Design and Simulation of Online Uninterrupted Power Supply

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Abstract – This paper provides overall view of online uninterrupted power supply. The modern day society with growing technology, the work task in many industries and data centers operate on networks and require continuous power supply. Even a momentary drop can cause loss to industry or organization. Hence, uninterrupted power supply is crucial part of system. In this paper the online uninterrupted power supply is designed and simulated for all three modes of operation. The simulation is done using PSIM software in both open and closed loop conditions. The system with a peak power of 5KVA is designed which includes power factor correction circuit, pure sine wave inverter and bidirectional DC-DC converter.

Key words – Online uninterrupted power supply, Pure sine wave, Bidirectional DC-DC converter, PSIM.

1. INTRODUCTION

Over the last few years the Uninterrupted Power Supply (UPS) has been widely installed in various sectors like data centers, commercial telecoms, cloud computing and various sensitive sectors are having zero tolerance towards the power outage. Meanwhile the requirement of uninterrupted power supply for providing highly efficient, more reliable and secured electrical power supply for the equipment's connected to it. The Uninterruptible Power Supply (UPS) is a device which helps to maintain power to the load during disturbance in power supply like fault or outage. It doesn't only provide power to load during emergency but it also helps to solve common problems in power supply. It protects from interruptions in supply, protection from high voltages than a operating level, regulation of voltage in output part of system and stabilization. The uninterrupted supply includes double conversion like AC to DC and DC to AC. Initially AC-DC conversion occurs using rectifier to charge the battery and DC-AC provides sinusoidal output to the load. There is a power factor correction (PFC) circuit to obtain high power factor. The inverter is a sine wave inverter that provides pure sinusoidal output. The gating pulses are provided to DC-DC converters and inverters to maintain constant output by taking feedback. This feedback signal is given to microcontroller to generate appropriate gating signal required. The gate driver transfers the gating signal received from microcontroller to the respective converters to maintain constant output

2. RELATED WORK

Uninterrupted power supplies are very helpful in providing power supply to the equipment's whenever there is any occurrence of power outage. There are different types of uninterrupted power supplies available. Based on the power requirement, risk of outage, performance parameters, reliability and cost type of uninterrupted power supply is chosen. They are as follows:

- Offline UPS
- Line Interactive Power Supply
- Online UPS

2.1. DEVELOPMENT OF ONLINE 1-PHASE UPS FOR LOW POWER APPLICATION

This paper provides the information about the online UPS for low power application such as personal computers up to 400W capacity. The UPS is designed to provide backup for 15 minutes with the output specification of 240VAC, 50Hz. However the output produces was a square wave rather than pure sine wave and suggests using filters to obtain pure sine wave output.

2.2. DESIGN & DEVELOPMENT OF ON-LINE UNINTERRUPTED POWER SUPPLY USING PIC MICROCONTROLLER

The ON-Line (UPS) proposed offers Regulation of AC voltage on continuity basis That is incorporated with the controllable battery charger. Here Lead acid battery is used in this circuit. The technique used for charge control of battery is constant current charging technique. The protection of lead acid battery during over charging and under discharge is done using the technique of tripping relay by microcontroller

PIC16F877A by continuous monitoring of voltage. The lead acid battery of 12V is charged by constant current technique

3. PORPOSED MODELLING

The proposed architecture is for high power application such as industries and data centers where even a momentary drop can result in damage to equipment or data leading to loss to an organization.

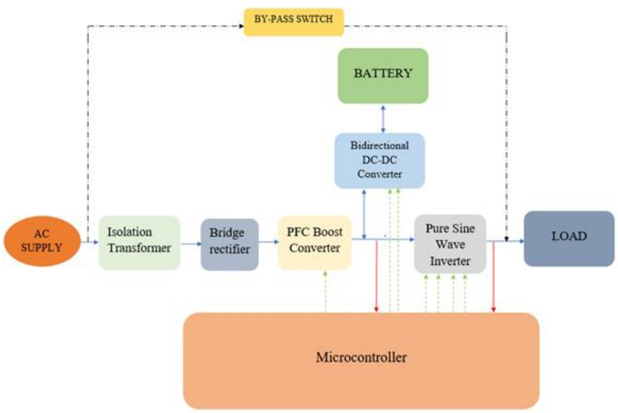

Fig.1 Block diagram of proposed online UPS

In fig.1 the proposed system block diagram is shown. It includes following:

3.1 Overview

3.1.1 Isolation Transformer: The isolation transformer used here is to provide galvanic isolation for the protection purpose. This isolates source and load thereby providing protection for supply side and load side devices.

3.1.2 Bridge Rectifier: The rectifier here is used to offer complete rectification of input AC supply provided from grid.

3.1.3 Power Factor Correction : The circuit used here is a conventional boost PFC circuit. This helps to maintain input voltage and input current in phase with one another. The Fig 2 shows PFC circuit used to obtain 400V dc bus voltage.

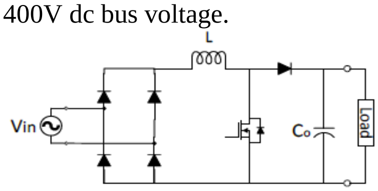

Fig.2 Conventional boost PFC circuit with bridge rectifier

3.1.4 Bi-directional DC-DC Converter: This converter operates in buck manner while charging and in boost manner while discharging. The Fig 3 shows bidirectional dc-dc converter circuit.

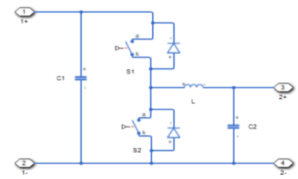

Fig.3 Bidirectional dc-dc converter circuit

3.1.5 Sine wave Inverter: Inverter used here is an H-Bridge inverter as shown in fig.4. It provides pure sine wave output with 230V, 50Hz. The input to inverter is a DC bus with voltage of 400V DC .

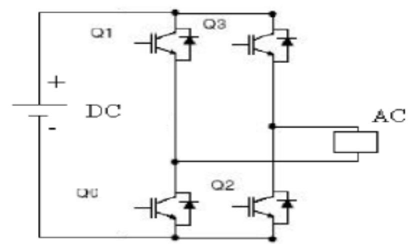

Fig.4 H-bridge inverter circuit

3.2 Methodology

The online UPS is also called as a double conversion UPS. The power to the load flows through inverter all the time as it is in series with load and ac supply. There are three modes of operation.

1. Normal mode
2. Stored energy mode
3. Maintenance mode

In normal mode, the AC supply is rectified and converted to 400V DC. This is used to feed the inverter as well as charge the battery. In stored energy mode, there will be no availability of power supply from grid and battery discharges to power the load. In Maintenance mode, the bypass switch is closed so that the AC supply is directly connected to load.

3.3 Design

The design of PFC circuit and bidirectional dc-dc converter is shown below

3.3.1 PFC Design

The output voltage of bridge rectifier is given as

$$V_{rec} = (2*V_m)/\Pi \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This voltage is fed to PFC circuit to obtain DC bus voltage of 400V. The design equations are given as

$$D = (V_{out}-V_{in})/V_{out} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The passive elements are designed based on the equations given below

$L = (V_{in}*D)/(\Delta i_L*f)$ ……………... (3)

$C= D/(R*(\Delta V_o/V_o)*f)$ …………... (4)

3.3.2 Bidirectional DC-DC Converter

The voltage from DC bus needs to be stepped down during charging and boosted during discharge. Hence the design is as follows

In buck mode,

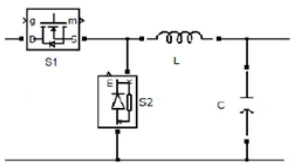

Fig 5. Buck mode circuit

The buck mode operation is shown in fig.5. The 400V DC is stepped down to 120V DC to charge the battery. The design equations are as follows

$D = V_o/V_s$……………... (5)

$L = D*T(V_s-V_o)/\Delta i_L$……………. (6)

$C = (1-D)/8*L*f2*(\Delta Vo/V_o)$........ (7)

In boost mode,

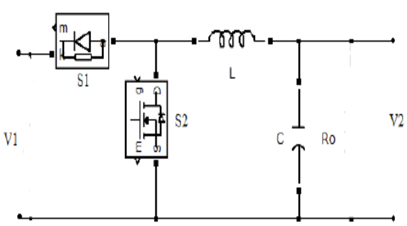

Fig.6 Boost mode circuit

The boost mode operation is shown in fig.6. Here the battery voltage of 120V is increased to 400V DC and powers inverter during absence of grid supply. The design equations are as follows

$D=1-(V_s/V_o)$……………………... (8)

$L= (D*V_s)/(f*\Delta i_L)$………………. (9)

$C=D/(R*f*(\Delta V_o/V_o))$……………… (10)

4. RESULTS AND DISCUSSIONS

The simulation is carryout in PSIM software to verify theoretical design. The AC supply from grid is rectified to obtain DC output. This rectified output is given to PFC circuit to obtain the DC bus voltage of 400V. This voltage is fed to inverter to provide 230V, 50Hz output. The same DC voltage of is used for battery charging and the battery of 120V boosted to 400V dc during outage of power to provide uninterrupted power supply. The simulation is carried out for open and closed loop operation.

4.1 Open loop simulation

The open loop circuit used in simulation is shown in fig.7 that includes PFC, bidirectional dc-dc converter and sine wave inverter.

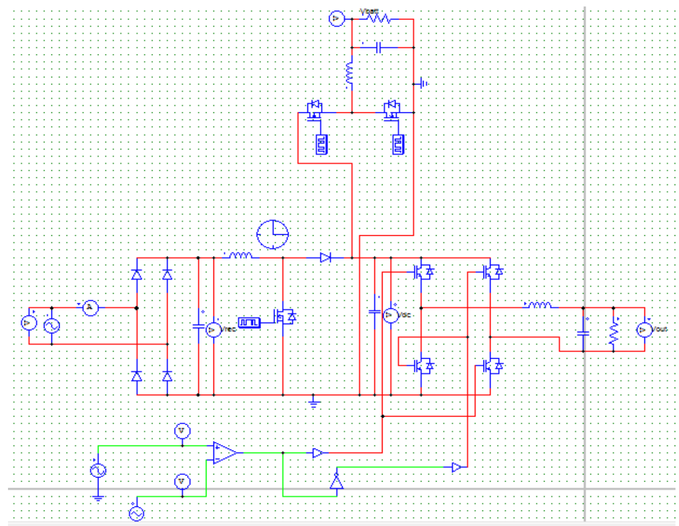

Fig.7 open loop simulation circuit.

The open loop simulation results in normal mode is shown in fig.8(a) and along with PFC waveform in fig.8(b) and stored energy mode is shown in fig.9.

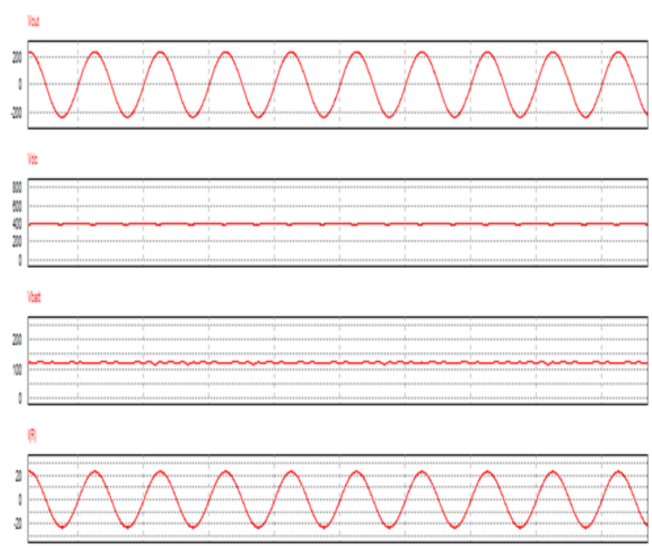

Fig. 8(a). waveform of output voltage, DC bus voltage, battery voltage and output current respectively

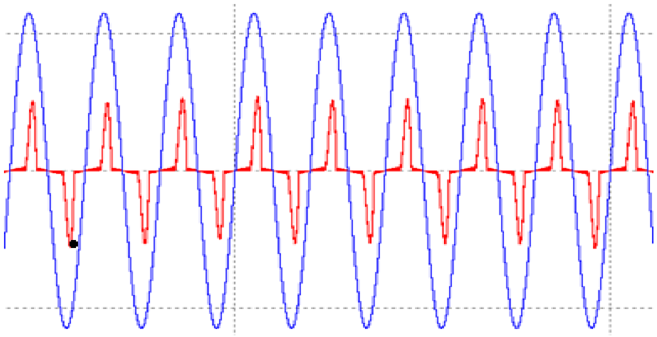

Fig.8(b). Power factor correction waveform.

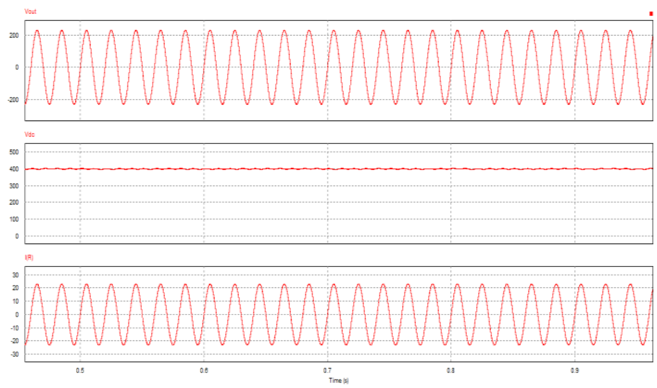

Fig.9 waveform consisting of inverter output voltage, dc bus voltage and output current respectively

4.2. Closed loop simulation

The closed loop simulation is done for change in supply voltage from 200V to 250V using PI controller. The simulation circuit is shown in fig.10. The output results for 200V and 250V is shown in fig.11 and fig.12 respectively

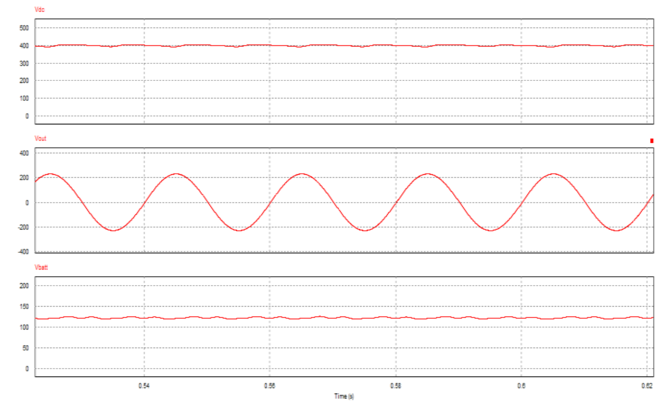

Fig.11 Output waveform of dc bus voltage, output voltage and battery voltage respectively for 200V supply

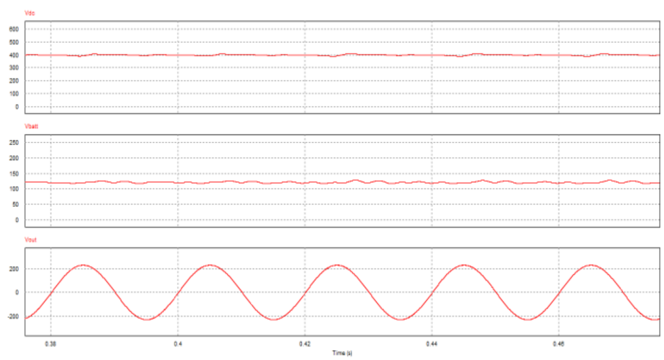

Fig.11 Output waveform of dc bus voltage, battery voltage and output voltage respectively for 250V supply

4.3 Maintenance mode

The fig.12 and fig.13 shown the circuit with bypass switch and its waveforms respectively.

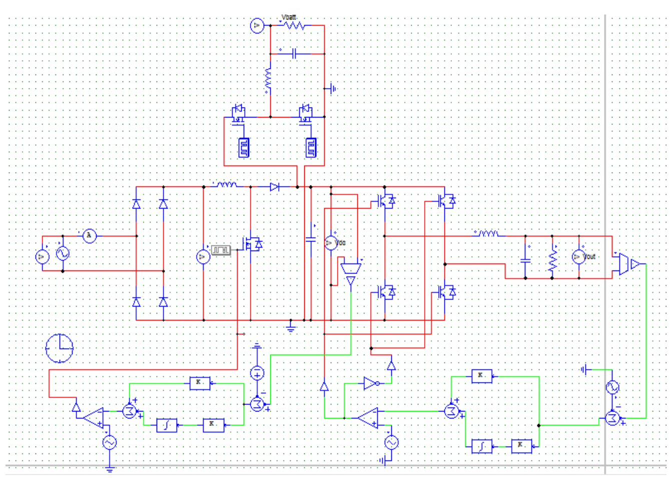

Fig.10 Closed loop simulation circuit

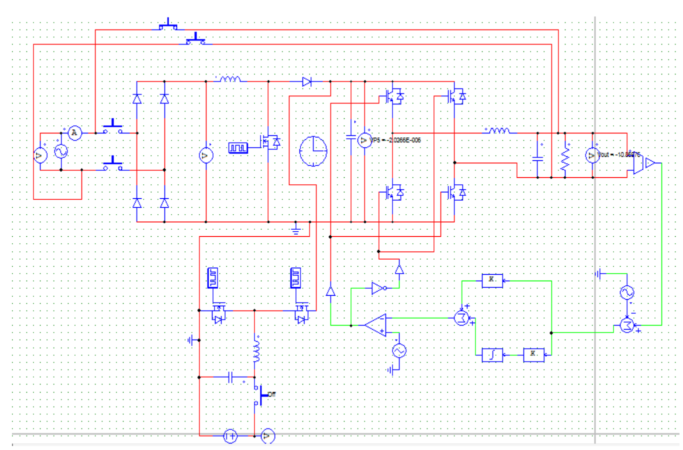

Fig.12 circuit with bypass switches for Maintainance

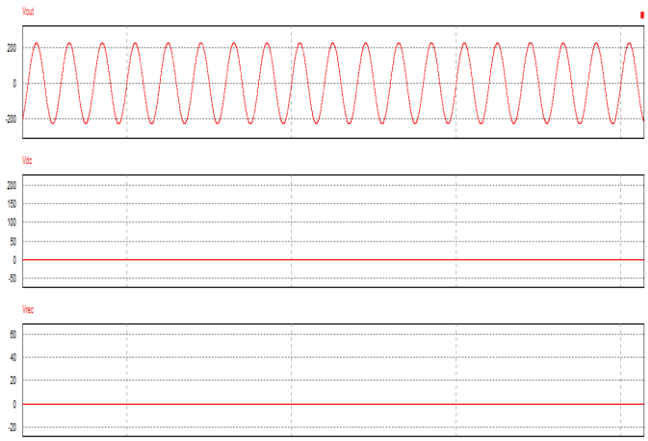

Fig.13. waveforms showing output voltage, dc bus voltage and rectifier voltage respectively

The voltage across the rectifier and DC bus voltage is zero as the power flow is bypassed directly to load. The specifications of components used and other numerical details are given in table.1.

Table.1 Parameters and their values used

Parameters	Values	Units
Input voltage(AC)	230	Volts
Input frequency	50	Hertz
Output power	5	KVA
Output voltage(AC)	230	Volts
Output frequency	50	Hertz
PFC design		
Output voltage(DC)	400	Volts
Duty cycle	0.625	
Inductor	244	micro Henry
Capacitor	20	microfarad
Bidirectional dc dc converter		
Output voltage	120(Buck)	Volts
	400(Boost)	
Duty cycle	0.3(buck)	
	0.7(boost)	
Inductor	400	micro Henry

5. CONCLUSION

The online uninterrupted power supply is designed for the peak power of 5KVA. The simulation of complete system is done using PSIM software for both open loop and closed loop operation. The output is satisfactory with inverter output voltage of 230V, 50Hz and output current of 20A.The output waveform of voltage and current are pure sine wave. The future work is hardware implementation of the system with same peak power rating of 5KVA and to improve the power factor waveform shown in fig.8(b).

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