Integrated Multi-Port Converter For Off-Grid Photovoltaic System

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Abstract. The multi-port converter proposed in this work is used for the integration of many converters in a single system. The system is the solar dc-dc standalone converter with the battery storage. The proposed integrated multiport converter consists of three separate converters they are, bidirectional PWM converter, switched capacitor converter, series resonant converter. The numbers of switches are reduced and thus the loss in the power electronics circuit is also reduced. A 300 watts prototype model of the system is implemented and the hardware results obtained is discussed and the same system is simulated using matlab software and the results are matched.

Keywords: multi-port; PV standalone; PWM converter; reduced switching; PID controller.

1. Introduction

Recently, control gadgets examine has concentrated on usage of sustainable power sources to supplant petroleum product, on account of its harmful natural impacts (Debnath et al., 2015). Because of the ecological issue, e.g., environmental change, and political and monetary reasons, e.g., less reliance on the remote vitality import, high oil cost, sustainable power source has pulled in colossal consideration. As extraordinary development in sustainable power source has been made, the cost for power delivered with sustainable power source drops. The national normal power levy cost is around 5 rupees for every kWh. The cost for particular sorts of sustainable power source is lower than 5 rupees for each kWh. As the expense of ordinary vitality assets is expanding each year, the retreating pattern in the expense of sustainable innovations is empowering, making sustainable power source an efficient methods for control age sooner rather than later. Sustainable power source advances not exclusively can tackle the environmental change and decrease the reliance on remote vitality import, it is likewise appropriate for dispersed power age. In remote territories, where there are no transmission lines or the expense of building new transmission lines is high, sustainable power source can give control without costly and muddled framework foundation. Multi-port segregated converter topologies positively affect utilizing different sustainable power sources, and can accomplish higher
power and voltages with improved productivity because of develop medium power semiconductor innovation, they are starting to stand out for control hardware(Su.G et al., 2008) Switched capacitor converters are minimal effort and smaller and are fit for accomplishing efficiencies more prominent than 90%. Clearly, the present yield is restricted by the current conveying limit of the switches and the size of the capacitors. Switched capacitor voltage converters don’t keep up high productivity for a wide scope of proportions of contribution to yield voltages, not at all like their exchanging controller partners. Since the contribution to yield current proportion is scaled by the essential voltage transformation paying little mind to whether guideline is utilized to lessen the multiplied or reversed voltage, any yield voltage size under 2VIN for a doubler or not exactly |VIN| for an inverter will bring about extra power dispersal inside the converter, and productivity will be debased relatively.

Bidirectional PWM converter has increased voltage transformation proportion and programmed current adjusting capacity for single-cell battery control frameworks. By adding just two capacitors to the ordinary interleaved three-stage PWM converter the voltage transformation proportion at a given obligation cycle is significantly increased, henceforth counteracting extraordinary obligation cycle activities. Inductor flows can be naturally adjusted gratitude to the additional capacitors, and no present sensor is essential for inductor current adjusting. Moreover, the additional capacitors lessen voltage worries of switches and charged-released energies of inductors, adding to effective power transformation and diminished circuit volume.

The series-resonant converter (SRC) are utilized to infer shut structure answers for the yield qualities and enduring state control attributes, to decide working mode limits, and to discover top segment stresses. There are two ways: Zero current exchanging and Zero voltage exchanging. Turn-on or turn-off changes of semiconductor gadgets can happen at zero intersections of tank voltage or current waveforms, along these lines lessening or killing a portion of the exchanging misfortune instruments. Thus converters can work at higher frequencies than PWM converters. Zero-voltage exchanging likewise lessens converter-created EMI Zero-current exchanging can be utilized to commutate SCRs. In particular applications, thunderous systems might be unavoidable. High voltage converters: critical transformer spillage inductance and winding capacitance prompts resounding system.

2. Block Description
The block diagram of switched converter multi-port system switched capacitor multi-port converter is the integration of three separate converters into single converter (Sun.X et ., 2015).the three converters are Series resonant converter it consist of two switches S1, S2. bidirectional PWM converter S3,S4.finally Switched capacitor converter it have S1,S2,S3,and S4 switches, by using these four switches the three converter are combined in a single MPC.
2.1. Switched Capacitor Converter Based Multiport Converter Major Benefits

In examination with the traditional PV framework, the framework is drastically streamlined by incorporating 3 converters into a 1 unit. Moreover, the complete switch tally can likewise be decreased, subsequently accomplishing the circuit rearrangements; the proposed Multi-port requires four mosfet switches altogether, though the all-out mosfet switch tally is the traditional framework is ten. Notwithstanding the framework and circuit-level rearrangements, scaled down plan is additionally achievable gratitude to the Switched capacitor converter. The proposed Multi-port is fundamentally a crossover Switched capacitor converter that can extraordinarily cut back inductors, as announced.

2.2. PWM- Pulse Width Modulation

Pulse width modulation (PWM) is a strategy, which the exchanged voltages are created for various frequencies and voltages. PWM gives an approach to diminish the All-out Symphonies Twisting (THD) of burden current. The THD necessity can be met when the yield of a PWM inverter is sifted since the unfiltered yield of a PWM based reversed will have a moderately high contortion. There are numerous PWM plans, the most mainstream ones being sinusoidal PWM (SPWM). It very well may be actualized utilizing simple systems, the remaining PWM require the utilization of a chip. The PWM innovation redresses the yield voltage as indicated by the changing the Width of the exchanging recurrence in the oscillator side.

2.3. Circuit of the System with Mosfet

This MPC presents a recently structured, non-segregated single-input double yield 3 level of dc-de converter. With a support of control procedure, the converter profits by the 3 levels and multiport system. Inferable from its 3 level structure, the given converter has the upsides of decreased voltage weight on diodes and switches, improved effectiveness and diminished aloof parts size.
3. Principle Operation
There are three modes of operation in this multi-port converter each operation are used with different types of switches. The red line in figure 2,3 and 4 denotes the active switching elements in the converter. This converter consists of four mosfet switches S1, S2, S3 and S4.

3.1. Mode 1
In mode 1, the mosfet switches S1 and S3 turns on and the current passes through the capacitor C2 to the S2 switch, from the switch S2 to the capacitor C3, from the capacitor C3 to the switch S4. Voltages at the Vx and Vw, are in their elevated state. Capacitors are associated in parallel in the switched capacitor converter charge and release one another so their voltages are brought together and the current flow in SRC.

Mode 1: (0.5 < d2 & d1 < 1) & (d1 > d2).

3.2. Mode 2
In mode 2, the MOSFET switches S4 and S2 turns on and the current passes through the capacitor C2 to the S2 switch, from the switch S2 to the capacitor C3, from the capacitor C3 to the switch S4. Voltages at the Vx and Vw, are at their elevated level. Meanwhile, there is no current flow in SRC.

Mode 2: (0.5 < d2 & d1 < 1) & (d1 < d2).

3.3. Mode 3
In Mode 3, the multi-port converter is similar to mode 2 operation here the current iLr1 and iLr2 become zero. The SRC is inactive in this mode.

Mode 3: (d2+0.5 < d1 < 1) & (0 < d2 < 0.5).

![Figure 2. mode 1](image1.png)  ![Figure 3. mode 2](image2.png)
From Table I and the switching sequences S1, S2, S3 and S4 are given, the output voltages conversion ratio can be gained for mode 1 as follows:

For the L1 inductor,

\[ \text{Vin} \{d2-0.5\} + \{\text{Vin-Vo1/2}\}(d1-d2)+\{\text{Vin-Vo1}\}(1-d1)=0 \]

Hence,

\[ \frac{\text{Vo1}}{\text{Vin}}=\frac{1}{2-d1-d2} \]

(1)

Table 1 Operating Range of The Converter

| Mode | Duty-cycle | Voltage limits |
|------|------------|----------------|
| 1    | 0.5<d2&d1<1 | Vin/2<Vo       |
|      | d1>d2      |                |
| 2    | 0.5<d2&d1<1 | 0<Vo<Vin/2     |
|      | d1<d2      |                |
| 3    | d2+0.5<d1<1 | Vo<2Vin        |

\[ (-\text{Vo2})(d2-0.5)+(\text{Vo1/2-Vo2})(d1-d2)+(\text{Vo1/2-Vo2})(1-d1)=0 \]

Hence,

\[ \frac{\text{Vo2}}{\text{Vo1}}=1-d2 \]

(2)

Thus,

\[ \frac{\text{Vo2}}{\text{Vo1}}=(1-d2)/(2-d1-d2) \]

(3)

The voltage gains in mode 2 and 3 can also be obtained in the same way as the above procedure. Voltage gains for all three cases become

\[ \frac{\text{Vo1}}{\text{Vin}}=\frac{1}{2-d1-d2}, \text{ mode 1&2} \]

\[ \frac{1}{(1-d2)}, \text{ mode 3} \]

\[ \frac{1}{2-d1-d2}, \text{ mode 1&2} \]

\[ 1/(1-d2), \text{ mode 3} \]
\[ \frac{V_{o1}}{V_{in}} = \frac{1-d_2}{2-d_1-d_2}, \text{ mode 1} \& 2 \]  
\[ \frac{d_1-d_2}{1-d_2}, \text{ mode 3} \]

From (4) and (5), it can be seen that \(d_1\) and \(d_2\) are the control values for output voltages \(v_1\) and \(v_2\). In mode 1 and 2, the step-up output voltage is related to both duty cycle \(d_1\) and \(d_2\), while in the mode 3, it is only related to \(d_2\). On the other hand, the step-down output voltage in all 3 cases is similar to both duty-cycle \(d_2\) and \(d_1\). More detailed analysis of the control strategy will be tested in the following system.

4. Simulations and Hardware Model

The figure 5 shows the Simulink model of the proposed system. The power generated from the dc source as PV systems is passed over the subsystem. The output of the converter is used to link the single phase light load and if excess power is generated from PV more than load, the surplus power passes to the multi-port through link. Simulation input is highly given so comparatively the output is higher than hardware output.

![Simulation Model](image.png)

**Figure 5. Simulation In Matlab.**

Based on the power generated (low or high voltage) there will be a variation in the graph (In other words, the power generated is directly proportional to the variation in the
Figure 6 shows the current and voltage waveforms at the load while the connection of Load.

![Simulation Output](image)

**Figure 6. Simulation Output.**

The waveform shows that the voltage and the current with the time in X-axis and amplitude in Y-axis.

| Table 2 Experimental Results |
|-----------------------------|
| Parameter                  | Value  |
| Total output power         | 300W   |
| Input voltage              | 15.4V  |
| Output voltage V1          | 36V    |
| Output voltage V2          | 30.3V  |
| resistive load             | 20 ohm |
| Switching frequency        | 20 kHz |

4.1 Hardware analysis

A prototype of 300W converter has been designed for the proposed system the DC source is taken instead of Solar-panel. The maximum power obtained from the panel is when the panel is 15-28 degree inclined. Accordingly the maximum power is set to 30W. In the converter we use MPPT based on perturb and observation method. The input voltage is taken as 15.4V given in figure 8. Every single converter are verified and tested separately by giving different pulse to the multi-port converter (figure 8 to figure 12). the converter is tested in two stage, pulse s1&s2 and pulse s3&s4 in figure 9,10. From the multi-port converter output waveform 15.4V stepped-up to 36V the output voltage V2 is step-down to 30.3V. From the bidirectional PWM converter the pulse output waveform is tested. The PID controller is used for the control operation of the system.
Figure 7. Hardware Output

Figure 8. Input voltage in DSO for converter
5. Conclusions
The switched capacitor multiport converter for solar system has been said in this paper. The MPC are determined by incorporating a stepping tool such as series resonant converter(src), switched capacitor converter(scc) and bidirectional PWM. and these are integrated in an single system by sharing the mosfet switches the Square wave voltages made at trading center points in the SCC are utilized to drive course of action full tanks in the Series Resonant Converter and a divert inductor in the PWM-converter. The proposed system are given in mat lab and the simulation for the multiport system is taken in an pwm
waveform. The prototype of the system is verified with the matlab. The characteristics of the MPC matched with simulation results model.

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