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A Low Cost Transformerless Inverter with Closed Loop PI Controller for Grid-connected PV Power Systems

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Abstract:

Now-a-days, PV power systems became one of the best alternate for energy supply both commercial and domestic sectors. Transformerless inverters are significantly gaining importance in the small scale installation of PV panels where there is no need of transformers in the event of power distribution. But when a transformerless inverter is installed to a PV source common mode leakage current creeps in to the system due to the parasitic capacitance between PV panel and the ground. Hence, these leakage current should be eliminated since the system performance is deteriorated. Thus atopology can be developed using closed loop PI controller based pulse width modulation (PWM) so that the ripples in the output current will be decreased. Consequently, a small filter inductor is used to decrease the size and the magnetic losses in the inverter.The implementation in SIMULINK represents the system with very less harmonic distortion and high power factor.

I.INTRODUCTION:

Now-a-days, the need for the PV power systems increasing due to increase in the power demand. No single power system is enough to satisfy the present day demand for the reliable power supply. Hence, PV power systems are gaining their demand in most of the commercial and residential sectors [1]-[3]. Generally, inverters play a major role in feeding PV power into the utility grid. The efficiency of the inverter can be increased with reduction in the leakage current and hence system performance improves. Generally, PV systems are used as the main source of energy for the generation of power using transformerless inverters to maintain high efficiency and reduced size and cost. In olden days, grid-tie inverters used either a line frequency or a high frequency transformer for galvanic isolation.

This isolation transformer if removed helps in increasing the efficiency and also the size and cost of the entire system can also be decreased [4]. However, in the absence of transformer, the common mode ground leakage current creeps into the circuit and will have serious effects on the reduction of efficiency in power conversion, increased distortion in grid current, the electric magnetic compatibility is deteriorated, and more significantly, safety threats rises [5].

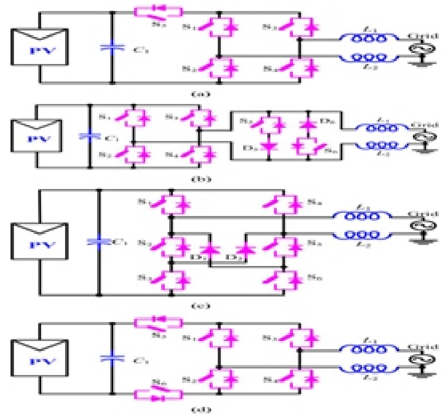

Fig. 1 Transformerless full bridge based inverter methods .
(a) H5 inverter circuit
(b) HERIC inverter circuit
(c) H6 inverter circuit with ac bypass
(d) H6 inverter circuit with dc bypass

For realization of this goal in a simple way is to use the bipolar sinusoidal pulse width modulation (SPWM) for full bridge inverter, in that CM voltage is equal to that of the voltage at half of the dc bus. [6] The double frequency SPWM yields better results when compared with the bipolar SPWM considering switching losses and ripples of the output current. But it should not be used directly in the application of transformerless inverters because of the generation of switching frequency CM voltage.

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Therefore, some advanced methodologies referring to full-bridge inverter considering HERIC inverter or H5 inverter [7][8] and so on are developed, to maintain CM voltage constant even the double frequency modulation is used. There are some topologies represented in Fig.1 based on full bridge inverter. If additional switches are introduced both on ac or dc sides of the full-bridge inverter, the dc bus gets isolated from grid when zero voltage level of the inverter output voltage. Thus, the CM current path is remove.The common mode leakage current can be effectively decreased using closed loop PI controller based PWM technique.

Thus, the harmonic distortion of the system can be decreased. Using switched capacitor technology the current stress on the inverter switches decreases and thereby long life of the system can be expected. [9][10] The systematic arrangementis discussed as follows. In Segment II, closed loop PI controller is explained. Proposed method and respective modulation strategy along with the operational principles are discussed in section III. The simulation model and its results are represented in segment IV and V respectively. The conclusion in the final segment.

II.CLOSED LOOP PI CONTROLLER:

It is a kind of linear feedback control system.Similar to P-Only controller, the Proportional-Integral (PI) algorithm calculates and conveys a controller output (CO) signal for each and every point of sample time, T, to the last control element (e.g., valve, variable speed pump). The computed CO from the PI algorithm is varied by the controller tuning parameters and the controller error, e (t). [11] The block diagram representation of PI controller is as follows.

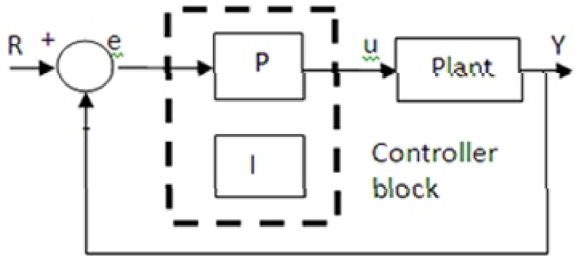

Fig. 2: Proportional Integral (PI) Controller block diagram

The proportional and integral terms is given by:

$$u(t) = K_p e(t) + K_i \int e(t)dt$$

Where,Kp ¬andKi are the tuning knobs, are adjusted to get the necessary output.A DC motor dynamics equations are characterised with second order transfer function,

$$G(s) = \frac{\dot{\theta}}{V} = \frac{K_t}{(Js+b)(Ls+R) - K_e K_t}$$

Where

K_t = K_e = electromotive force constant = 0.01Nm/Amp

b = damping ratio of the mechanical system = 0.1Nms

J = moment of inertia of the rotor = 0.02kgm^{2}s^{-2}

R = electric resistance = 1Ω

L = electric inductance = 0.5H

After we include the PI controller, the closed-loop transfers function become:

$$G_P(s) = \frac{Y}{R} = \frac{K_t K_p}{(Js+b)(Ls+R) - K_e K_t - K}$$

• PI controllers are adjusted using two types of tuning parameters. Though this makes them more challenging to tune than a P-Only controller, they are not as difficult as the three parameter PID controller.

• Integral action allows PI controllers to remove offset, a major drawback of a P-only controller. Therefore, PI controllers offer a balance of complication and capability that makes them definitely the most extensively used algorithm in process control applications. [12]

III. PROPOSED MODEL AND MODULATION TECHNIQUE:

Fig.3 shows the advantages of the proposed methodology for a new inverter topology which is based on closed loop PI controller.

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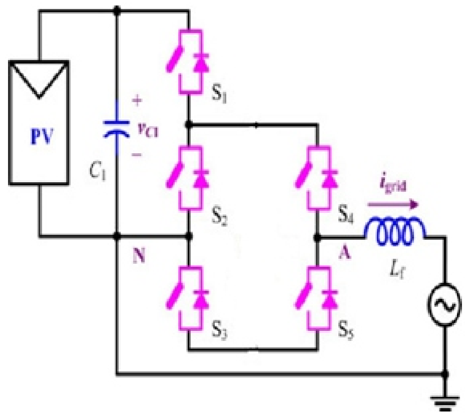

Fig. 3 Proposed topology.

A.PULSE WIDTH MODULATION (PWM) TECHNIQUE:

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a technique used to encrypt a message into a pulsing signal. In addition, PWM is one of the two principal algorithms utilized in photovoltaic solar battery chargers the other being MPPT.

The typical value involving voltage (and current) fed towards load will be managed by simply switching this switch between supply as well as load on and off quickly. The longer this switch will be with when compared to off of cycles, the more higher the whole electrical power delivered towards load.

This PWM switching frequency has to be more achievable than exactly what would have an effect on the load (the system of which utilizes the power), which is to state that the resultant waveform identified by the load should be as smooth as possible.

Usually switching has to be done many times a minute within the stove, 120 Hz within a light fixture dimmer, by couple of kilohertz (kHz) to be able to tens regarding kHz for any motor generate along with well in to the tens or countless kHz throughout music amplifiers along with computer electric power materials.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

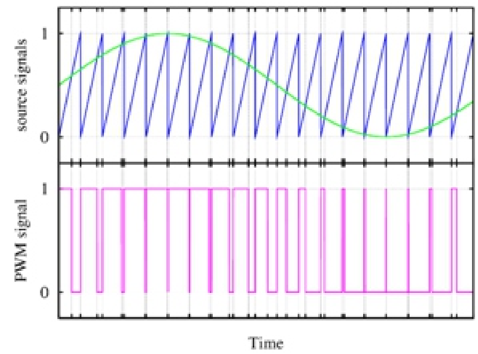

Fig. 4. Pulse Width Modulation

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM in addition has already been utilised in specific communication techniques wherever its duty cycles have been employed to share information over the communication channel.

IV.SIMULATION MODEL:

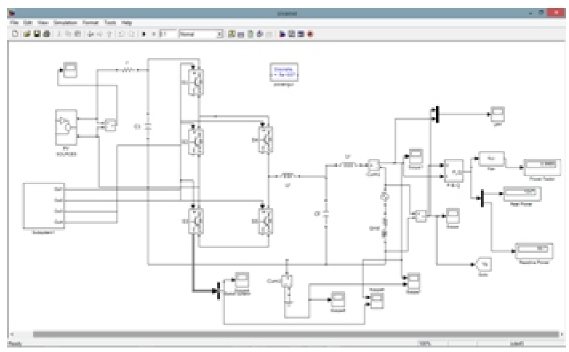

Fig. 5. Simulation model

V.SIMULATION RESULTS:

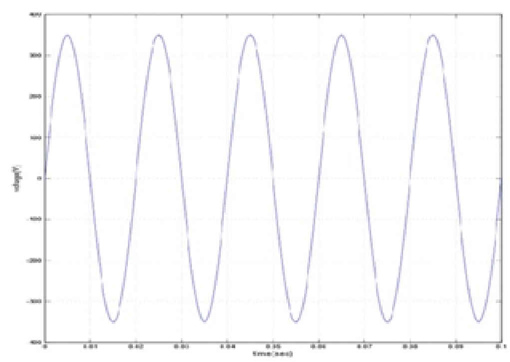

Fig.6. Output voltage waveform

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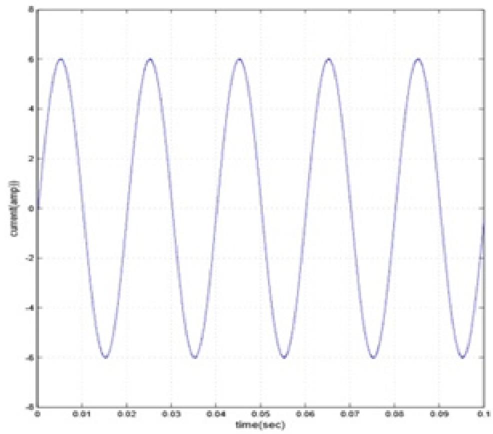

Fig.7. Output current waveform

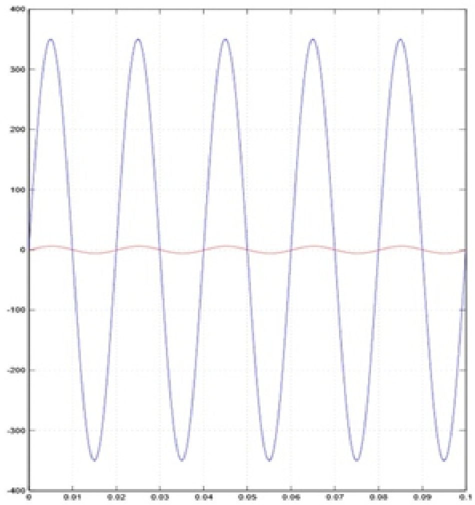

Fig. 8. Output power factor

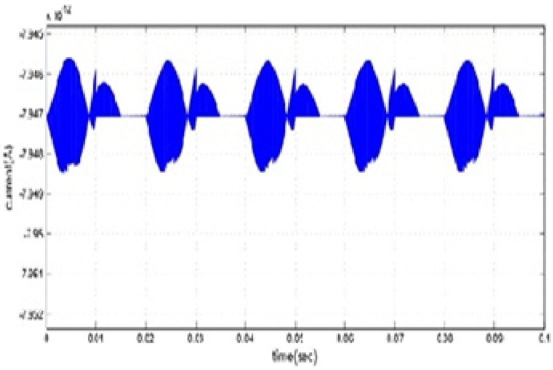

Fig. 9. Leakage current

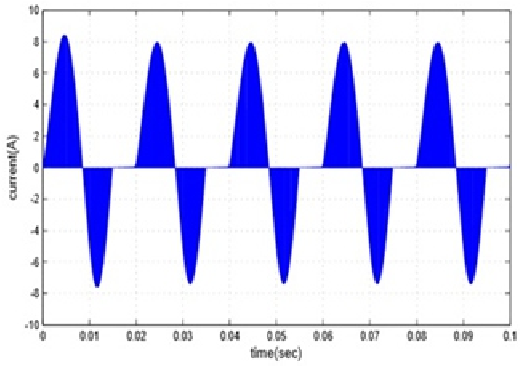

Fig.10. Switching current

VI.CONCLUSIONS:

The closed loop PI controller is introduced to suppress the common mode leakage current for the grid tied transformerless inverter. The precise outputs are obtained through this controller and harmonics are also reduced considerably. The system efficiency is improved through continuous sampling of error signals controlled by the PI controller.

The proposed topology is best suitable where there is a problem of ripples in output waveforms and effecting the grid parameters. Limited number of switches are employed so that current stress on power switches is reduced. Since, the promising performance in the elimination of leakage current, this concept of closed loop PI controller provides a hopeful solution for the grid connected transformerless inverters.

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