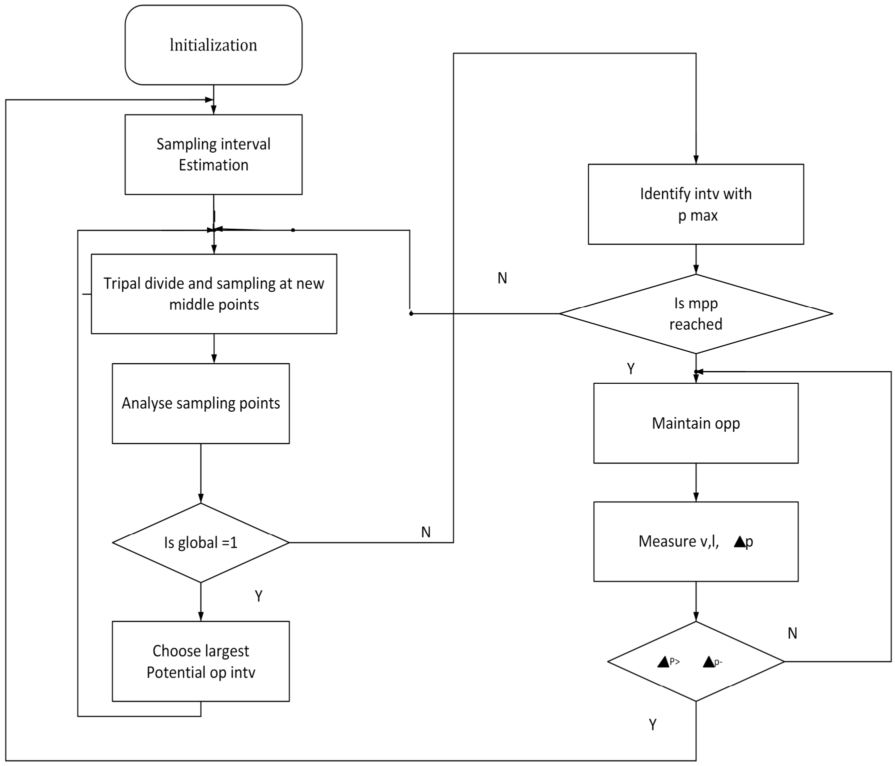

Fig 18:- Direct MPPT algorithm[17]

V. POWER CONVERTERS IN DC GRID APPLICATION

A) HIGH GAIN STEPUP DC-DC CONVERTER FOR DC MICROGRID APPLIACTION

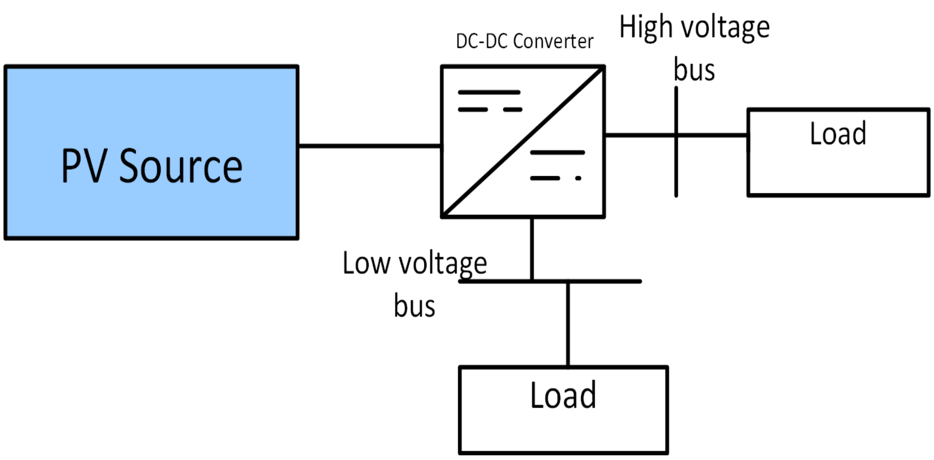

Fig 19: Schematic of DC microgrid with two DC buses.

The DC grid system are becoming more prominent ones in recent days as it is used in the optimal control of power from source to the loads and it is supplying high quality power to consumers. Nowadays consumer loads are either DC or adaptable to the DC where it requires a different voltage level. Here photovoltaic panels are used as a source as it offers less cell voltage but when it is connected in series to achieve more voltage, it faces reliability problem. When conventional converters like boost converters, switched inductor converter, switched capacitor converter, cascaded converter faces reverse recovery problem when they are operated to get high voltage gain. Isolated converters like push-pull converters, forward converters, fly back converters can achieve high voltage gain with transformer turns ratio but it also faces problems like high voltage spikes and power loss due to leakage inductance.

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To overcome the above issues, high gain DC-DC converter are proposed as it is able to maintain two DC voltage level that is high voltage level for high power DC bus and low voltage level for low power DC bus. This feature makes it more suitable for microgrid application.

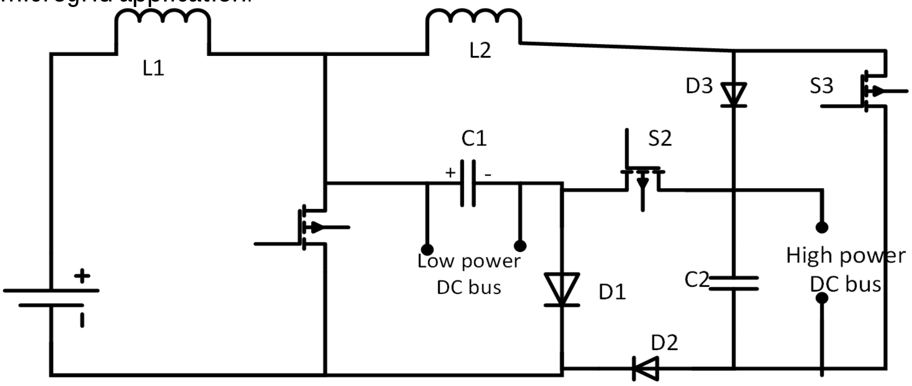

Fig 20. Circuit diagram of step-up DC-DC converter with two DC buses.

B) MODULAR DC/DC PHOTOVOLTAIC GENERATION SYSTEM FOR HVDC GRID CONNECTION

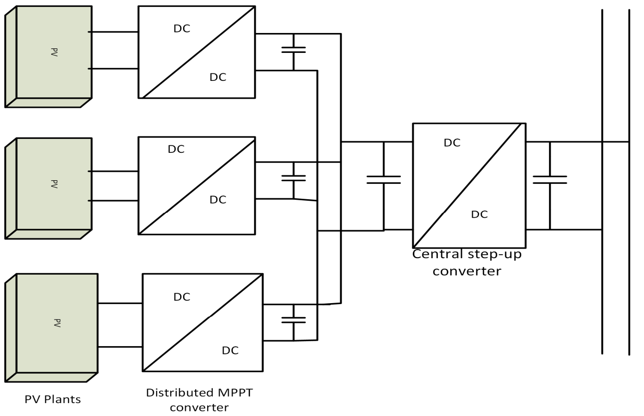

Fig 21. System configuration of the proposed HVDC grid-connected PV system

Modular DC/DC conversion system with distributed MPPT and centralised step up converter for photovoltaic energy integrated into HVDC grids is proposed. The conversion system consists of two power stages. First stage is MPPT converter and second stage is step up converter. Both the stages are modular structures. For distributed MPPT stage, interleaved boost converter topology is used in order to minimise the input and output voltage ripple. For centralised step up stage, narrow switching frequency variation LLC topology is employed. To reduce the switching losses, soft switching operation of LLC is achieved.

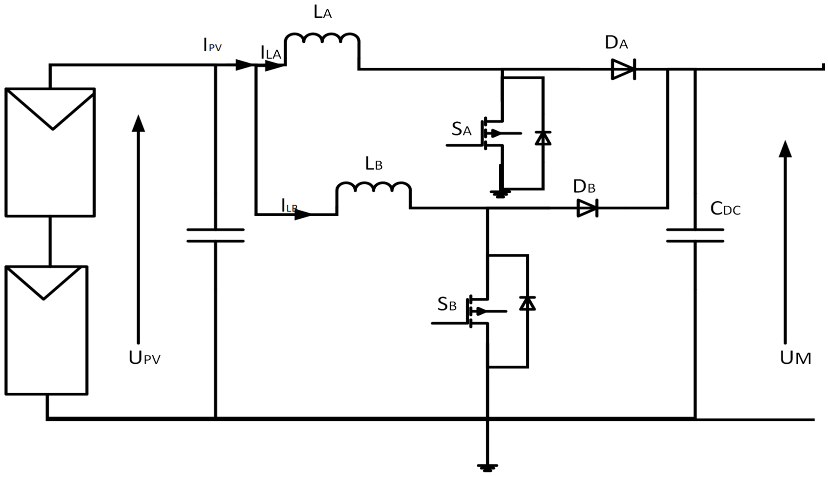

Fig.21 Interleaved boost topology of the MPPT module

Figure shows proposed HVDC grid connected PV system with two stages distributed MPPT stage consists of multiple uni-directional isolated dc-dc converters. Centralised dc-dc converters are placed in the step-up station that is out of the PV plant, it performs the function of voltage step up and high voltage galvanic isolation. Distributed MPPT stage consists of interleaved two-phase boost circuit. This interleaved operation can minimise the output and input ripples of the stage which in turn reduces the use of filters.

VI. COMPARISION TABLE

This section offers an overview of different types of power converters, control techniques and MPPT algorithms used for the photovoltaic applications. The use of particular type of converter will depends on the requirements for the output voltage, ripple factor and the pulse in the output current, the cost involved and the application.

TABLE 1. COMPARISION TABLE OF VARIOUS POWER CONVERTERS WITH DIFFERENT CONTROL TECHNIQUE

Proposed converter	Control technique	source	No. of diodes	No. of switches	Advantages	Disadvantages	Applications
Buck converter	Sliding mode control	PV	1	1	Regulated duty cycle	-	MPPT
Boost converter	ZVT	battery	4	2	High frequency operation, high efficiency	High stress	Microgrids, low and medium power applications
Buck-boost converter	Fuzzy logic control	battery	1	-	Faster transient response, stability	High fabrication cost	Battery and load systems
Multilevel SEPIC converter	PWM	PV	3	1	High voltage gain, harmonic reduction	More number of switches	Battery applications, renewable energy applications
Fly back converter	-	Voltage source	2	1	Simple structure, low production issues, good power density	Low efficiency, complicated control system	PV applications
Push-pull forward converter	PI control	Voltage source	2	2	Improve efficiency, reduce development cost	Drift problem occurs	PV simulator
High gain step-up converter	MPC-MPPT	Voltage source	3	2	Increased efficiency, superior performance	Complexity and reliability problems	PV applications
Multilevel boost converter	Voltage mode contro	Voltage source	3	1	High voltage gain	Cost and complexity of control design	High power applications
SEPIC converter	Sliding mode controller	PV	1	1	High robustness, high conversion efficiency	Complexity and cost	Standalone applications
Boost converters	PWM based sliding mode control	Voltage source	1	1	High feasibility, good regulation	High fabrication cost	Satellite systems
Boost converter	PD like fuzzy logic control	Voltage source	1	1	Improved stability, better economics	Low conversion efficiency	Mobile transportation

VII. CONCLUSIONS

An overview of different types of DC-DC converters has been presented. Different types of DC-DC converters for PV applications have been highlighted. Various control techniques have been studied along with a comparison of parameters like applications, advantages and disadvantages, etc. This paper also gives the clear picture of their application of MPPT to solar PV systems and different MPPT algorithm using various dc-dc converters are also described. This paper includes concept of DC-DC converters in DC grid system. Finally, this paper concludes with various power converters along with control techniques, MPPT algorithms for different PV applications and also this paper highlights the importance of power converter in DC grid systems.

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