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THREE PHASE UNINTERRUPTIBLE POWER SUPPLY BASED ON TRANS Z SOURCE INVERTER

Radhika A., Sivakumar L. and Anamika P.
Department of Electrical & Electronics Engineering, SKCET, Coimbatore, India
E-Mail: radhikamathan@gmail.com

ABSTRACT

UPS with traditional inverter requires additional step up transformer to boost the voltage. Due to the presence of step up transformer, the inverter current is much higher than the load current, this causes high stress across the switches. This paper proposes a new topology of uninterruptible power supply (UPS) by using a Trans Z-source inverter. The Trans Z source inverter solves this problem with reduced switching stress. Here the impedance network (two inductors with one capacitor) is placed in between battery and the inverter. Compared to traditional inverter, the Trans Z Source Inverter produces high voltage. Further, it reduces the current ripple. The simulation model of a 3-Kw UPS with the Trans Z-source inverter has been developed and verified.

Keywords: shoot – through vector, uninterruptible power supply, trans Z-source inverter.

INTRODUCTION

Uninterruptible power supply (UPS) systems are used to provide uninterrupted, reliable, and high quality power for sensitive loads. UPS provide a backup power circuitry when a power outage occurs. Applications of UPS systems include medical facilities, life supporting systems, data storage and computer systems, emergency equipment's, industrial processing, telecommunications, and on-line management systems. In conventional method there are three types of UPS [7]. The first method couples a battery bank to the inverter using transformer shown in Figure-1. The transformer is used to boost the level of voltage but it causes high current stresses on the switches. The transformer also increases the weight, volume and cost of the system. The second method couples a battery bank to a booster with inverter shown in Figure-2. This method requires additional booster which leads to high cost and low efficiency. It complicates the controlling of switches in the inverter. The dead time in the pulse width modulation (PWM) is required to prevent the upper and lower switches at the same leg. The third method [1] - [5] & [15] combine booster and inverter into a single stage power conversion shown in Figure-3. The level of the voltage is low and it increases the stresses. It is explained in papers [8] – [10] and [14].

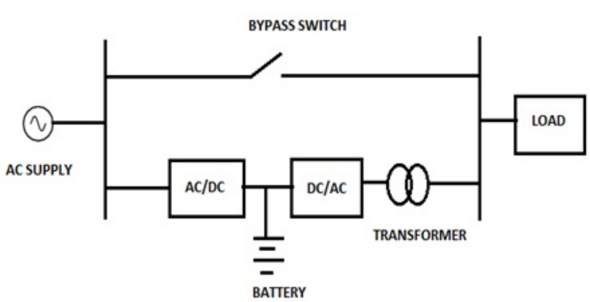

Figure-1. UPS with the combination of inverter and transformer.

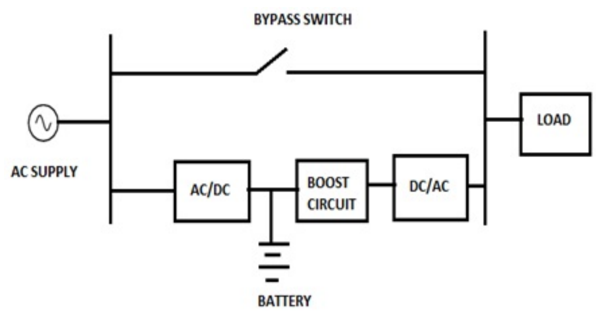

Figure-2. UPS with the combination of booster with inverter.

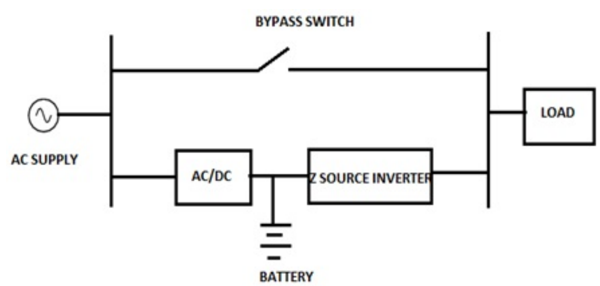

Figure-3. UPS with Z source inverter.

In this paper, a new topology using Trans Z source inverter is proposed. The advantages of this proposed paper are:

1. It increases the level of voltage
2. It reduces the voltage stresses
3. It reduces the input current ripple

TRANS Z SOURCE INVERTER

To overcome the problems in the traditional method the proposed method is implemented using Trans Z source inverter [13] and [11]. It employs a unique impedance network to combine the converter main circuit to the inverter, load. The Trans Z source inverter consist of an inductor L1 and L2 and capacitor C1 connected in T-shape is employed to couple the circuit with the inverter. In case of power outage the battery bank supplies power to the inverter. The inverter consist of Trans Z source symmetrical network (L1 = L2 and C1) and inverter (S1 – S6). When the shoot-through vectors are taken the load is shorted by upper and lower switches on the same leg of the inverter. The proposed UPS can boost the voltage by using shoot-through vectors shown in Figure-4.

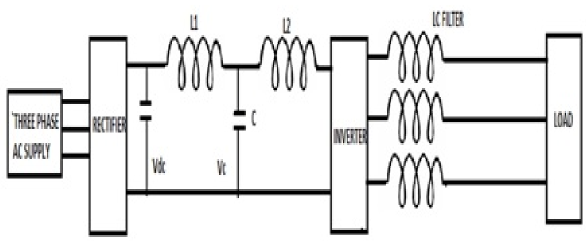

Figure-4. Proposed UPS with Trans Z source inverter.

The inductor (L1 and L2) have the same inductance, the Trans Z source network becomes symmetrical. From the symmetrical and equivalent circuit in Figure-5 (a) the voltage equation can be derived as

$$VL_1 = VL_2 = VL \tag{1}$$

The voltage equation of the non-shoot through states are derived as,

$$Vdc = Vc + VL \tag{2}$$

$$Vin = Vc - VL \tag{3}$$

Substituting (2) into (3) yields

$$Vin = 2Vc - Vdc \tag{4}$$

When the Z-source inverter is working in shoot-through states shown in Figure-5 (b) during time interval T0, where T0 = Ts − T1, and Ts is the switching period, the inverter can be considered as a short circuit.

The voltage equation of the Trans Z-source inverter at shoot-through states are,

$$Vc = VL \qquad Vin = 0 \tag{5}$$

The average voltage of inductor L1 (or L2) over one switching period in steady-state operation is zero

$$(Vdc - Vc)T_1 + VcT_0 = 0 \tag{6}$$

Or

$$Vc = \frac{T_1}{(T_1 - T_0)} Vdc \tag{7}$$

Substituting (7) into (4) gives

$$Vin = \frac{(Ts)}{(T_1 - T_0)} Vdc = BVdc \tag{8}$$

Where,

$$B = \frac{(Ts)}{(T_1 - T_0)} > 1 \tag{9}$$

B is the boost factor. If the voltage across the inductor *L*s is ignored, the output peak voltage is

$$V_0 m = V_1 m = M \,.\, Vin = M \,.\, B \,.\, Vdc \tag{10}$$

Where V1m is the peak value of fundamental voltage of the inverter and *m* is modulation index ($m \leq 1$).

The selection of the boost factor and the modulation index can obtain the desired ac output voltage regardless of the battery bank voltage.

The transfer function of the inverter is given as,

$$K = 1 - \frac{\left(\frac{T_0}{(Ts)}\right)}{\left(1 - 2\left(\frac{T_0}{(Ts)}\right)\right)} Vdc = \frac{(1-d)}{(1-2d)} Vdc \tag{11}$$

Where T0/Ts=d is the shoot through duty period. The high switching frequency fs = 1/Ts. The capacitor voltage over one switching period is constant, which is equal to average input voltage.

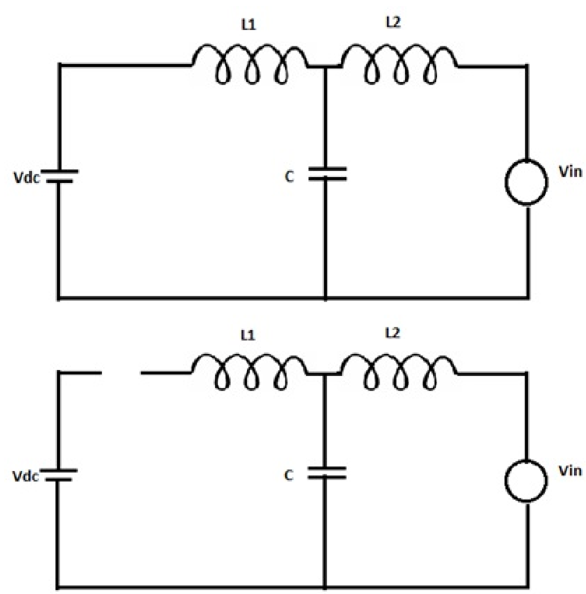

Figure-5. Equivalent circuit of Trans Z source inverter a) non shoot through b) shoot through.

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CONTROL OF PROPOSED UPS WITH TRANS Z SOURCE INVERTER

The control of inductor current i_L in the inner loop and the output voltage V_0 in the outer loop shown in Figure-6 and it is based on paper [6] and [7].

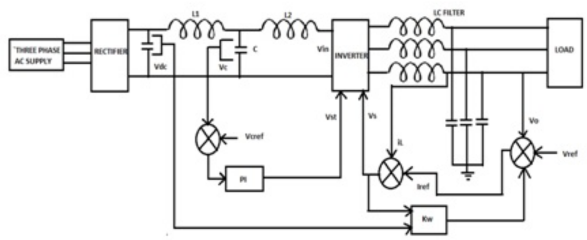

Figure-6. Control system of Trans Z source inverter for the proposed UPS system.

Inner Loop

The current feed forward control of the inner loop has eliminated the load current disturbance shown in Figure-7.

$$iref - iL = Vs \tag{12}$$

Where iL is the current across the filter. iref is the reference voltage obtained from the comparison of voltage.

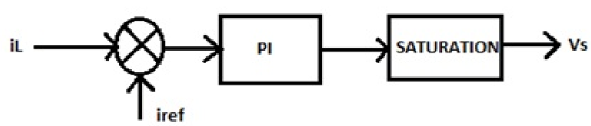

Figure-7. Block diagram of inner loop.

Outer Loop

The output voltage V_0 is regarded as a disturbance to the current inner loop. To smooth the output voltage, a voltage feed forward control is adopted shown in Figure-8.

$$V_0 \,.\, Kw \,.\, (1-d) \,.\, \frac{(Vdc)}{((1-2d)(sTs+1))} - V_0 \tag{13}$$

Where Kw is the transfer function of voltage feed forward controller.

$$Kw \sim \frac{(1-2d)}{((1-d)Vdc)} \tag{14}$$

The voltage across the inductor Ls can be given as,

$$VL = V_1 - V_0 = Vs\frac{((1-d)Vdc)}{((1-2d)(sTs+1))} - V_0 \tag{15}$$

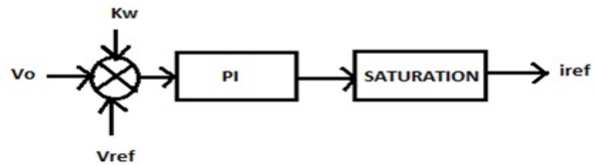

Figure-8. Block diagram of outer loop.

Shoot Through Zero Vector Control

The zero vectors can be controlled to boost the capacitor voltage in the Trans Z-source network, which maintain the desired level of the average input voltage of the Trans Z-source inverter. When the battery bank voltage drops, voltage across the capacitor of the Trans Z-source inverter also drops. Thus, the voltage difference between the reference and the actual capacitor voltage is sent to the PI controller which generates the shoot-through zero vectors.

The shoot through zero vectors can be calculated as,

$$L = \frac{(H - H_1)}{H} \,.\, B \tag{16}$$

where H is the height of carrier wave. B is the width of carrier wave. H1 value is obtained by comparing the voltage across the battery and the reference value.

SIMULATION RESULTS

The simulation model of a 3-Kw UPS with the Trans Z-source inverter has been developed.

The voltage and current waveform across the load of the proposed UPS are shown in Figure-9 and 10.

The DC link Voltage of Trans Z Source Inverter is shown in Figure-11.

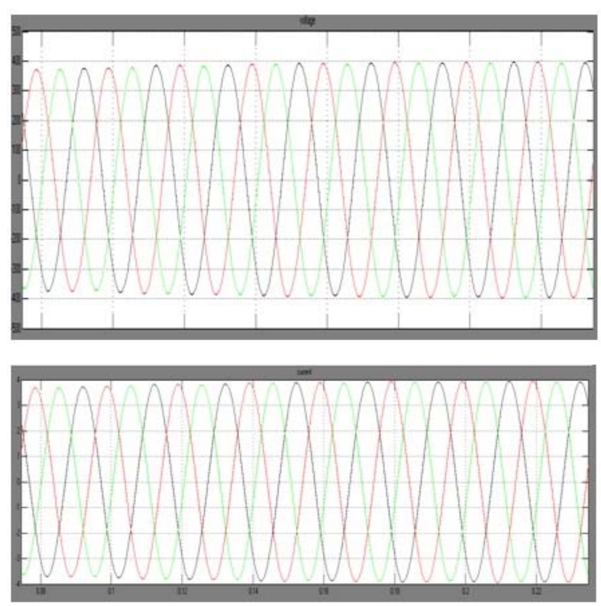

Figure-9. Voltage and current waveform across the load of the proposed UPS-open loop.

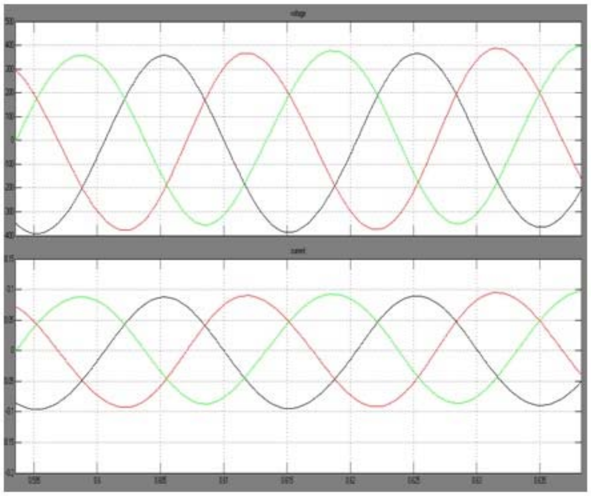

Figure-10. Voltage and current waveform across the load of the proposed UPS-closed loop.

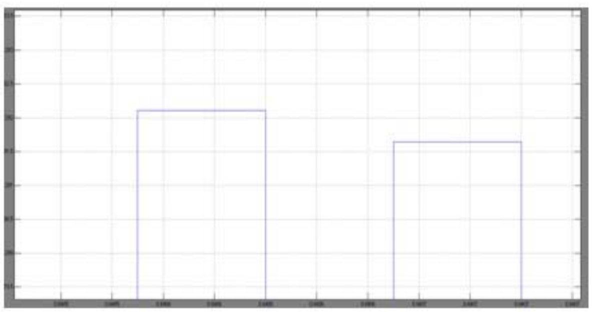

Figure-11. DC link voltage of Trans Z source inverter.

Table-1. Comparison of theoretical and simulated values in open loop.

	Traditional Inverter	Z Source Inverter	Trans Z Source Inverter
DC Input Voltage	150	150	150
DC Link Voltage	215	225	285
AC Output Voltage	70	147	210

Table-1 shows the comparative results of Inverter and Trans ZSI. This results show us the increment of voltage with less size, cost, and weight.

CONCLUSIONS

The traditional Z Source inverter is well suited only for low modulation index condition. However, for high modulation index the stress across the switches are high. To sort out this problem Trans Z Source inverter has been introduced. In this paper a three phase uninterruptible power supply using Trans Z source inverter has been designed and simulated. A model for 3-Kw UPS with the Trans Z-source inverter has been developed in MATLAB Simulink software and the results are verified.

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