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TRANSFORMER – LESS SINGLE PHASE UNINTERRUPTIBLEPOWER SUPPLY (UPS) SYSTEM

InduBhai R N. Elakkiya
Dr. Pauls Engineering CollegeVannur(Tlk),
Villupuram (Dist), Tamilnadu(St) – 605109.
indurajpillai@gmail.com elakkiyacrazy.2011@gmail.com

Abstract-- **In this paper, a high performance singlephase transformer-less online uninterruptable power supply(UPS) is proposed. The proposed UPSconsists boost rectifier &buck boost converter.This analysis shows that the buck boost converter hascharacteristics an with normal DC link voltage, the bydirectional converter is operated as in buck converter & act asbattery changes. When the input power failure occurs, the de –link voltage decrease and bidirectional converter cuts as boostconverter.**

The overall voltage, thus the transient effect of outputvoltage can be minimized. The overall efficiency of the softwareis improved with significant reduction in big and weight of thesystem due to decreases in number of batteries. The rectifier hascapability of power factor correction and provides required DClink voltage whereas the inverter provides a regulatedsinusoidal output voltage to the load.

Key Words—Transformer-less, Uninterruptable powersupply (UPS), Bidirectional Converter, DC Link Voltage,Inverter

I. INTRODUCTION

Uninterruptible power supply (UPS) are used to supplyclean, uninterruptible, conditioned power to equipment incritical applications under any normal or abnormal utilitypower condition. The use of bidirectional buck – boostconverter with high conversion ratio not only reduces thenumber of batteries but also ensures a transformer – lesssystem.

The rectifier has the capability of power factor correctionand provides regulated DC link voltage whereas the inverterprovides a regulated sinusoidal output voltage with low totalharmonic distortion (THD).

In order to control the transit effect, efficient controlscheme is adopted in the system. The overall efficiency of thesystem is improved with significant reduction in weight andsize of the system due to decrease in number of batteriesA three leg-type converter has also been proposed in [8]-[10]. A common leg for both the PWM rectifier and the PWMinverter results in reducingthe power loss in the system.

But the drawbacks caused bythe transformer are still here.

Other topologies wereproposed as a solution to overcome this problem byusing transformer at highfrequency as shown in theFig. 2. Although it helps inreducing the size and weightof the system, but it results inan increase number of activeswitches affecting the

efficiency and reliability ofthe system [5]-[7].

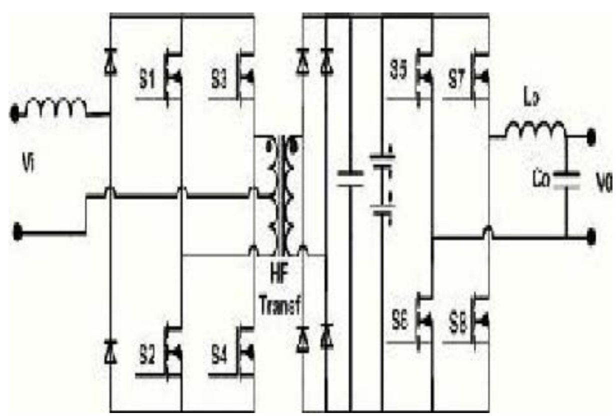

Figure. 1.Conventional UPSsystem

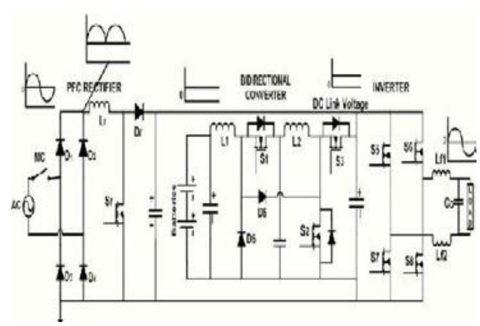

Figure. 2. Highfrequencyisolation UPS system

Transformer-less UPS,incorporatingbidirectionalconverter has attractedspecial interest due to itshigh efficiency and smallweight and volume of thesystem. But it still has somedisadvantages as theswitches of rectifier and DCDCconverter are directlyexpose to DC link voltage sothe transformer-less UPS ismore susceptible tointerference from spikes andtransients caused by load[11]. Also, a high batterybank is required to achievehigh DC link voltage, whichleads to the increase in thestorage battery cost andlower reliability.

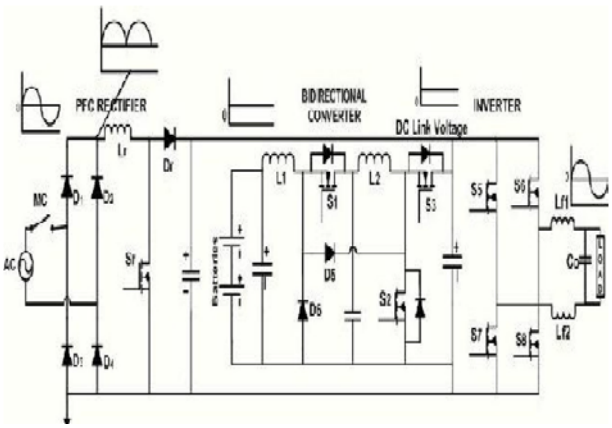

Figure. 3. Configuration of the proposed transformer-less online UPS system

According to the analysis of the drawback related to the main advantages of the proposed system are highaforementioned UPS topologies, a feasible transformerlesspower factor correction by the rectifier andefficientcontrolUPS system is proposed inthispaper. Fig. 3showstheof the DC link voltage which results inReductionoftheproposed UPS topology, which consist of PFC boost rectifier,atransient effect cause by the output voltage. Butthe mostcascaded bidirectional buck-boost converter, and an inverter.

Itimportant is the utilization of bidirectional Converterwhichis important to accentuate the fact that the use ofbidirectionalprovides high efficiency andconsiderablereduction intheconverter reduces the number of batteries considerable. Thusfor number of the batteries.low powerapplications,the proposed system is morefeasibleThis paper is organized as follows: theproposedwith high efficiency and reduced size, and weight. topology is explained in section II. The controltechniqueisThe major drawback of the transformer- less UPS is thedescribed in section III.

Design considerationsarepresentedin section IV, followed by experimental results in sectionsusceptibility to the interference from V.thespikes and
Transientscaused by assorted Section VI is the conclusion.Devicesconnectedtothe utility grid.

II. TOPOLOGY DESCRIPTION

Problem, acontrol technique is employedwhichlimits the excessive current and quickly recover theoutput The proposed UPS is shown in Fig. 3. It is composedofvoltage under transients and impulsive load . Underthisthe following parts: An isolated boost rectifier comprisingoftechnique, mode of operation of bidirectional converterisrectifier diodes D1 -D4 and traditionalboostconverterchanged by DC link voltage according to the shutdownorconsisting of switch Sr, Diode Dr, Capacitor Cr and Inductorrestoration of the gridpower.

Lr; Cascaded Bidirectional BuckboostConvertercomprisingof switch S1-S3 , Diodes D5 -D6,
Andinductors L1 , L2;aWith normal DC link voltage, the bidirectional converter isfull-bridge voltage source inverter comprising of theswitchesoperated as a buck converter and act as a battery charger.WhenS5-S8; and the output filter formed by inductors Lf 1,Lf2the input power failure occurs,theDC link voltagedecreases and capacitor Co.abruptly, and now the bidirectional converter acts asboost.

A. Modes of Operation:

Converter and starts discharging the battery. In this way,the operation of the proposed UPS can bedividedintotwooperation mode of the buck-boost converter is changed bythemodes, as shown in the Fig. 4, the grid mode or thenormalDC link voltage, thus the transient effect of the outputvoltage mode, and the battery powered mode.can be minimized. Grid Mode: When there is no power failure or theutilitypower is at least 80% of its rated operating condition,theGrid Mode is active.During this mode the rectifier.

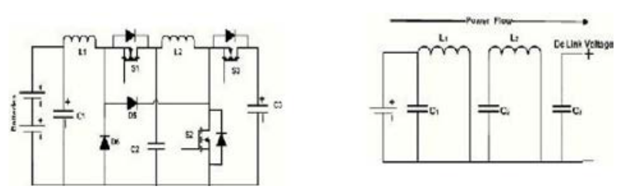

Figure. 4. Circuit Diagram of bidirectional DC-DC converter (b)(a)(c)

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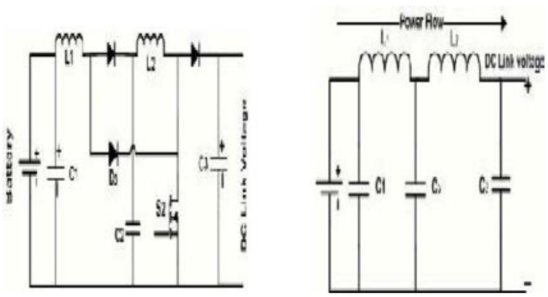

Figure.5 (a) Boost Mode of operation of bidirectional Converter (b) When S2 is ON (c) When S2 is OFF(a)(b)(c)

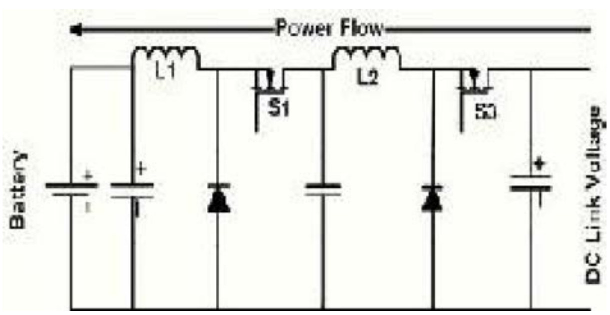

Figure.6 (a) Buck mode of operation ofbidirectional Converter(b) S1 & S3 is ON, (c) S1 & S3 is OFF

bidirectional converter, and the inverter arein operation. The rectifier converts the inputAC voltage to DC link voltage. Thebidirectional converter operates as a buck converter and acts as a charger for thebattery bank. The inverter providessinusoidal output voltage.

Battery Powered Mode:In case of theinstantaneous decreasein the DC link voltagedue to AC power failureor abrupt decrease in theinput voltage, the
battery powered modeactivates. During thismode the magneticcontactor (MC) isopened, and the rectifieris disabled. The batteriesprovide the requiredpower to the load. Thebidirectional converteracts as a boost converterand converts the batteryvoltage to DC linkvoltage. The invertermaintains the AC outputvoltage during aspecified batterydischarge time.

B. BidirectionalConverter:

The bidirectionalconverter is shown in the
Fig. 5. The proposedconverter has two booststages, thus highconversion ratio can beachieved which results inreduced battery bank.The control of theswitches S1-S3 depicts theoperational mode of thebidirectional

converter.During the battery poweredmode of operation of theUPS system, thebidirectional converteroperates as a boostconverter. The power willbe delivered from lowvoltage side (battery bank)to high voltage side (DClink voltage) by controllingthe duty cycle D of theswitch S2. During thisperiod, the switches S1 andS3 are off. The circuitdiagram is given in Fig. 6and the voltage conversionratio is given by Eq. 2Since both thestep up stages arecontrolled by a singleswitch S2, so it will sufferhigh switching losses. Thusthe efficiency of the systemwill decrease. To overcomethis problem, some suitablesnubber circuit is placed inthe converter structure tocontrol the switching-onand switching-off losses[13]-[14]. In the proposedtopology RCD passivesnubber circuit is used toreduce the switching loss ofthe S2 as shown in Fig. 8.This snubber consists ofcapacitance, resistance, and
diodeFig. 8. Circuit Diagram of SnubberDuring the witching-off transients, the diode Ds connected thecapacitor Cs in parallel to the switch. The resistor Rs limits thedischarge capacitor current. On the other hand, the Rs must confirmthat the capacitor will be completely discharged during the nextinterval ON.

Thus it will prevent extra voltage stress on the switch.During Grid mode of operation of the UPS system, theconverter will operate as buck converter. The power will be deliveredfrom high voltage side (DC link voltage) to the low voltage side(battery Bank) by controlling the switches S1, S3 simultaneously.During this period the switch S2 will be off. The equivalent circuit isshown in Fig. 7. The voltage conversion ratio is given by Eq. 3Two PWM control IC TL494 with voltage sensor athigh voltage side (DC link voltage), and current sensor like ACS715at low voltage side (battery bank) are adopted to achieve theobjective of feedback a control. A conventional proportional integral (PI) control is used and the corresponding PI gain is chosen to obtainthe best dynamic changes in experiments.

C. Boost Rectifier:

During Grid mode of operation of the UPS system, the boostrectifier converts the AC grid voltage to the DC link voltage. So aboost power factor correction (PFC) regulator has been used as asolution to suppress current harmonics, achieve unity power factorand utilize full line power. The boost regulator input current must beforced or programmed to be

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proportional to the input voltagewaveform for power factor correction.

Boost power corrector circuit is shown in Fig. 9.There is a diodebridge ahead of the inductor of boost converter to rectify the ACinput voltage. The output capacitor must be rated to handle thesecond harmonics ripple current as well as the high frequency ripplecurrent from switch of the boost converter. Since an active powerfactor corrector must control both the input current and theoutput voltage, so a conventional technique of averagecurrent mode control is implemented by using well knownPWM controller UC3854[15]-[16].

D. Inverter

A voltage source full bridge inverter isused at the output of the boost stage to convert the DClink voltage to sinusoidal output voltage. The circuit isshown in the Fig. 10. In order to control the outputvoltage, a sinusoidal PWM control with unipolar voltageswitching is applied.

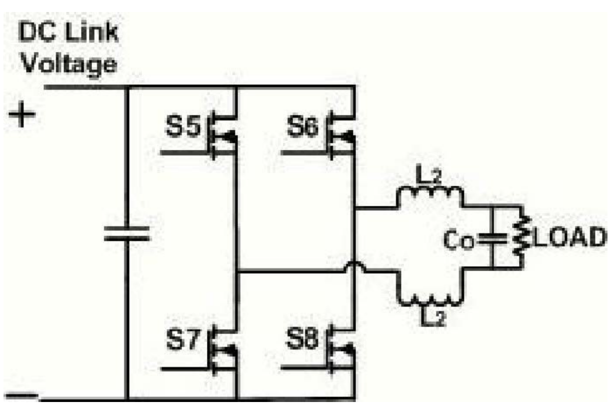

Figure. 9. Circuit Diagram of Boost Rectifier

$$M = \frac{V_{out}}{V_{in}} = \left(\frac{1}{1-D_1}\right) \times \left(\frac{1}{1-D_2}\right) \quad (1)$$

$$M = \left(\frac{1}{1-D}\right)^2 \qquad D_1 = D_2 = D \quad (2)$$

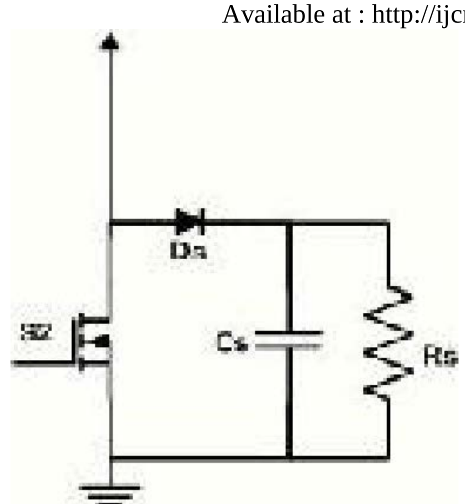

Figure. 10. Circuit Diagram of Voltage Source Inverter

At the output of the inverter, the LC filter is employed to obtain theregulated sinusoidal output voltage for the load.

III. CONCLUSION

In order to improve the performance of the system, the fastdetection technique of the input voltage is required in order todecrease the transient effect of the system. Thus an efficient controltechnique of the DC-link voltage is employed in the proposedsystem [17]. Fig. 11 shows the condition of the input power according to the variation in the DC link voltage. Due to the failure in theinput power, the DC link voltage decreases instantly. When the DClink voltage reaches the starting voltage of the Battery poweredmode V-start, the magnetic contactor (MC) is opened and thebidirectional converter operates as a boost converter. The batteryvoltage is step up to the DC link voltage. The DC link voltage isregulated to the output voltage of the bidirectional converter Vdischarge.The rectifier is disabled by MC due to loss of the inputpower.Upon the restoration of the input power, the rectifier comes againto its operation condition, and the bidirectional converter operates asbuck converter. The DC-link voltage steps down to the battery voltage in order to charge the battery. The rectifier provides regulatedDC link voltage to the inverter as well as the bidirectional converter.During this transition period between charging and dischargingmode, the capacitors connected to the DC link bus areselected such to provide sufficient energy to the invertertill the battery bank or the rectifier is connected. Since theoperation of the bidirectional converter is changed by theDC link voltage, the power required for the load issupplied by either input power or the battery power.