**Modeling and Simulation of H6 Topology using Single Phase Transformerless Grid Connected Photovoltaic System**

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**ABSTRACT**

This paper proposes a new technology of solar energy system, which is gaining immense fashion ability due to the increase of significance to exploration on indispensable sources of energy over reduction of the conventional reactionary energies each around the world. The systems which are being developed excerpt energy from the sun in the most effective manner and suit them for the available loads without affecting their performance. In this paper, the design and control issues associated with the development of a1.8 kW prototype single- phase grid- connected photovoltaic system of multilevel protruded inverter are bandied. For the system current regulator, a ramp time zero average current error control system algorithm combined with an optimized cyclic switching conception sequence is suggested. Simulation results of Grid tie inverter have been presented to demonstrate the felicity of the total control system. The Simulation results parade bettered performance under the presence of harmonics and the studied system is modeled and dissembled in the MATLAB/ Simulink.

**Keywords−**Maximum power point tracking, Interleaved Flyback converter, H6 topology, SCR ­­­­Bridge.

# I.INTRODUCTION

PV inverter is getting popular due to unattainable centralized maximum power point tracking( MPPT) mismatching issue during partial shading situations( 1- 4). Module integrated motor system is therefore proposed to overcome the issue (5). With each panel is optimized with its own MPP Tracker (MPPT), the resolution is advanced. Therefore the system achieves advanced effectiveness. Similar systems are called as AC Modules integrated motor ( MIC) or inverters. Several inverter topologies are introduced for PV operations. Transformerless bones came up for its small size, but they've issue with the panel’s parasitic capacitor (6). Also a DC- link capacitor is needed in between the inverter and the motor. Incapability to gauge its affair voltage into several times advanced also makes the topologies impracticable to serve in countries with high grid voltage. To overcome the voltage boosting issue, slinging insulated motor to an inverter is proposed (7). It also connects to a low frequency unfolding inverter to flip the opposition making the affair as sinusoidal waveform. This way the DC- link capacitor is reduced to only the one coming to the panel. Also, away from the MPPT, the only control task is on the DC- DC motor to shape its affair as asked. Flyback motor has its dynamic analogous to that of buck boost motor, but it utilizes a motor to give a large voltage step- up rate and galvanic insulation. Due to the actuality of anon-minimum phase (NMP) zero (8) and system dynamic issue (9) in CCM, the topology has rather been designed to operate in DCM. Therefore admixture of operation is suggested for similar systems (10, 11). The control problem for CCM, still, has lately been overcome by using a simple analog regulator (8, 12) for the current regulator. Another system is testing the affair from grid side sludge rather (9), making it possible to control the system using digital regulator. Indeed though the system is designed under CCM operation, it also works veritably well in DCM during grid voltage opposition shifting period (12). These designs deliberately ameliorate the topology effectiveness, but deformations in the affair current are also there (8, 9, 12). This paper offers a topology for interleaved flyback inverter participating two common switches and grid- side sludge with other transformers from different panels. To do so, primary current control scheme is demanded (8).

**II.HIGHER EFFICIENCY FOR BOOST CONVERTER**

##### For these single stage grid connected inverters, either a motor is used for boosting the input voltage or the input voltage will be needed to be advanced than the peak of the grid voltage. But this demand isn't good for PV operations because the solar panel’s characteristics changes all the time. The energy storehouse needs to be at the front of a single stage inverter and it's substantially enforced by electrolytic capacitors. Although the electrolytic capacitors have limited continuance, it can still be used by applying minimal voltage and current ripple to protract its continuance. Because the end of its life does not mean it failed, the electrolytic capacitor can work outside longer than its estimated continuance. As the capacitance also has an impact on Maximum power point tracking (MPPT) effectiveness, the maximum capacitance leads to advanced MPPT effectiveness. Latterly on, a boost- buck motor connected inverter is proposed. This system can operate in either boost or buck mode; therefore, a wide input voltage range or high effectiveness can be achieved. Also the system analysis of its middle capacitor and CCM DCM operation condition is presented. Since the common- mode voltage in the flyback inverter is equal to the grid voltage, it changes at line frequency. Its leakage current is veritably small indeed at an extreme case.

**III.SYSTEM STRUCTURE OF SINGLE STAGE GRID CONNECTED INVERTER**

A single- stage regulator solar inverter system block illustration is shown in Figure 1. It tracks the array of maximum power and labors in AC current supplying the mileage grid (3). The inverter system consists of a solar- array source, bulk input array sludge, capacitor CBULK, line- sludge, DC/ DC motor, 50/ 60Hz switching ground, affair sludge and a system regulator design. The system regulator can be perished into six introductory control sub-systems videlicet( 1) maximum power point shadowing( MPPT),( 2) solar- system array voltage regulation,( 3) motor affair normal-current regulation,( 4) DC/ AC switching ground inverter,( 5) compensated current supplying reference creator and( 6) mileage over-voltage protection.

The applications of solar- array voltage and solar- array current as the feedback signals, the MPPT control sub-system continuously updates the set- point voltage reference. The set- point voltage reference commands the solar- array voltage regulation sub-system (or voltage regulation error amplifier) to produce the error voltage drive signal for regulation of the solar- array voltage, at the corresponding position. Upon reaching a steady state operation, it's controlled to swing back and forth around the peak- power array system voltage with respectable AC ripple voltage of the frequency at doubly as much the mileage frequency.

The signal is sufficiently band- limited to have negligible AC ripple voltage, especially at twice the mileage frequency despite the presence of the motor power stage to deliver duly the affair current of the remedied sinusoidal surge shape. Latterly, the DC/ AC switching ground inverter sub-system provides switching control at the mileage frequency of 50/ 60Hz switching ground that converts into an AC current in synchronization with the AC mileage voltage and system delivers to the mileage grid the in- phase AC current with low total- harmonics deformation(4). When an over-voltage is detected from the remedied mileage voltage, the over-voltage protection sub-system further reduces the error voltage drive signal through an active pull- down transistor Q.

Under this condition, either the absolute normal of regulated voltage at a predetermined position of the power motor is shut down while the absolute normal formerly exceeds the predetermined position (5- 7).

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**Figure 1 Single Stage Maximum Power Tracking Solar Inverter**



Figure 2 Full-Bridge Phase-Shift DC/DC Converter and Full-Bridge Unfolding Circuit

A full- bridge unfolding circuit is connected to the inverter for converting the rectified sinusoid current into sinusoid current, which will be switched in 50/ 60Hz frequency. Without high- frequency switching, the unfolding circuit has much advanced effectiveness than a high- frequency PWM conventional inverter.



Figure 3 Block Diagram of a Solar-Based Inverter System

From Figure 3, the solar- based inverter system will include five separate corridor videlicet full- bridge phase- shift DC/ DC motor, unfolding circuit and exertion board, DSP regulator board and load monitor. The exertion board senses the voltage and current of the solar system array and sends these signals to the DSP regulator board. The DSP regulator will regulate the solar system array working under the maximum power point and drive the full- bridge phase- shift DC/ DC motor and unfolding the circuit to deliver the sinusoid current to the load or utility grid.

**IV.INTERLEAVED ACTIVE CLAMP FLYBACK DESIGN.**

The interleaved flyback motor was named as a single stage topology that can boost the low PV panel voltages (20- 45 V DC) to a remedied AC affair and both sides are handed a galvanic insulation from the PV panel and the grid. Flyback transformers are generally used in low power system and step- down operations. The system lower than a couple outside watts have a grid side low affair current. A forward motor can also step up the PV panel voltage and give galvanic insulation. When comparing the operation of two topologies, the flyback motor requires smaller factors as there's no footloose diode needed on the affair side or the need for an affair inductor; For this purpose only, the interleaved clamp flyback topology is named and also the created system energy is also stored in the setting capacitors. However, the active clamp circuit also provides Zero Voltage drop switching on the flyback MOSFET, which reduces the switching losses and improves the overall effectiveness, If rightly enforced.



Figure 4 Active clamp flyback converter

The DC- AC inverter is a standard single- phase full bridge based on IGBTs with ultrafast co pack diodes, as depicted in Figure 4. The connection to the grid is realized by means of current control performed in DQ rotating reference frame. An LCL filter is placed between the bridge and the grid in order to reduce the current harmonics generated by the unipolar sinusoidal pulse-width modulation (USPWM) at 17 HHz. L filters or LC filters may also be chosen for the operation, but in the first case large values of inductance are needed to perform good high frequency noise damping and large currents through the capacitor may arise in the alternate case together with high voltage harmonics. LCL filters show good performance in terms of current harmonious reduction but they may lead to insecurity of the control circle in the presence of large grid impedance.

**V PROPOSED BUCK-BOOST BASED ON PV INVERTER**

A boost- buck type of circuit dc- dc motor is proposed as the first stage with regulated output inductor current. A full- bridge motor unfolding circuit with 50 or 60 Hz line frequency is applied to the dc- ac stage, which will unfolding clamp the remedied sinusoid current regulated by the dc- ac stage into a pure sinusoidal current, as shown in Figure 5. Since the circuit runs either in boost or buck mode, its first stage can be veritably effective if the low conduction voltage drop switching power MOSFET and ultra-fast rear recovery diode are used. For the alternate stage, due to the unfolding circuit only operates at the no loss line frequency and switches at zero voltage and current, the switching loss can be rejected. The only loss is due to the conduction voltage drop, which can be minimized with the use of low drop power bias, similar as thyristor or slow- speed IGBT. In this interpretation, IGBT is used in the unfolding circuit because it can be fluently turned on and off with gating control. Since only the boost dc- dc motor or buck dc- dc motor operates within a high frequency switching, the effectiveness of proposed system is bettered all the time. In addition, trust ability can be greatly enhanced because there's only one high operating frequency power processing stage in this complete PCS. Also the analysis of middle capacitor and CCM DCM operation condition is also presented. Figure 6. Show the illustration of Buck- boost grounded PV inverter.



Figure 5 Buck-boost operation mode



Figure 6 Buck-boost based PV inverter

**VI BOUNDARY MODE ANALYSIS**

As already discussed, during the buck mode, the input current can be treated as the input filter’s inductor’s current, whose ripple is reduced from the filtering effect. Similarly, during the boost mode, the output current can be treated as output circuit filters and inductor’s current, whose ripple is also much mitigated. Due to this dual filter effect, the DCM mode operates very rarely in the proposed circuit. In fact, the circuit is always running in continuous current mode (CCM) for input current in buck mode and output current in boost mode. This operation also indicates that discontinuous current mode (DCM) or boundary mode can happen only in output current in buck mode and input current in boost mode. Then it can be analyzed as a normal buck and boost converter. The boundary condition can be derived based on the input current ripple for boost mode and output current ripple for buck mode as shown in Figure 7 and 8.

  **Figure 7 Boundary power condition for Input current Figure 8 Boundary power condition for output**

 with different input voltage current with different input voltage

**VII LEAKAGE CURRENT ANALYSIS**

It's inferred that the capacitance between the point of contact and a single PV module always lies in the range between 100 – 400 pF. The capacitance value depends on rainfall conditions, and in the worst case as stormy days, the capacitance can be as high as 80 nF KW. Because of no insulation between the input and output without a motor, the transformerless grid tied inverter needs to consider the leakage current issue as shown in Figure. 9.



Figure 9 Leakage current in grid tied inverter system

Because of this safety issue, the leakage current should be as small as possible for transformerless inverter. Numerous literatures anatomized the leakage current in transformerless grid- connected inverter. For the proposed topology, the negative outstation of solar modules is set as the reference point, and the middle points of the bridge legs are set as phase and neutral for the affair outstations. Since grid voltage isn't constant but sinusoidal with 60 Hz, there's a small line frequency leakage current in the proposed inverter. For a2.5 kW system, the capacitance between the PV modules and the ground CPV would as grandly as 200 nF.

**VIII CONTROL OF THE BOOST –BUCK MODE PV INVERTER**

During buck mode, inductor current can be treated as normal buck motor’s affair inductor current which can be fluently controlled. still, it's critical to control inductor current in boost mode because the control target in this mode is affair circuit pollutants ’ inductor current. therefore, the compensator for boost mode needs to be designed first and also applied it to buck mode. In practice, if the boost mode is stable and well controlled, buck mode will be stable and well controlled. The circle earnings of boost mode at different operating points are shown in numbers 10 and 11. It easily shows that the RHP zero and double pole make 2700 phase detention, which makes it delicate to be compensated. therefore, the compensated crossover frequence needs to be before double- pole’s frequence of the boost mode and assured that the peak Q value is lower than 0 dB. In order to have a compensator that's good for every operation point, the compensator design is system grounded on the worst conditions, which is defined as a condition with loftiest Qpk and the foremost phase drop. In our case, worst condition happens when input voltage is the smallest defined value 200 V and output voltage is the peak voltage of the grid 340V.



Figure 10 Analog control for smooth



Figure 11 Digital control for smooth

In order to achieve smooth waveform in transition between boost to buck modes, an offset of the saw tooth carrier right on the top of the buck mode PWM modulator needs to be applied to boost mode as shown in Figure 12.



Figure 12 Block diagram of the buck boost single phase voltage source inverter

The maximum power point tracking power can be implemented as an outer loop with lower bandwidth control, providing the magnitude of the output current reference for smooth transition between buck and boost modes respectively.

## **Grid-Tie Converter Controller**

To transfer the energy to the grid, the ensuing regulator algorithm must be realized in this system

1. Phase- locked loop( PLL) regulator sense is used to attend with the grid voltage, which can give a reference system phase to the current regulator.

2. Grid- tie current regulator can insure the affair current is a sine surge signal and trace the current reference to balance the input power and the affair power.

3. Maximum power point tracking( MPPT) is used to track the panel into a maximum power affair stage.

4. The phase error discovery descry the phase error between the reference and the sine surge out. This discovery is done in 1ms task A0. The PLL regulator and the unrestricted circle regulator operations are executed in 1ms task A0. The Sine creator systems induce the sine surge according to the frequence and sample time which is done in the ISR. The equation( 1) and( 2) represent cargo sharing transfer function as

*Ipv1(s) = Gd, ipv1(s) Xd(s)*  (1)

*Ipv2(s) = Gd, ipv2(s) Xd(s)* (2)

Let the error between the currents be equal to ΔI.

The equation (3) represents a load sharing current error as

*Ipv1(s) = Ipv2(s) = ΔI = (Gd, ipv1(s) – Gd, ipv2(s)) X d(s)* (3)

The objective is to make both the currents the same (i.e. make *Ipv1* as *Ipv1(s) – ΔI/2* and *Ipv2* as *Ipv2(s) + Δ I/2*) by including correction factors of *±Δd.*

The equations (4) and (5) of load sharing the correction factor are

*Ipv1(s)-ΔI/2 = Gd, ipv1(s) X (d(s) - Δd(s))* (4)

*Ipv2(s) + ΔI/2 = Gd,ipv2(s) X (d(s) + Δd(s))* (5)

The equation (6) of a load sharing current,

*ΔI = (Gd, ipv2-Gd, ipv1) d(s) + (Gd, ipv2+Gd ipv1) Δd(s)* (6)

Assuming *Gdipv2 ≈ Gdipv1 ≈Gdipv*

*ΔI(s) = 2Gdipv(s) Δd(s)*



Figure 13 current control loop

Using the system of PI regulator, the regulator operating frequency is 22 KHz. The open circle bandwidth must be set to 1 to 2 KHz. Figure 13 indicates that the feedback of the unrestricted circle must be the primary side current ip, but in the real system it's the wind middle point current when Q1 is turned on in the real system. However, the relationship between the system of primary feedback and the secondary average current is to get a sine surge affair current, If the motor is working in a nonstop mode. The secondary average current must be a sine surge signal. Thus, it's necessary to modify the affair feedback current to the following model in figure 14.



 Figure 14 modified current loop

**IX SIMULATION MODEL AND RESULTS**

1. **GRID AND PLL SIMULATION**

The PLL is integral to the operation of the inverter in that DC/ AC conversion is managed in coincidence with the AC line. All state operation is accompanied to the line. All inversion- related control operations are accompanied to the line. The only item that isn't directly accompanied to the line (although it could be) is the ripple cancellation control algorithm. The PLL is operated slightly else than that of other PLLs for this design. Simulation model of proposed System and Interleaved Flyback Inductor Simulation Sytem are shown in figures 15 and figure 16.



**Figure 15. Simulation model of proposed System**



**Figure 16. Interleaved Flyback Inductor Simulation Sytem**

A line cycle is divided into 1024 slices, or 512 slices per half- sine and the number of slices doesn't change. Still, the distance between each slice is allowed to change. One crucial advantage is that the sine reference information is always the same. Figure 17 and 18 represents Average flyback input currents and Current error.



Figure 17 Average flyback input currents



Figure 18 Current error

The load sharing local load and grid to control circle constantly monitors the error between the input currents of the transformers and will minimize this error. It also stoutly adjusts the duty rate of each of the transformers by the addition/ deduction of a small common correction factor value depending on the sign of the error.

A combined feed- forward and feedback system can ameliorate the system performance of the control system to a large extent, whenever there's a major measurable disturbance. In an ideal situation, gain of the feed-forward compensator will fully reject the measured disturbance signal better than the compensator acting alone. The main part of the feed-forward compensator in the solar inverter system is to give the steady state duty rate D( t), to the sharing system, thereby allowing the compensated value to the error system. The feed-forward network will help the compensator to reject the disturbances caused by oscillations in both the solar panel input voltage and the affair voltage of the grid. The cargo resistance has been included in the term, Rf, coming bone for a sludge inductor and DCR is in series to the cargo resistance in the AC-original circuit. From the open- circle forebode plot, it can be observed that both gain periphery and phase periphery of the system are low and therefore, the system innately has a poor relative stability. Also, it's substantially observed that the switching frequency ripples attenuation needs enhancement and that the system gain at the needed system operating frequency (100/120 Hz) is veritably low. Grid current and current reference and Grid voltage are shown in numbers 19 and 20.



Figure 19 Grid current and current reference



Figure 20 Grid voltage



 Figure 21 Ripple control result



 Figure 22 DC/AC controlled output current

Thus, the MPPT circle and the current control circle appears as a concinnity gain system with zero or minimum phase error. The current circle modulates the motor current into a remedied signal as a sine surge affair. Ripple control result and DC/ AC controlled affair current are shown in numbers 21 and 22. The MOSFET full- ground unfolds this remedied current into an interspersing current to be delivered to the grid. The current circle bandwidth can be bettered through the use of a gain feed forward compensator. The steady- state duty cycle can be stoutly reckoned using the measured PV panel voltage and AC grid voltage. While the feed-forward compensator supplies the steady- state modulation, the current control circle takes into account dynamic variations and modulates the controlled current consequently. The ensuing sections bandy the transfer function computation and fine modeling of the solar inverter system to gain the transfer functions of affair to control input and control affair to disturbance inputs of the system.

**X. CONCLUSION**

A new system control approach for a solar- grounded inverter that tracks the outside available power and produces a near concinnity power factor is presented. It's inferred that the new approach produces excellent signal- to- noise rate for the feedback signals, icing dependable and robust Maximum power point tracking (MPPT) while tightly regulating the sinusoidal waveform of AC current supplied to the mileage grid with the concinnity power factor. While employing a feed-forward compensation fashion coupled with one stage of the DC/ DC power conversion, the proposed inverter system is simplified when compared to conventional inverter deigns. This discussion suggested a single stage boost- buck motor grounded high effectiveness grid- tied PV inverter. Grounded on its unique operation mode, the proper control system is proposed for smooth mode transition. Grounded on the analogous conception, three other inverters with both step- up and step-down functions are proposed. In addition, three advanced control styles are also proposed. Grounded on the operation mode conception, numerous topologies can be proposed. However, it can be integrated with boost part, If any inverter is working grounded on buck motor’s conception. As a result, the new inverter wo n’t have the limitation on its input voltage, which means the input voltage does n’t need to be advanced than the peak of the affair ac voltage. In this way, the input voltage range could be widened and the topology has lower switching losses and ameliorate the overall system effectiveness. High effectiveness is achieved by enforcing a new interleaved active- clamp flyback topology with to Zero Voltage Switching ( ZVS).

Therefore, the MPPT loop and the current control loop appears as a unity gain system with zero or minimal phase error. The current loop modulates the converter current into a rectified signal as a sine wave output. Ripple control result and DC/AC controlled output current are shown in figures 21 and 22.The MOSFET full-bridge unfolds this rectified current into an alternating current to be delivered to the grid. The current loop bandwidth can be improved through the use of a gain feed forward compensator. The steady-state duty cycle can be dynamically computed using the measured PV panel voltage and AC grid voltage. While the feed-forward compensator supplies the steady-state modulation, the current control loop takes into account dynamic variations and modulates the controlled current accordingly. The following sections discuss the transfer function calculation and mathematical modeling of the solar inverter system to obtain the transfer functions of output to control input and control output to disturbance inputs of the system.

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