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REVIEW ON GRID CONNECTED PV SYSTEMS FOR PERFORMANCE OF HIGHLY EFFICIENT CONSTANT POWER GENERATION

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ABSTRACT

A fast and smooth transition between maximum power point tracking and Constant Power Generation (CPG) is ensured which limits the maximum feed-in power of PV systems by using advanced power control strategy. High-performance and stable operation are always achieved regardless of the solar irradiance levels. Without stability problems, the PV output power is regulated to any set-point and operates at the left side of the maximum power point. It describes the operational principle of the P&O-CPG algorithm which is applied to two-stage single-phase grid connected PV system to obtain a stable CPG operation. The effectiveness of the proposed CPG control in terms of high accuracy, fast dynamics, and stable transitions can been verified.

Keywords: Constant power control, maximum power point tracking, PV systems, power converters.

I. INTRODUCTION

In order to maximize the energy yield using PV systems, Maximum Power Point Tracking (MPPT) operation is mandatory. Advanced power control schemes as well as the regulations are required to avoid adverse impacts from PV systems like overloading the power due to more PV installations. As stated in the German Federal Law: Renewable Energy Sources Act, the PV systems with the rated power below 30 kWp limits the maximum feed-in power unless remotely controlled by the utility [4]. Such an active power control is referred to as a Constant Power Generation (CPG) control. By modifying the MPPT algorithm at the PV inverter level, CPG control can be achieved. Specifically, when the PV output power P_{pv} is below the setting-point $P_{limit,}$ PV system is operated in the MPPT mode. However, when the output power reaches P_{limit}, the output power of the PV system is constant, i.e., $P_{pv} = P_{limit}$, and leading to a constant active power injection as shown in (1) and illustrated in Fig. 1.1.

$$P_{PV} = P_{MPPT}, \quad \text{when } P_{PV} \leq P_{LIMIT} \quad \text{-------- (1)}$$
$$P_{PV} = P_{LIMIT}, \quad \text{when } P_{PV} > P_{LIMIT}$$

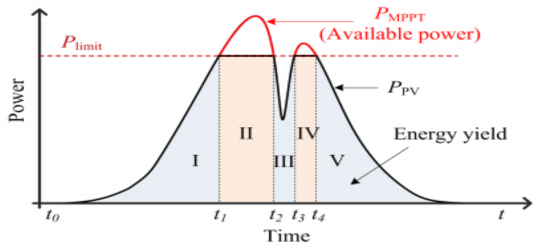

Fig. 1.1 Constant Power Generation (CPG) concept: 1) MPPT mode during I, III, V, and 2) CPG mode during II, IV

II. LITERATURE SURVEY

This work discusses the technical and economical benefits of different active and reactive power control strategies for grid-connected photovoltaic systems in Germany. The aim of these control strategies is to limit the voltage rise, caused by a high local photovoltaic power feed-in and hence allow additional photovoltaic capacity to be connected to the mains. Autonomous inverter control strategies, which do not require any kind of data communication between the inverter and its environment, as well as an on-load tap changer for distribution transformers, is investigated. The technical and economical assessment of these strategies is derived from 12-month root mean square simulations, which are based on a real low voltage grid and measured dc power generation values. [1]

This work demonstrates a fast maximum power point tracking (MPPT) control algorithm for the photovoltaic (PV) in a hybrid wind–PV system, in which the PV generator may also need to work in a reduced power mode (RPM) to avoid dynamic overloading. The two control modes, MPPT and RPM, are inherently compatible and can be readily implemented, without the need of a dumping load for the RPM. Following the establishment of a dynamic system model, the study develops the guidelines to determine the variables of a direct hill-climbing method for MPPT: the perturbation time intervals and the magnitudes of the applied perturbations. [2]

This work investigates a hybrid power control concept for grid-connected photovoltaic (PV) inverters. The control strategy is based on either a maximum power point tracking control or a constant power generation (CPG) control depending on the instantaneous available power from the PV panels. The essence of the proposed concept lies in the selection of an appropriate power limit for the CPG control to achieve an improved thermal performance and an increased utilization factor of PV inverters, and thus, to cater for a higher penetration level of PV systems with intermittent nature. [3]

This work discusses an imperative demand of clean and reliable electricity generation in some countries, the increasing adoption of new photovoltaic (PV) systems pushes the Distribution System Operators (DSOs) to expand the transmission/distributed lines.

However, the potential cost and increased maintenances introduce new obstacles. The DSOs starts to reduce PV installations in order to avoid an extension of the power infrastructure and limit the maximum feed-in power of the existing PV systems to a certain level. It can contribute to a weakened requirement of grid expansion and an increased penetration level. Therefore, to meet the need by future PV systems, a Constant Power Generation (CPG) control concept of PV inverters can be done. It investigates two main issues: a) analyzing the reduction of the energy yield due to CPG control to study its feasibility from an economic point of view and b) developing robust CPG control methods, otherwise, it may introduce instabilities. [4]

This work discusses significant expansion of PV-grid installations that escalated new problems of PV penetration because of intermittent nature of the PV source and inertia-less interface. A novel active and reactive power control scheme for a single stage PV-grid system is used with large distributed generation system (DGS) contributions. The proposed work incorporates a PV power control algorithm, which not only facilitates maximum power point tracking (MPPT) but also provides precise PV power control, unlike conventional MPPT schemes. These features significantly overcome power and voltage fluctuations, reverse power flow problems and overvoltage issues, which are considered as major potential PV penetration problems and the main reason for limiting large PV installations. In addition, the reactive power control ability improves feeder voltage profile and utilization of the interfacing power converter. A 3-Ph, single stage PV-grid system is considered with the PV source directly integrated with the DC link of the inverter which controls DC link voltage. [5]

This work proposes a method of modelling and emulation of a two-stage photovoltaic (PV) inverter system by using a single power converter. The PV emulator is used in a converter-based power grid emulation system – Hardware Test-bed (HTB), to investigate the influence of solar energy sources on the power grid. Both physical components and control strategies of the two-stage PV inverter system are modelled in the converter controller, which enables the emulator to represent the behaviours of the two-stage PV inverter system accurately. The performance of the two-stage PV inverter system emulator in both the MPPT mode and the reserved power control mode under variable solar irradiance circumstances can be illustrated. [6]

Although photovoltaic (PV) systems are generally based on Maximum Power Point Tracking (MPPT), many situations such as stand-alone systems or micro-grids increasingly require the PV system to operate below maximum power. The problem is that the power regulation becomes unstable when the MPP power is lower than the reference power as a result of a decrease in irradiance. A control strategy for a DC/DC boost converter that makes it possible to operate in both modes: at either maximum or limited power point tracking can be investigated. [7]

This work demonstrates inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid. The inverters are categorized into four classifications: 1) the number of power processing stages in cascade; 2) the type of power decoupling between the PV module(s) and the single-phase grid; 3) whether they utilizes a transformer (either line or high frequency) or not; and 4) the type of grid-connected power stage. [8]

Renewable energy sources like wind, sun, and hydro are seen as a reliable alternative to the traditional energy sources such as oil, natural gas, or coal. Distributed power generation systems (DPGSs) based on renewable energy sources experience a large development world wide. Due to the increasing number of DPGSs connected to the utility network, new and stricter standards in respect to power quality, safe running, and islanding protection are issued. As a consequence, the control of distributed generation systems should be improved to meet the requirements for grid interconnection. The structure of DPGS is based on fuel cell, photovoltaic, and wind turbines. In addition, control structures of the grid-side converter, the possibility of compensation for low-order harmonics and control strategies when running on grid faults can be investigated. [9]

This work demonstrates a grid-connected photovoltaic (PV) power system with high voltage gain, the steady-state model analysis and the control strategy of the system. For a typical PV array, the output voltage is relatively low, and a high voltage gain is obligatory to realize the grid-connected function. The PV system employs a ZVT-interleaved boost converter with winding-coupled inductors and active-clamp circuits as the first power-processing stage, which can boost a low voltage of the PV array up to a high dc-bus voltage. Accordingly, an accurate steady-state model is obtained and a full-bridge inverter with bidirectional power flow is used as the second power-processing stage, which can stabilize the dc-bus voltage and shape the output current. Two compensation units are added to perform in the system control loops to achieve the low total harmonic distortion and fast dynamic response of the output current. A simple maximum-power-point-tracking method based on power balance is applied in the PV system to reduce the system complexity and cost with a high performance. [10]

The work discusses different techniques for maximum power point tracking of photovoltaic (PV) arrays. The techniques are taken from the literature dating back to the earliest methods. It is shown that at least 19 distinct methods have been introduced in the literature, with many variations on implementation. [11]

III. METHODOLOGY

In single stage grid connected PV systems [7], the CPG based on a Perturb and Observe (P&O-CPG) algorithm was introduced, where the operating area is limited to be at the right side of the Maximum Power Point (MPP) of the PV arrays (CPP-R).When PV systems experience a fast decrease in the irradiance, the robustness of the control algorithm decreases.

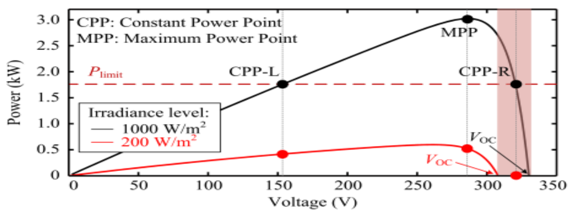

Fig. 3.1 Stability issues of the conventional CPG algorithms, when the operating point is located at the right side of MPP.

The above issues are resolved, by extending the operating area of the P&O-CPG algorithm using two-stage grid connected PV system. By regulating the PV output power at the left side of the MPP (CPP-L), a stable CPG operation can be achieved, since the operating point will never “fall off the hill” during a fast decrease in the irradiance. Thus, the P&O-CPG algorithm can be applied to any two-stage single-phase grid connected PV system.

IV. PROPOSED MODEL

4.1 CONVENTIONAL CPG ALGORITHM

4.1.1 System Configuration:

Fig.3.1.1 shows the basic hardware configuration of a two-stage single-phase grid-connected PV system and its control structure. The CPG control is implemented in the boost converter. The cascaded control of the full-bridge inverter is done where the DC-link voltage is kept constant through the control of the AC grid current, which is an inner loop. The PV system operates at a unity power factor, only when active power is injected to the grid. Here the two-stage configuration can extend the operating range of both the MPPT and CPG algorithms. In the two-stage case, the PV output voltage vpv can be lower (i.e at the left side of the MPP), which is stepped up by using boost converter to match the required DC-link voltage.

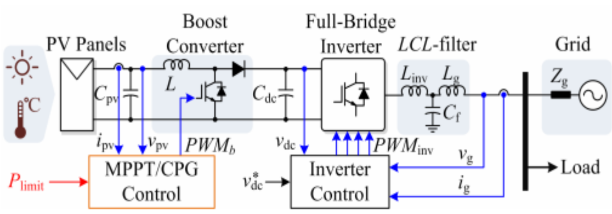

Fig 4.1.1 Hardware schematic and overall control structure of a two-stage single phase grid-connected PV system.

4.1.2 Operational Principle:

The operational principle of the conventional P&O-CPG algorithm is given in Fig 4.1.2.a. It operates into two modes: a) For MPPT mode (Ppv ≤ Plimit), the P&O algorithm should track the maximum power,b) For CPG mode (Ppv > Plimit), the PV output power is limited at Plimit. The behavior of the algorithm is similar to the conventional P&O MPPT algorithm during the MPPT operation. The operating point will track and oscillate around the MPP. For CPG operation, the PV voltage *v*pv is continuously perturbed toward a Constant Power Point (CPP), i.e., $P_{pv} = P_{limit}$. The operating point will reach and oscillate around the CPP, after a number of iterations. Only the operation at the left side of the MPP (CPP-L) is considered for the stability concern, even if the PV system with the P&O-CPG control can operate at both CPPs. The control structure of the algorithm is shown in Fig 4.1.2.b. where $v*_{pv}$ can be expressed as

$$v_{pv}^{*} = \begin{cases} v_{MPPT}, & \text{when } P_{pv} \le P_{limit} \\ v_{pv,n} - v_{step}, & \text{when } P_{pv} > P_{limit} \end{cases}$$ -----(2)

where vMPPT is the reference voltage from the MPPT algorithm (i.e., the P&O MPPT algorithm), vpv,n is the measured PV voltage, and vstep is the perturbation step size.

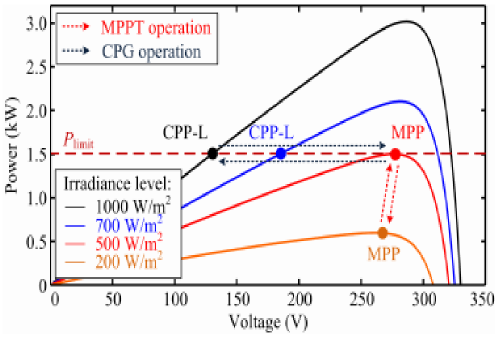

Fig 4.1.2.a Operational principle of the P&O-CPG algorithm with stability issues.

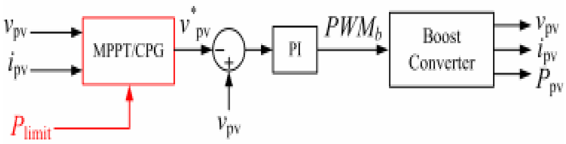

Fig 4.1.2.b Control structure of Algorithm with Proportional Integrator (PI)

4.1.3 Issues of the P&O-CPG Algorithm:

As shown in Fig 4.1.3.a, during a clear day, when the operating point is at the left side of the MPP, under slow changing irradiance conditions the P&O-CPG algorithm has a satisfied performance. However, in a cloudy day irradiance fluctuation will result in overshoots and power losses as shown in Fig Fig 4.1.3.b.

Assuming that the PV system is operating in MPPT mode initially and the irradiance level suddenly increases, the PV power P_{pv} increases by the change in the irradiance causing large power overshoots, as shown in Fig 4.1.3.c. (i.e. A→B→C). Similarly, if the PV system is operating in the CPG operation (e.g., at CPP-L) and the irradiance suddenly drops, the output power *P*p decreases suddenly, (i.e., C→D). The operating point reaches the new MPP (i.e., E) at that irradiance condition, after undergoing number of iterations, resulting in loss of power generation.

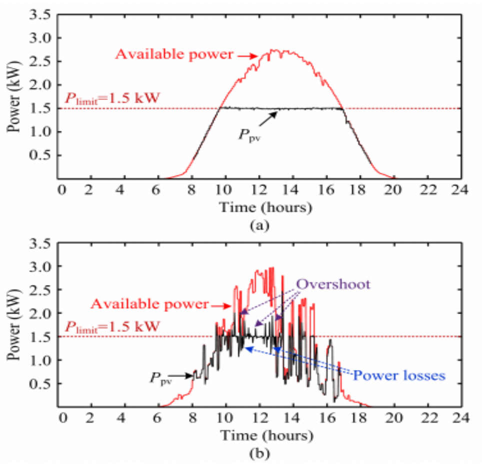

Fig 4.1.3. Experimental result algorithm (P&O-CPG) under two daily conditions: (a) clear day and (b) cloudy day

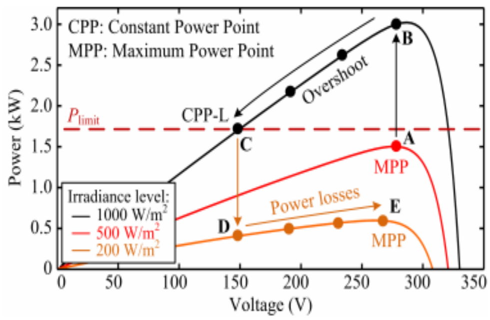

Fig 4.1.3.c. Operating trajectory of the algorithm resulting in overshoot and power losses.

Minimizing Overshoots:

Minimizing the overshoots as the tracking speed is increased is done by increasing the perturbation step size. Specifically, a large step size can reduce the required number of iterations to reach the corresponding CPP. When the algorithm detects a fast increase in the Irradiance Condition, only then step size modification can be enabled.

Minimizing Power Losses:

When the CPG operating point is at the left side of the MPP, the P&O-CPG algorithm reaches the new MPP with a number of iterations during a fast decrease in irradiance, leading to power losses. There is no much change in operating point of the PV system if the PV system operates in the MPPT mode under different irradiance levels.

V. DESIGN PARAMETERS

5.1 Boost converters:

As we know boost converter is essential to boost the DC output obtained from PV panels. Efficiency of the interleaved boost converters can be improved by soft switching techniques. Interleaved converters experience the power loss during the switching operations. The soft switching techniques include Zero Current Switching (ZCS), and Zero Voltage Switching (ZVS). These techniques use resonant circuit with the main circuit to make either voltage or current zero. ZCS can remove the switching losses at turn off time and reduce the switching losses when the switch is turned on. In ZCS switches are under high current stress, so they results in higher conduction loss. However ZCS is relatively effective to reduce loss for power devices such as IGBT. Using ZVS we can avoid the capacitive losses during turn on. ZVS is useful for operations under high frequency. ZCS operation is done with constant on time control and ZVS operation is done with constant off time control.

5.1.1 ZVT Boost Converter:

ZCS and ZVS make the current or voltage zero under either Turn-On or Turn-Off time. So it has some switching losses exists in the circuit as well as some amount of current ripples and output power ripples. To avoid these losses Zero Voltage Transition (ZVT) topology is introduced. The ZVT converters make zero voltage across the switches during turn ON and turn OFF transitions of the switch. These converters use few additional elements which are placed in a parallel path with the main circuit which provides zero voltage commutation for the main switch without any additional voltage stresses and current stresses. Thus, this approach overcame the drawbacks presented by ZVS converters, and ZVS converters. In ZVT converter all the switches are both turned on and off under exact or near ZVS. This converter has a simple structure, ease of control, low cost and high efficiency. The overall efficiency, which is 91% in the hard switching case get increases to about 97%.

Although ZVT is a commonly used technique, several ZVT has drawbacks such as:

- Turn-on capacitive losses at auxiliary switching,
- Main switch current stresses are higher,
- Also higher auxiliary switch voltage stresses,
- Operation can be done under limited voltage converter ratio,
- Works with additional components count

To overcome these drawbacks, new ZVT topology is introduced as, High step-up ZVT interleaved boost converter with WCCIs (Winding Cross Coupled Inductors) and reduced clamp switch number [8].

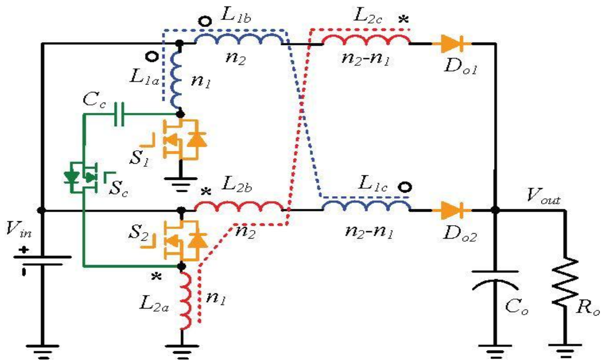

Fig. 5.1.1. ZVT interleaved boost converter with WCCIs (Winding Cross Coupled Inductors)

The topology is obtained from its isolated counterpart. Only one set of active clamp circuit containing a capacitor and an auxiliary switch is necessary for the interleaved two phases for suppress the voltage spikes and recycle the leakage energy. The switch voltage stress is reduced and the voltage gain is extended. The reverse recovery problem of output diode is reduced by the leakage inductance. By adding two additional clamp capacitor *Cd1 (Cd2),* changing the turns of the third winding *L1c (L2c)* from *(n2-n1)* to *n2.*

Converter has two coupled inductors each having three windings. The primary winding *L1a* is coupled to the second winding *L1b* and also it is coupled to the third winding *L1c* in another phase. Primary winding having turn *n1* and secondary and third winding has the turns as equal to *n2.* N is defined as the turns ratio of n2/n1. The coupled inductor 2 is having the same structure. The coupling reference is pointed by "*****" marks and "**o**". Using this converter the drawbacks get removed as follows:

- The switching losses are reduced in a great manner.
- The reverse-recovery losses at the output diode are reduced greatly.
- ZVT soft switching performance is made for the main and the auxiliary switches due to the auxiliary commutation circuit.

Topology modification with built-in LC low pass output filter:

The proposed ZVT interleaved dc-dc boost converter has some advantageous performances as compared to the conventional interleaved boost converter used for high step-up applications, In the second and third windings of the coupled inductors the leakage inductance existed and the output diodes parasitic capacitor form a resonant circuit during turning off output diodes, this causes additional voltage ringing at the output diode and increase in the voltage stress of output diode. The resonant ringing causes additional losses and decreases the efficiency of the converter. Furthermore, the current into the output electrolytic capacitor is the addition of the output diodes currents and is discontinuous; this results in high EMI noise and parasitic losses caused by the output capacitor. And the life of the electrolytic capacitor is get shortened because of the discontinuous pulsed current. And making some modification in topology the converter can be improved as [9],

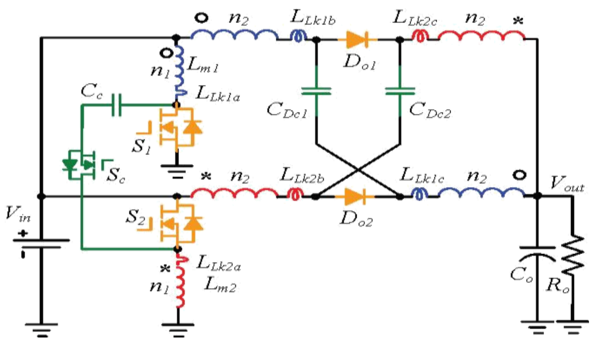

Fig. 5.1.2 Modified ZVT boost converter

The voltage ringing on the diode connected at output is regulated by the additional capacitors and built in low pass LC output filter. It is formed by the additional capacitors and the leakage inductance. So the ripple in output current is cancelled and the EMI noises get reduced.

5.2 Inverters:

The boosted DC output of boost converter is converted into AC for further utilization by using inverters. Different topologies were including in the transformer-less grid connected PV system which improves the performance of inverters are as follows:-

- H5 topology
- HERIC topology (Highly efficient and Reliable Inverters Concept)
- H6 topology
- HB-ZVR topology (H-bridge zero voltage rectifier)
- PN-NPC topology (Neutral point clamped)

- Solidly clamped topologies-
  a) NPC three level VSI
  b) Dual parallel buck topology

Out of above topologies HERIC topology is the best topology with improved efficiency with using this topology. We can design very efficient inverter which controls the output of inverter that are fed to the grid or load. HERIC type inverter is also reliable in order to convert DC into AC with higher efficiency [10,12].

5.2.1 Heric Inverter:

The HERIC topology is shown in Fig. 5.2.1. The HERIC inverter where C_{dc} is DC-link capacitor, L_1 and L_2 are filter inductance at grid side and C_0 is the filter capacitor. HERIC employs two extra switches on the ac side of inverter [10].These additional switches have the two major functions:- isolating the photovoltaic panel from grid and preventing the reactive power exchange between the filter inductors and capacitors during the zero voltage state, thus increasing efficiency. Also the leakage current path is cut off as well.

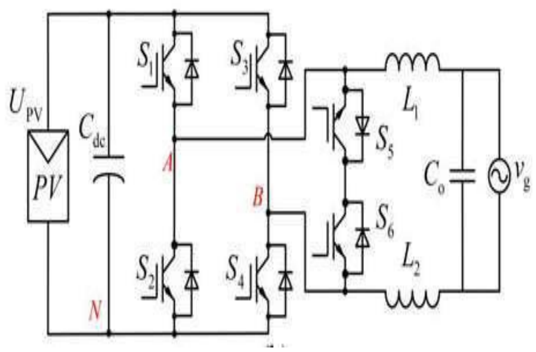

Fig. 5.2.1 HERIC Inverter

There are four operation mode in mode (1) S1, S4 Switches conduct. In Mode (2) S_5, S_6 switches conduct. Same as in Mode (3) S_2, S_3 switches conduct and in Mode (4) S_5, S_6 switches conduct. Table of above 4 mode of operation can be given as follows –

Mode	Half Period	Conducting Devices	V_{out}
Active	Positive	S1,S4, S_5	V_{in}
Free wheeling	Positive	S_5,D6	0
Active	Negative	S_2, S_3, S_6	$-V_{in}$
Free wheeling	Negative	D5,S6	0

Table 5.2.1 Modes of inverter operation

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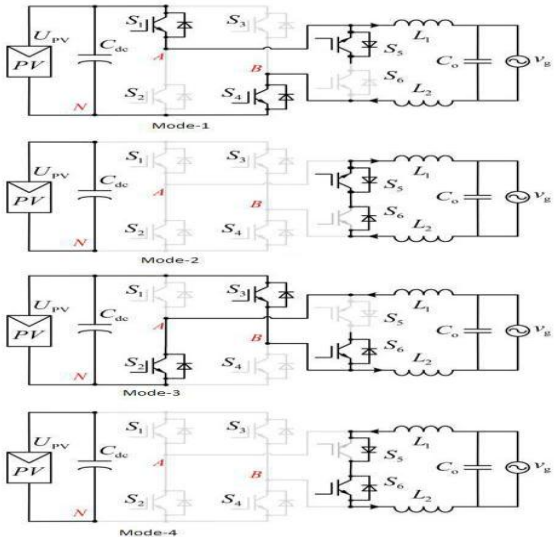

Fig. 5.2.2 Operation of HERIC inverter

During positive half cycle, known as active mode where conducting devices are S1,S4 and S5 are in conduction mode.S5 is in conduction to obtain active and zero vectors. The current flow through the path PV-S1-L1-L2-S4-PV.and freewheeling action take place through S5 and D6 as shown in mode 2.positive vector is appear across Vg i.e. Vout =Vin and during freewheeling action zero vector is obtained.[13]

During negative half cycle, conducting devices are S_2, S_3 and S_6 are in conduction mode as shown in mode 3. S_6 is in conduction to obtain active and zero vectors. The current flow through the path PV-S_3-L_2-L_1-S_2-PV and freewheeling action take place through S_6 and D_5 as shown in mode 4. Negative vector is appear across V_g i.e. V_{out}=-V_{in} and during freewheeling action zero vector is obtained.

As shown in the graph below, three topologies are mentioned in terms of their efficiencies and power. The efficiencies of H5, HERIC, and H6 are 96.78%, 97%, and 97.09%, respectively.

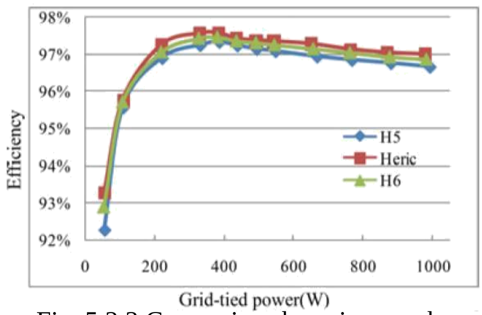

Fig. 5.2.3 Comparison by using graph

Even though H6 has high efficiency, conduction losses are more than that of HERIC and best thermal stress distribution than that of H6. So we can conclude that HERIC topology is the best for INVERTERS.

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H6 TOPOLOGY	*H5 TOPOLOGY*	*HERIC TOPOLOGY*
Includes2 Extra switches on the DC side of the Inverter	Includes 2 extra switches on the DC side of the Inverter	AC side of the Inverter have 2 extra switches
Total Device number is 6	Total device number is 5	Total device number is 6
Device cost Is same as that Of HERIC	Have lowest device cost	Device cost is same as that of H6
H6 topology Has four modes Of Operation	H5 topology has four modes of Operation	HERIC topology has four modes of operation
Conduction losses Higher Than HERIC	Have highest conduction loss	Conduction loss less than H6
Good Thermal stress distribution	Worst thermal stress distribution	Good thermal stress distribution
Switching losses are same as that of H5 and HERIC	Switching losses are same as that of H6 and HERIC	Switching losses are same as that of H5 and H6
Diode freewheeling loss is same as that of H5 and HERIC	Diode freewheeling loss is same as that of H6 and HERIC	Diode freewheeling loss is same as that of H5 and H6
European efficiency is 97%	European efficiency is 96.78%	European efficiency is 97.09%

Table 5.2 Comparison between inverters

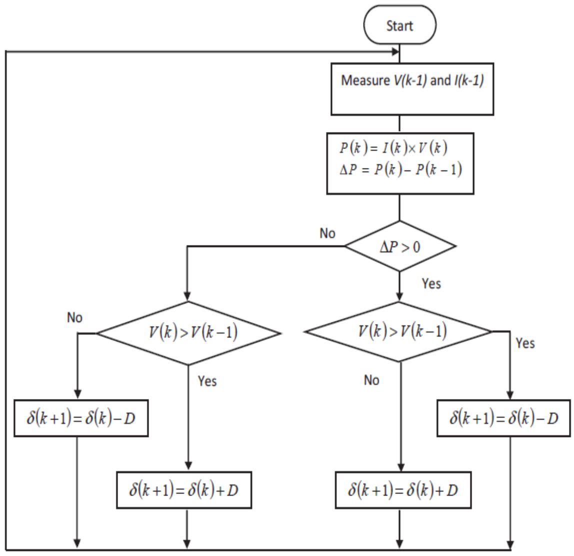
5.3 Selection of desired MPPT:

The major characteristics of all MPPT techniques are summarized in one table which gives better understanding with simplicity and comparative analysis. Only those techniques which are applicable for efficient and reliable operation of PV system can be choosen.

5.3.1 Perturb & Observe (P & O):

P&O is widely used due to easy implementation. This technique force the PV system to approach MPP by increasing or decreasing the panel output voltage.

5.3.2 P& O Algorithm:



To check direction change in maximum power, the P&O method perturbs the operating voltage of PV panel. There are two conditions: 1)When power increases; operating voltage perturbs in same direction. 2) When power decreases; operating voltage perturbs in reverse direction. This process will continue until MPP is reached. The oscillations around MPP is minimized by reducing perturbation step size D.

MPPT techniques and having good performance characteristic are generally used. When we take parameters in account like efficiency, implementation, sensor, cost and applications etc. The P&O is one of the best conventional technique.

MPPT Technique	PV Array Dependent	True MPPT	Analog or Digital	Periodic Tuning	Convergence Speed	Implementation Complexity	Sensed Parameter
1.Hill-climbing / P & O	No	Yes	Both	No	Varies	Low	Voltage, Current
2.Incremental conductance	NO	Yes	Digital	No	Varies	Medium	Voltage, Current
3.Fractional V_{oc}	Yes	No	Both	Yes	Medium	Low	Voltage
4.Fractional I_{sc}	Yes	No	Both	Yes	Medium	Medium	Current
5.Fuzzy Logic Control	Yes	Yes	Digital	Yes	Fast	High	Varies
6.Neural network	Yes	Yes	Digital	Yes	Fast	High	Varies
7.RCC	No	Yes	Analog	No	Fast	Low	Voltage, Current
8.Current sweep	Yes	Yes	Digital	Yes	Slow	High	Voltage, Current
9.DC link capacitor droop control	No	No	Both	No	Medium	Low	Voltage
10.Load I V Maximization	No	No	Analog	No	Fast	Low	Voltage, Current
11.*dp/dv* or *dp/di* Feedback Control	No	Yes	Digital	No	Fast	Medium	Voltage, Current
12.Array Reconfiguration	Yes	No	Digital	Yes	Slow	High	Voltage, Current
13.Linear current control	Yes	No	Digital	Yes	Fast	Medium	Irradiance
14.I_{mpp} or V_{mpp} computation	Yes	Yes	Digital	Yes	N/a	Medium	Irradiance, Temp.
15.State based MPP	Yes	Yes	Both	Yes	Fast	High	Voltage, Current
16.OCC MPPT	Yes	No	Both	Yes	Fast	Medium	Current
17.BFV	Yes	No	Both	Yes	N/A	Low	None
18.LRCM	Yes	No	Digital	No	N/A	High	Voltage, Current
19.Slide Control	No	Yes	Digital	No	Fast	Medium	Voltage, Current

Table 5.3 Different MPPT techniques

VI. CONCLUSION

The proposed solution can ensure a stable constant power generation operation. Compared to the traditional methods, the proposed control strategy forces the PV systems to operate at the left side of the maximum power point, and thus it can achieve a stable operation as well as smooth transitions. Experiments can verify the effectiveness of the proposed control solution in terms of reduced overshoots, minimized power losses, and fast dynamics. The PV voltage operating range can be limited and minor changes in the algorithms are necessary to ensure a stable operation. We found that by using ZVT boost converter and HERIC inverter the energy transmission efficiency can be increased up to 98% and 97% respectively.

REFERENCES

[1] T. Stetz, F. Marten, and M. Braun, "Improved low voltage grid integration of photovoltaic systems in Germany," IEEE Trans. Sustain. Energy, vol. 4, no. 2, pp. 534–542, Apr. 2013.

[2] A. Ahmed, L. Ran, S. Moon, and J.-H. Park, “A fast PV power tracking control algorithm with reduced power mode,” IEEE Trans. Energy Conversion, vol. 28, no. 3, pp. 565–575, Sept. 2013.

[3] Y. Yang, H. Wang, F. Blaabjerg, and T. Kerekes, “A hybrid power control concept for PV inverters with reduced thermal loading,” IEEE Trans. Power Electron., vol. 29, no. 12, pp. 6271–6275, Dec. 2014.

[4] German Federal Law: Renewable Energy Sources Act (Gesetz fur denVorrang Erneuerbarer Energien) BGBl, Std., July 2014.

[5] R. G. Wandhare and V. Agarwal, “Precise active and reactive power control of the PV-DGS integrated with weak grid to increase PV penetration,” in Proc. of PVSC, pp. 3150–3155, Jun. 2014.

[6] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, “Overview of control and grid synchronization for distributed power generation systems,” IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1398–1409, Oct. 2006.

[7] T. Esram and P. L. Chapman, “Comparison of photovoltaic array maximum power point tracking techniques,” IEEE Trans. Energy Conversion, vol. 22, no. 2, pp. 439–449, Jun. 2007.

[8] “A Review of Non-Isolated High Step-Up DC/DC Converters in Renewable Energy Applications.” Wuhua Li, Xiaodong Lv, Yan Deng, Jun Liu, Xiangning He

[9] “Interleaved ZVT Boost Converters with Winding-Coupled Inductors and Built-In LC Low Pass Output Filter Suitable for Distributed Fuel Cell Generation System.” Wuhua Li, Yan Deng, Rui Xie, jianjaing Shi, Xiangning He.

[10] "H6 Transformerless Full-Bridge PV Grid-tied Inverters." Li Zhang, *Member, IEEE*, Kai Sun, *Member, IEEE*, Yan Xing, *Member, IEEE* and Mu Xing

[11] "Single Phase Transformer less Grid Connected PV Inverter" Carmaline Joel Anthony, S.Gotekar, S. P. Muley

[12]"Different Type of Inverter Topologies for PV Transformerless Standalone System" Chiragsinh Raj, Mr. Hitesh Lade

[13] "Design of HERIC Configuration Based Grid Connected Single Phase Transformer less Photovoltaic Inverter" Payal Somani, Divyesh J. Vaghel