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Simulation of Three-phase Transformerless Online UPS using MATLAB/SIMULINK

Shruti Vaidya[1], Dinari Kiran Kumar[2], Madhu. S[3], Ashitha S Kumar[4]

[1,4] *Semester(M,Tech), Dept of EEE, BNMIT,Bangalore-560070, Karnataka , India*
[2] *Scientist CSIR-National Aerospace Laboratories, Bangalore, Karnataka 560017, India*
[3] *Assistant Professor, Dept of EEE, BNMIT, Bangalore-560070, Karnataka, India*

ABSTRACT:- *This paper explicate the modeling and simulation of an alternate configuration to the conventional transformer based online Uninterruptible power supply(UPS). It proposes a transformerless three phase online UPS with power factor correction. The proposed model consists of Battery bank, half-bridge rectifier, Auxiliary circuit , Split DC bus and an inverter. Auxiliary circuit consists of switching leg(low rating) and an inductor , employed for charging the battery bank during normal operation of UPS and also to maintain the DC bus capacitors voltage during backup operation. This configuration adds the advantages by reduction of overall size, cost and weight of the system. The system is modeled and simulated using MATLAB/SIMULINK. Detailed control design, circuit operation with the simulation results have been presented in paper for verification of its feasibility and behavior.*

Keywords: *Transformerless, online Uninterruptible power supply(UPS), Auxiliary circuit, MATLAB/SIMULINK.*

I.INTRODUCTION

The Uninterruptible power supply(UPS) is mainly implemented to provide supply from the battery when the main supply fails to supply power to the loads. There has been huge development in the field of the UPS. One such development with time includes Online UPS. The switching time of an Online UPS from normal mode to battery mode is very small. Hence the need of such online UPS systems is increasing day by day in fields where the switchover time of supply cannot be more such as medical fields, life supporting systems, telecommunications etc. The conventional online UPS systems are transformer based. Conventional online ups systems consists of bypass switch, rectifier, inverter, DC/DC converter, battery bank. The DC/DC converter used should be fully rated and a transformer is required both on the grid side and the output side for proper operation during overloads or failures of the mains. Transformer considerably having weight and cost increases the weight and cost of complete system.

Hence, a model is proposed which consists of a bypass switch, rectifier/discharger, inverter, battery bank, an auxiliary circuit thus eliminating the need of transformer[1]. The low rated switching leg and inductor together form auxiliary circuit. The main role of this proposed element charges battery when the UPS operates in usual mode and in back up mode the DC link voltage is maintained.Thus Incorporating the proposed transformerless Online UPS reduces the cost and weight of the overall system and also increases the efficiency and reliability of the system[2][3][4]. Fig.1 shows the proposed system.

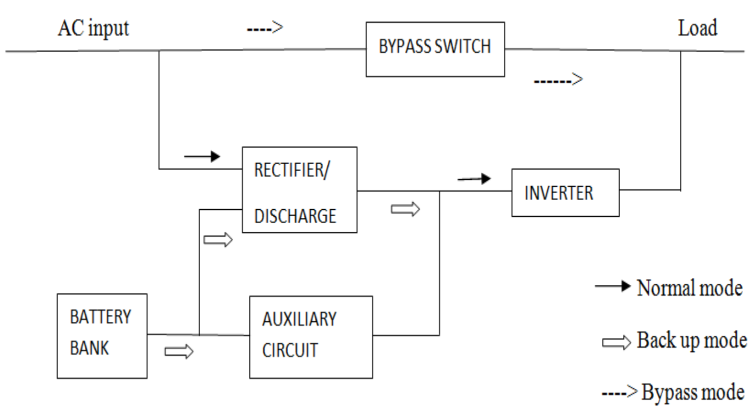

Fig.1. Proposed transformerless online UPS

II.PROPOSED TRANSFORMERLESS ONLINE UPS.

The diagram of the discussed three phase online transformerless UPS is shown in Fig.2[1]. It is composed of a rectifier, an auxiliary circuit, Dc bus link, an inverter, a battery bank, a bypass switch. Pulses for all the switches in the proposed system is obtained by using Pulse width modulation control scheme. The ac supply is connected to the rectifier. During the overload of the inverter or when the load is sensitive, the power demand of the load is supplied directly from the supply via the bypass switch.

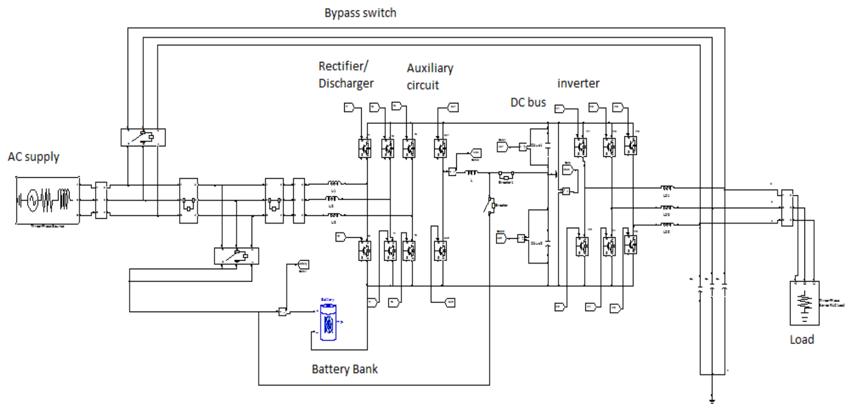

Fig.2. Proposed three phase transformerless online UPS

when the supply is within the preset limits, the input voltage is boosted to V_{bus} by the rectifier in normal mode. In this mode, Auxiliary circuit charges the battery bank. The DC voltage is converted to 3Ø ac and is supplied to the load. The power required by the load during the interruption is supplied by battery bank. The battery is discharged by inverter. During this operation, the DC bus voltage is balanced by auxilliary circuit.

III.CONTROL TECHNIQUE.

The control technique is modeled to offer power factor correction from the rectifier, maintain the Dc bus link voltage and also for charging the battery during the normal mode of operation. The control technique for inverter is also modeled to provide sinusoidal output voltage. The paper presents control strategy for linear loads.

A. Rectifier control.

The control strategy for the three-phase rectifier is shown in Fig.3. The model constitutes of 3 individual models for all the phases[5]. Fast inner loop which controls the current and slow outer loop that controls voltage are the two loops of each model. Proportional Integrator(PI) is used for inner loop to control current. During usual mode of operation of the system, inner loop reference is multiplied with the voltage reference(V_{r_ref}, V_{s_ref}, V_{t_ref}) which are phase shifted by 120^{o} so as to achieve power factor correction.

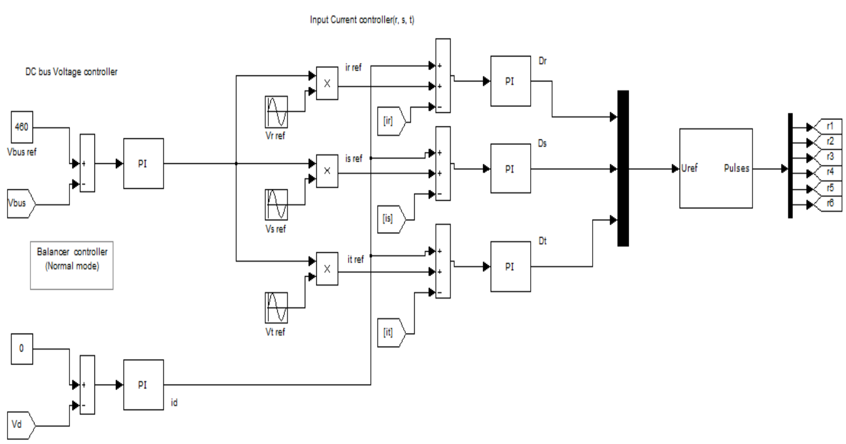

Fig.3.Control strategy for three-phase rectifier.

During disturbance in the usual mode of opereation, Voltage references are constants. The above control strategy introduces additional current i_d, the dc current accountable to maintain DC bus capacitors voltage during norminal operation of the system. V_d is the difference between the capacitor voltages(V_{c1}-V_{c2}). The pulses obtained are thus given to the six IGBT switches of the three-phase rectifier.

B. Auxiliary Circuit.

The control strategy for the auxiliary circuit is given in the Fig.4. The auxiliary circuit performs the function of voltage balancer[5]. When the structure is connected to an unbalanced load , only one capacitor discharges the dc current that leading to unbalanced voltages to the dc link. To overcome such problems of unbalanced voltages at the dc bus link, auxiliary circuit is designed to draw current of equivalent value from other capacitor.

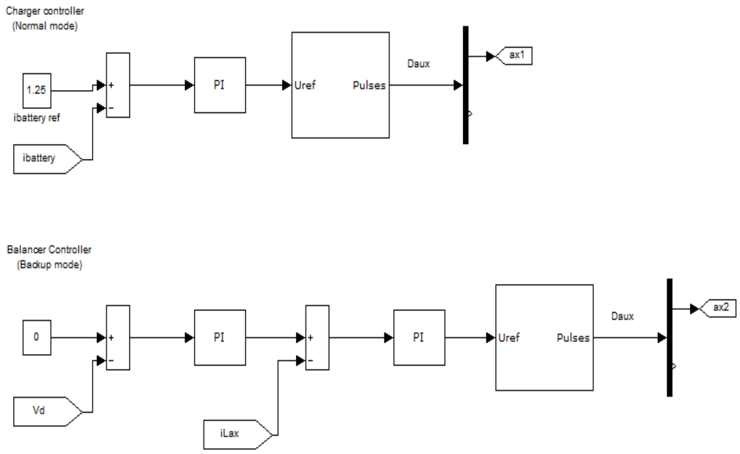

Fig.4: Control strategy for auxiliary circuit

The normal mode involves single loop, where the error obtained from the battery current and battery reference is given to the Proportional integrator(PI). During battery mode, it involves double loop controller. V_d is the voltage difference between the bus capacitor voltages. V_d is compared with null value and the error obtained is given to voltage controller. The inner loop uses current controller.

C. Inverter Control

The control strategy for the inverter section is given in Fig.5[6]. The control strategy uses single voltage loops. Average voltage control technique is used in this section. The error obtained from the comparison between the output voltage and reference voltage is given to the PI compensator.

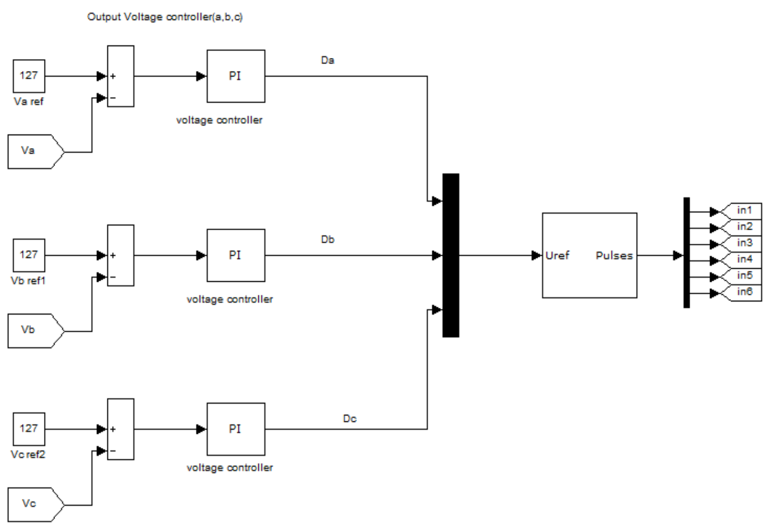

Fig.5: Control strategy for Inverter

IV. SIMULATION RESULTS

The proposed model is simulated and verified using software MATLAB/SIMULINK. The model simulations are carried out for linear load. Table I shows the simulation parameters.

Table I

Simulation parameters

Parameter	Value
Input/Output rms voltage	415V
Grid frequency	50Hz
DC bus voltage	460V
Battery bank voltage	240V
Switching frequency	15KHz
Input/Output filter inductors	3mH
Output filter capacitors	100uF
Auxiliary circuit inductor	10mH
DC bus capacitors	5400uF

TRANSITION OF BATTERY OPERATION WITH LINEAR LOAD

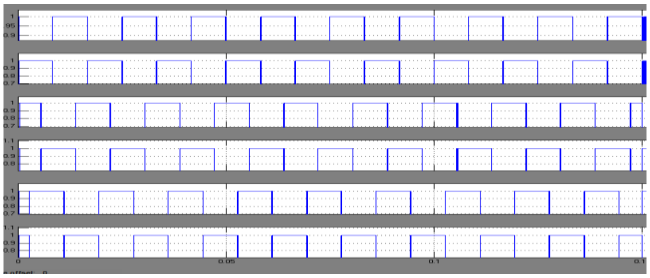

Fig.6 Pulses for Rectifier

Fig.6 shows the switching pattern for the rectifier. The switches are in the sequence S1 S4 S3 S6 S5 S2. S1 and S4 are complementary to each other. Similarly S3 and S6, S5and S2 are complementary to each other.

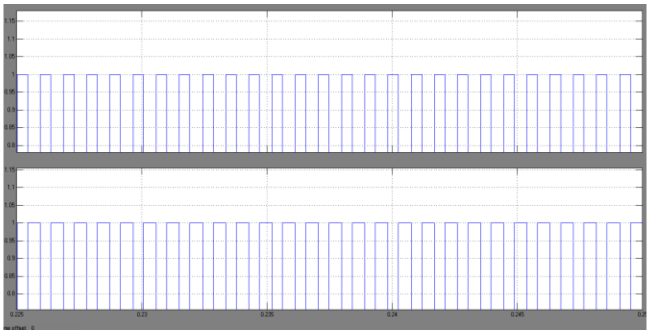

Fig.7 Pulses for Auxiliary switch leg

Fig.7 shows the pulses for the auxiliary switch leg. The S7 pulses is complementary to the S8 pulses. S7 pulses are obtained from single loop while the S8 pulses are obtained from the multi loop for battery mode of operation.

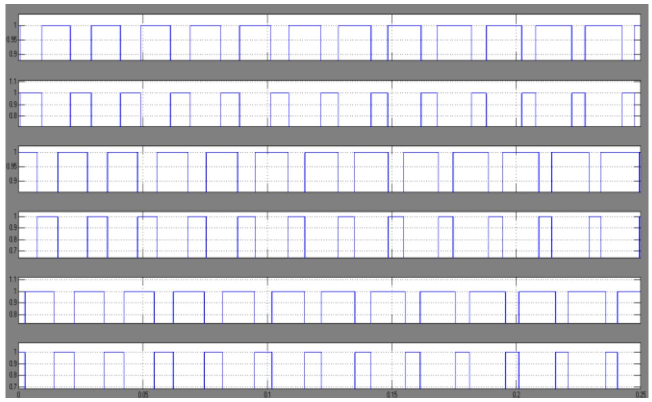

Fig.8 Pulses for inverter

Fig.8 shows the pulses for the three phase inverter. The switching pulses are in sequence S1 S4 S3 S6 S5 S2. The pulses are obtained by implementing single loops.

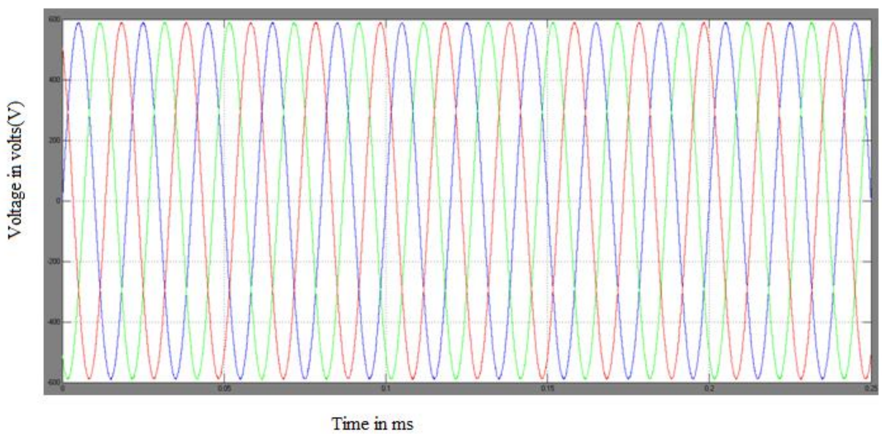

Fig.9 Three phase Output load voltage (586 V_{p-p})

Fig.9 shows the 3Ø output voltage for linear load. The waveform shows that the voltage is regulated during the transition from normal mode to back up mode.

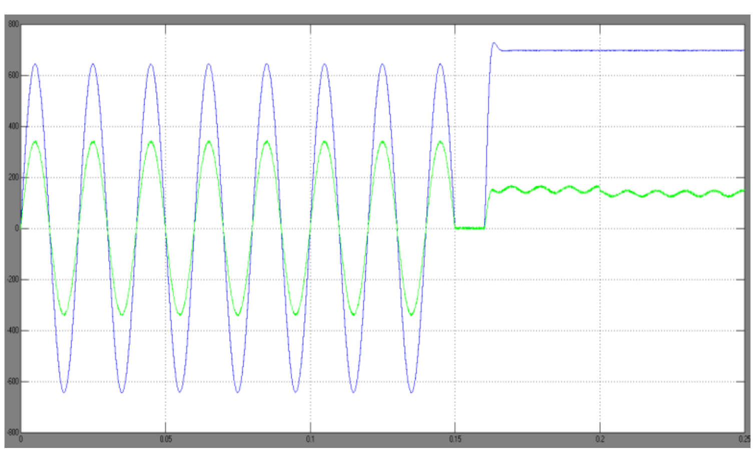

Fig.10 Input three phase currents

3Ø input currents for a single phase is shown in Fig.10. For 0.15s the system is operating in normal mode. The input voltage(blue) and the input current(green) are in phase with each other with little distortion during the normal mode of operation of the system. After 0.16s the system switches to battery mode. In battery mode, the battery supplies DC voltage and current.

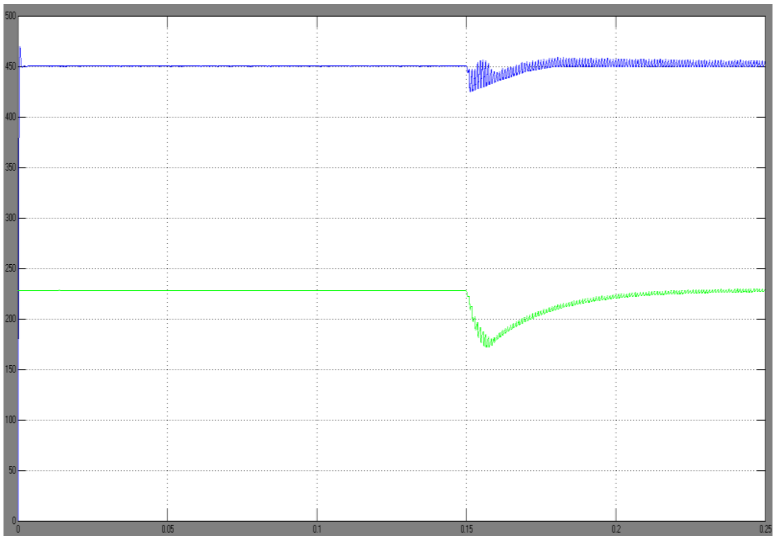

Fig.11 DC bus voltage(blue) and DC capacitor voltage(green)

Fig.11 depicts voltage at bus capacitor and bus voltage. The DC bus is well controlled and the transition time from back up to normal mode is less.

V. CONCLUSION

This paper provides the control structure for the Proposed three phase transformerless online UPS with linear load. Three phase regulated sinusoidal output for linear load with reduced harmonic distortion is obtained. The total harmonic distortion of the voltage is reduced to 0.13%.The proposed model is simulated using MATLAB/SIMULINK and the results are verified.

VI. REFERENCES

[1]. "**A LOW COST THREE-PHASE TRANSFORMERLESS ONLINE UPS**'', by William A. Venturini!

[2]."**UNINTERRUPTIBLE POWER SUPPLIES: CLASSIFICATION, OPERATION, DYNAMICS, AND CONTROL** ", by Stoyan B. Bekiarov and Ali Emadi EML: emadi@iit.edu URL: http://www.ece.iit.edu/~emadi.

[3]. "**COMPARISON BETWEEN TRANSFORMER-BASED VS. TRANSFORMER-LESS UPS SYSTEMS**", by Faisal Al Dubaikel Saudi Aramco Faisal.dubaikel@aramco.com.

[4]. R. Koffler, "**TRANSFORMER OR TRANSFORMERLESS UPS?**" lEE Power Engineer Journal, vol. 17, no. 3, pp. 34-36, 2003.

[5]. "**DC-LINK BUS ACTIVE BALANCER/FILTER FOR A HALF-BRIDGE THREEPHASE TRANSFORMERLESS UPS** ", Henrique Jank1, William A. Venturini1, Mário L. S. Martins1, Fábio E. Bisogno1, Humberto Pinheiro1, Cassiano Rech1, José R. Pinheiro1, Alexandre G. Bueno2 1Federal University of Santa Maria, Santa Maria – RS, Brazil 2SMS Electronic Technology Ltda., Diadema – SP, Brazil.

[6]. R.A. Gannett, "**Control strategies for high power four-Leg voltage source inverters**," M.Sc. Dissertation, Virginia Polytechnic Institute, July 2001.

AUTHORS

Shruti Vaidya, M.tech student, Dept. of EEE, BNMIT, Bangalore – 560070 Email:**shrutivaidya19@yahoo.com**

Dinari Kiran Kumar, Scientist, CSIR-National Aerospace Laboratories, Bangalore-17
Email**: kiran_dinari@nal.res.in**

Madhu S, Assistant professor, Dept of EEE, BNMIT, Bangalore - 560070.Email: s_madhuravikumar@yahoo.co.in

Ashitha S Kumar, M.Tech student, Dept of EEE, BNMIT, Bangalore - 560070.Email:**ashitha.shivakumar@gmail.com**