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PID Controlled Non Isolated High Step Up DC-DC Boost Converter Adopting Switched Capacitor Cell for Grid Connected PV Applications

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[1]

***Abstract*—:In a photovoltaic (PV) power system, a high step-up DC–DC converter is required to boost the low voltage of PV to a relatively high bus voltage for the DC–AC grid connected inverter. The Switched-Capacitor (SC) converter can obtain a high voltage gain, but the input current is pulsating. In the case of a non-isolated switching-mode DC-DC converter the output regulation is excellent, but the voltage gain cannot be too high for achieving high efficiency. This topology integrates the advantages of a Switched Capacitor (SC) converter and switching mode DC-DC converter. A method of combining the two types of converters is proposed in this paper.PID controllers are used to regulate the output voltage.**

***Index Terms*—**:Closed loop control ,Non isolated high step up DC DC converter, PID controller, Switched capacitor converter, Switched mode converter.

I. Introduction

The interest in using renewable energies has grown significantly in the last years. Photovoltaic (PV) cells are the leading renewable energy technology. Due to the high voltage boost required to interface the low output voltage of the PV module to the grid, the use of boost converters is widespread.

Renewable energy systems generate low voltage output, and thus, high step-up dc/dc converters have been widely employed in many renewable energy applications such fuel cells, wind power generation, and photovoltaic (PV) systems. Such systems transform energy from renewable sources into electrical energy and convert low voltage into high voltage via a step-up converter, which can convert energy into electricity using a grid-by-grid inverter or dc microgrid.

Some existing isolated converters, such as the phase-shifted full-bridge converters, can achieve a high-step-up gain by increasing the turn's ratio of the transformer. Unfortunately, the input current is pulsed, which greatly impacts on the life of the PV array. Moreover, more input electrolytic capacitors are required to suppress the large input current ripple. Furthermore, the output-diode voltage stress is much higher than the output voltage, which limits circuit efficiency in the high-output-voltage applications Moreover, the cost is increased because many power components isolated sensors and feedback controllers are required.

The boost converters based on the switched-capacitor (SC) circuits can provide high step-up ratios depending on the number of capacitors used in the SC cell. The SC converters only consist of capacitors, MOSFET's, and diodes and they do not require any inductive element, so this will have minimal radiated EMI. The main disadvantages of the SC topology are the input current is pulsating, the voltage regulation capability is poor and difficult in the presence of wide load variations and the dc voltage conversion ratio is usually predetermined by the circuit structure [3]

Non-isolated DC–DC converters can provide high step-up voltage gain, but with the penalty of high voltage and current stress, high duty-cycle operation. There are some non-isolated dc–dc converters operating with high static gain, as the quadratic boost converter, but additional inductors and filter capacitors must be used and the switch voltage is high [2]

Cascading of boost converters is one of the easy approaches to achieve a high step up gain, but it requires a lots of components and a final output stage still suffers from a high voltage stress. As the number of stages increases, cost will be high and efficiency will be poor.

II Circuit Diagram and OPERATING principle

The proposed topology is a combination of SC converter and the switching-mode DC-DC converter.[1] The basic approach is introducing multiple capacitors into the switching-mode DC DC converters. When the switch is off, the energy released from the inductor is used to charge the capacitors in parallel. When the switch is on, the capacitors are connected in series to supply the load. Thus, the voltage gain is increased, and the duty cycle is decreased, leading to small ripple current and turn off current of the switch, and high efficiency can be expected. Meanwhile, the voltages of the capacitors are well regulated, thus achieving a tightly regulated output voltage. This topology can be termed as non-isolated high step up dc dc converter with single inductor energy storage cell based switched capacitor. By combining both switched mode boost converters and switched capacitor cell, a new step up dc dc converter adopting switched capacitor cell is derived. This converter integrates the advantages of the high voltage gain of a Switched-Capacitor (SC) and excellent output regulation of a switching-mode dc dc converter.

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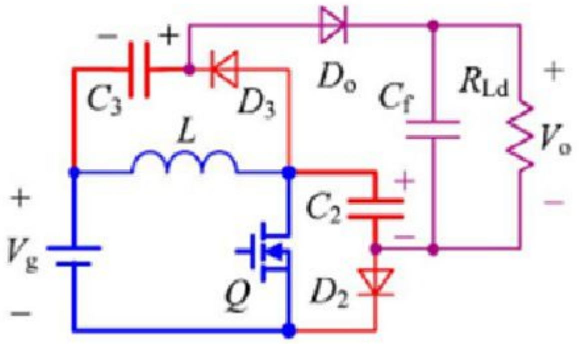

Fig.1 Non Isolated High Step Up DC DC Converter

The Fig.1 shows the circuit diagram of a high step up DC DC converter adopting switched capacitor cell,C_2 and C_3 are the switched capacitors,C_f is the output capacitor is the boost inductor, Vg input voltage, R_{Ld} is the load resistance. Do is the output diode.

MODES OF OPERATION

Mode 1, when Q is turned on, the input voltage source charges the inductor. Meanwhile, C2 is in series with the voltage source and C3, to supply the load through Q.During this mode diodes D_3 and D_2 are reverse biased .Direction of inductor current and load currents are shown in the fig 2. Mode II ,When Q is turned off, the inductor charges C_2 and C_3 simultaneously, and the load is powered by Cf

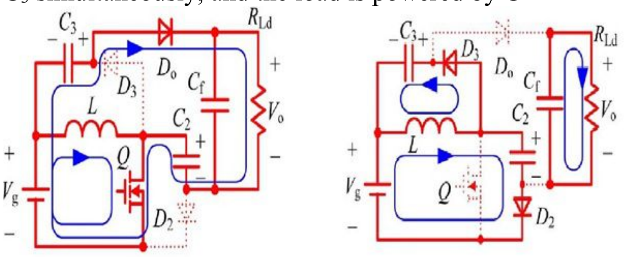

Fig.2 Modes Of operation

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DESIGN SPECIFICATION

Symbol	Parameter	Value
V_g	Input Voltage	20V-45 V
V_o	Output Voltage	380V
C_2,C_3	Switched capacitors	0:86µF
C_f	Output capacitor	220µF
L	Boost inductance	430µH
fs	Switching frequency	100KHz

Table.I Design Specification

III PID CONTROLLER

PID(Proportional, Integral, Derivative) Controllers are designed to eliminate the need for continuous operator attention. This Controller automatically adjusts some variable to hold the measurement at the set-point. Error is the difference between set-point and measurement. Adjusted variable is called the manipulated variable which usually is equal to the output of the controller. The output of PID controllers will change in response to a change in measurement or set-point. With proportional band, the controller output is proportional to the error or a change in measurement (depending on the controller).If deviation from set-point is present, increasing the controller gain will make the loop go unstable. Integral action is included in controllers to eliminate this offset. With integral action, the controller output is proportional to the amount of time the error is present. Integral action eliminates offset. With derivative action, the controller output is proportional to the rate of change of the measurement or error. The controller output is calculated by the rate of change of the measurement with time.

Consider a unity feedback system

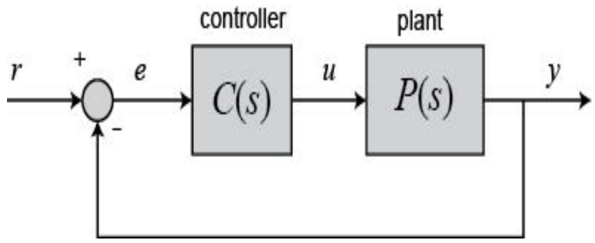

Fig.3 Unity feedback System

The output of a PID controller, equal to the control input to the plant, in the time-domain is

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_p \frac{de}{dt} \quad (1)$$

Variable (e) represents the difference between the desired input value (r) and the actual output (y). This error signal (e) will be sent to the PID controller, and the controller computes both the derivative and the integral of this error signal. The control signal (u) to the plant is equal to the proportional gain (K_p) times the magnitude of the error plus the integral gain (K_i) times the integral of the error plus the derivative gain (K_d) times the derivative of the error.

This control signal (u) is sent to the plant, and the new output (y) is obtained. The new output (y) is then fed back and compared to the reference to find the new error signal (e). The controller takes this new error signal and computes its derivative and its integral .

The transfer function of a PID controller is found by taking the Laplace transform

$$K_p + \frac{K_i}{s} + K_d s = \frac{K_d s^2 + K_p s + K_i}{s} \quad (2)$$

K_p = Proportional gain K_i = Integral gain K_d = Derivative gain

A proportional controller (K_p) will have the effect of reducing the rise time and will reduce but never eliminate the steady-state error. An integral control (K_i) will have the effect of eliminating the steady-state error for a constant or step input, but it may make the transient response slower. A derivative control (K_d) will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response.

The effects of each of controller parameters, K_p, K_d, and K_i on a closed-loop system are summarized in the table below.

RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	Steady State ERROR
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	No Change

Table II Effect of Each Controller Parameter

IV SIMULATION RESULTS

Fig 4 shows the simulation diagram of non-isolated high step up DC DC converter adopting switched capacitor cell. PID controller is used for the pulse generation of switch. Output voltage is compared with the desired DC bus voltage of 380 V.Simulation results shows that the output voltage is desired 380 V with reduced ripple as shown in Fig 5.Output voltage has an overshoot of 450V.Fig 6 is the inductor current Fig 7 and 8 are voltage and currrent across diode D_3 .

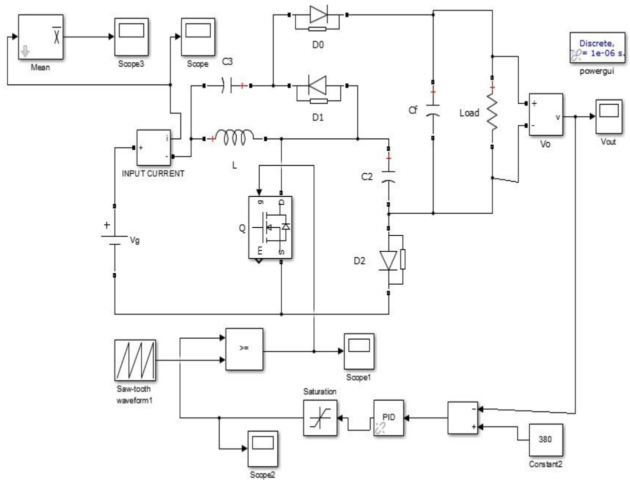

Fig 4 Non isolated high step up DC DC Converter adopting switched capacitor cell

SIMULATION WAVEFORMS

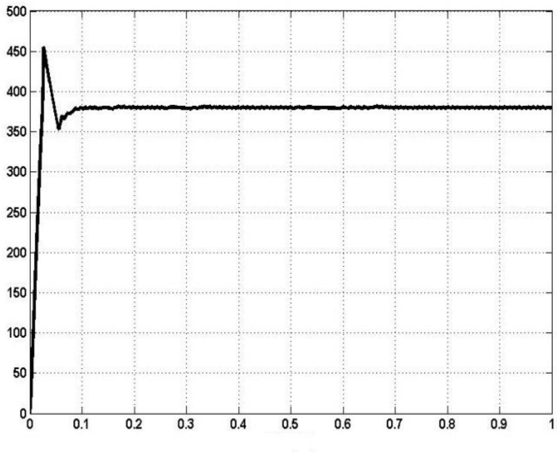

Fig 5 Output voltage of non isolated DC DC converter adopting switched capacitor cell

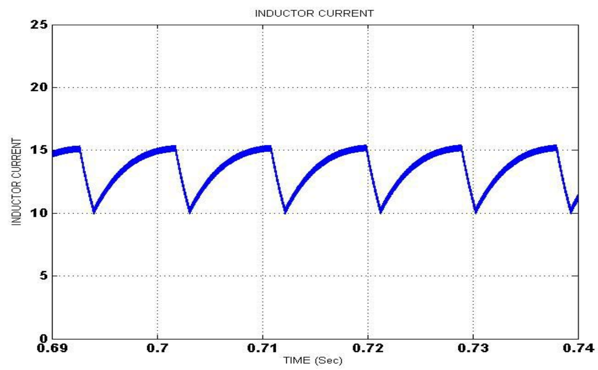

Fig.6 Inductor Current

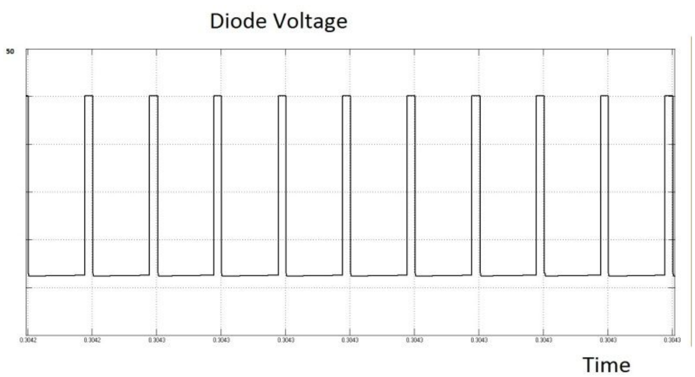

Fig.7 Diode Voltage

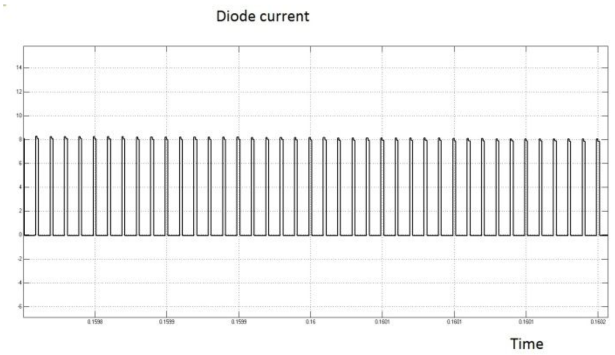

Fig 8 Diode Current

I. CONCLUSION

Merits of the SC converter and the switching-mode dc–dc converter are combined in this topology. In this converter a part of the energy is directly transferred to the load from the input source, Therefore the efficiency of the converter is higher than the conventional boost converter .The capacitor voltages are controlled by a pulse width modulation technique; when the switch is turned on, the capacitors are in series to supply the load. Thus, the voltage gain of the dc–dc converter is increased. The converter is able to attain the desired output voltage with minimum ripple using PID controllers. The results indicate that the converters proposed in this paper can steadily operate and that the performance is good.

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