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MODELLING AND CONTROLING OF THE DC-UPS USING MICROCONTROLLER PIC 16F877

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ABSTRACT *: In this paper, a DC-UPS has been proposed having a thyristorised six pulse rectifier. The controlling of the system is done using the microcontroller PIC 16F877. This system is used as a battery charger in the Railway Coach. The control circuit of the system consists of a feedback circuit, a firing signal control circuit and a power supply. The protection against overcurrent and overvoltage is provided for the output side. The output voltage regulation to be achieved should be 2%. The closed loop controlling has been developed and tested on the system having specifications 415 V, 50 Hz, 3-phase input; 405 V DC, 25 A output current system.*

Keywords— DC-UPS, PIC microcontroller

I. INTRODUCTION

The Uninterruptible power supply (UPS) is used where even a temporary loss of the supply have severe consequences. So the function of the UPS is to provide the interrupt free power supply to either AC or DC load. Basically, there are two types of UPS: the AC-UPS and DC-UPS. The DC-UPS does not have inverter energy conversion stage i.e. DC/AC conversion. The DC-UPS and an inverter as a whole create an AC-UPS. The DC-UPS is better than the AC-UPS in terms of the energy efficiency, reliability, power quality and economy. The DC-UPS have many applications such as LED traffic controls, SCADA systems, security system operation etc for lower rating and railway battery charger, telecom power supply in rural areas.

A number of topologies are available for the DC-UPS. Out of which three major topologies are (i) DC-UPS with a PWM rectifier (ii) DC-UPS with diode bridge rectifier and a booster (iii) DC-UPS with thyristorised- six pulse rectifier. In the first topology, though the system provides the unity input power factor, the reliability and current handling capacity as compared to a thyristor is less. In the second topology, the system has additional energy conversion stage i.e booster DC/DC conversion due to which the efficiency of this topology is very less. In the third scheme, efficiency and reliability of the system is more and moreover this topology economical as compared to the above two topologies.

In this paper, the DC-UPS with the six pulse rectifier is developed which is supplied by the 3-Ø, 50 Hz, 415 V line-to-line voltage. The controlling algorithm is provided by the PIC 16F877. The protection against under-voltage, over-voltage, over-current on input side and over-current and over-voltage is achieved. The closed loop thyristor angle control is also implemented using the PIC 16F877. The output voltage regulation achieved is less than 2%.

II. BLOCK DIAGRAM OF THE DC-UPS

Fig.1 shows the generalized block diagram of the system. This system consists of a six pulse rectifier, a battery bank, microcontroller PIC 16F877, a firing pulse control circuit, a power supply, a feedback circuit, fuse, MCCB, line choke etc. This system has two modes of operation.

Mode I: Mains are ON: When the mains of the system are ON, the load will be supplied from the mains through the rectifier. The six pulse rectifier is also charging the battery so the rectifier works as a charger when mains are ON.

Mode II: Mains are OFF: When the mains are interrupted, the load will be supplied by the battery. In this mode rectifier will not come into picture.

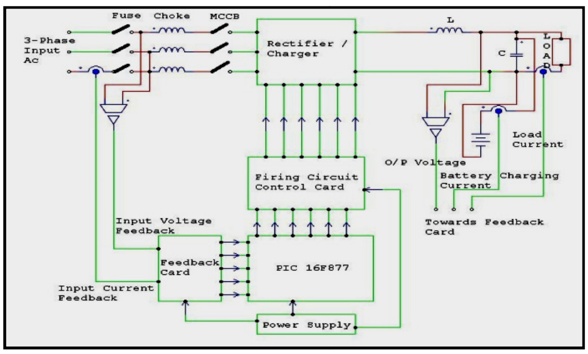


Fig.1 Generalized Block diagram of the DC-UPS

The lists of parameters are shown in the Table I.

Table I. Input and Output Parameters of the DC-UPS

Parameters	Values
Load Current IL	20 A
Battery Charging Current IB	5 A
Total Load Current IO	25 A
Output Power PO	11.475 KW
Efficiency	0.97
Input Power	11.83 KW
Input KVA	15 KVA
Input Line Current	20.6 A
Output DC Voltage VDC	405 V
Input Line-to-Line Current	415 V
Input Source Impedance	5.45 mH

A. Linear Power Supply

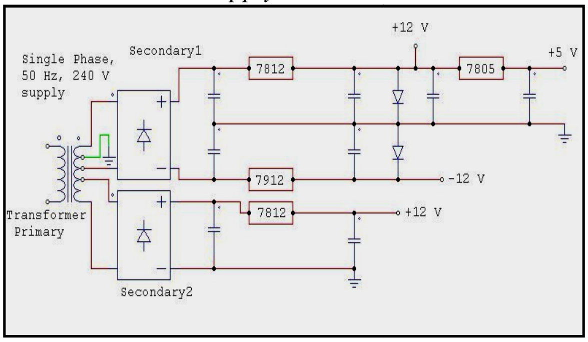


Fig.2 Circuit diagram of Power Supply Module

Fig. 3 shows the circuit diagram of linear power supply. This module generates +12 V DC, -12 V DC, +12 VP DC and +5 V DC. +5 V acts as a power supply to the controller, latches, analog and digital multiplexers. +12 V and -12 V are used for DC supply of the operational amplifier. +12 VP is used for the thyristor gate drive section. The both secondaries have isolated ground.

B. Feedback Circuit

An input current sensor, an input voltage sensor, an output voltage sensor and an output current sensor is developed to sense the prescribed quantities. The output of each of the sensor achieved is +5 V which is given to the ADC channels of the PIC 16F877 for the further processing.

The feedback quantities such as output current and output voltage are used for the closed loop firing angle control of the rectifier whereas other quantities are measured for the purpose of monitoring and controlling.

C. Firing Pulse Control Circuit

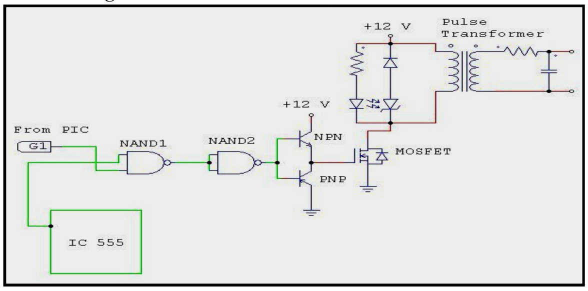
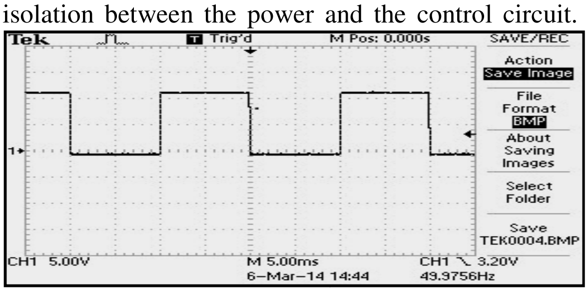
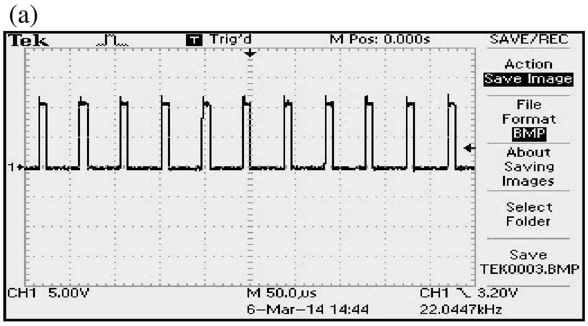


Fig3 Circuit diagram of Firing Pulse Control Circuit

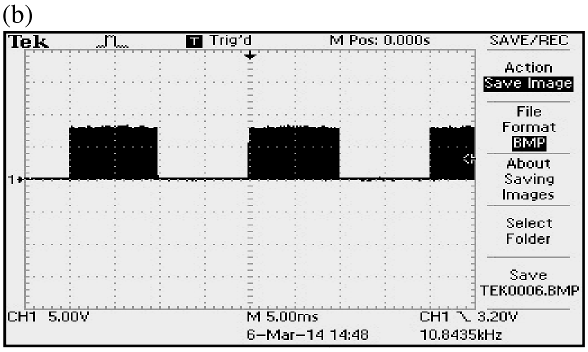
The circuit diagram of the Firing Pulse Control circuit is shown in the Fig3. A high frequency pulse is generated using IC 555. The frequency of this signal is 20 KHz. The signal generated by the PIC has the frequency 50 Hz. As seen from the fig3, both the signals are applied to the NAND1 and the low frequency signal from the PIC will be converted to high frequency. NAND2 acts as an inverting buffer. The totem- pole arrangement (combination of NPN and PNP transistor) acts as an non-inverting buffer. This signal has low current handling capacity. So it has to pass through the MOSFET. This pulse then goes to pulse transformer. The pulse transformer has turns ratio of 1:1 and it is used to provide the isolation between the power and the control circuit.



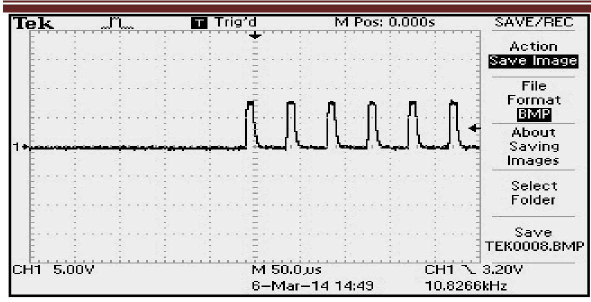
(a)



(b)



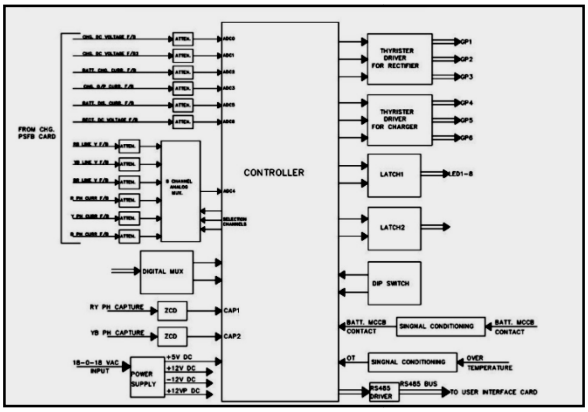
(c)



(d)

Fig.4 Firing Pulse generation (a) 50 Hz signal from PIC. (b) 20KHz signal from IC 555 (c) Gating Pulse for Thyristor (d) Expanded gating pulse

D. Microcontroller PIC 16F877 and Controlling of the DC-UPS



(a)

Fig.5 Interfacing among the PIC and the peripherals

The fig5 shows the interfacing among the microcontroller and its peripherals, Zero crossing detection circuit, Firing angle sequence control circuit etc. The microcontroller is used to perform the tasks like capturing of ZCD of RY and YB line voltages, monitoring of the phase sequence and frequency of the line voltages, controlling of the soft start of the rectifier, conversion of the analog quantities into digital quantities, generation of alarms and communication with the UI card. PIC 16F877 has in-bulid ADC and PWM module which are not available in the conventional microcontrollers.

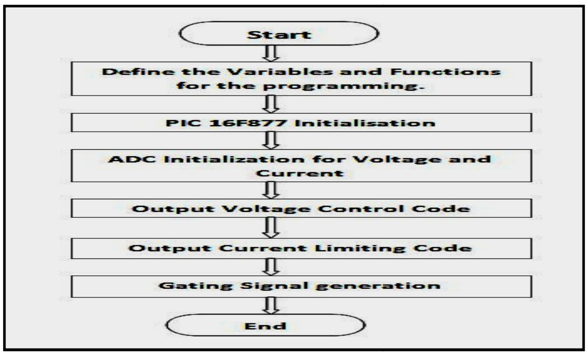


Fig.8 Flowchart of C programming implementation using PIC

The fig6 shows the flowchart of implementation of C programming using PIC 16F877. To limit the input current and voltage some boundaries is set by the PIC and if the quantity goes below or above the boundary, the PIC supplies the prescribed amount of quantity. Thus the protection against over-voltage, over-current, under-voltage can be achieved.

All the feedback quantities are applied to the ADC channels of the PIC. These analog quanitites are converted into digital quantities having 10-bit resolution in ADC. The RY and YB line voltages are applied to the capture units and the ZCD of the waveforms are measured so the frequency and phase. With help of this the frequency of the gating pulse will be decided.

The output voltage changes with the change in input voltage changes in the open loop system. With the help of the PIC, this voltage can be controlled. When the input voltage is less , the output voltage will also be less. To maintain a constant output voltage, the conduction angle will be increased and firing angle will be reduced. Similarly in case of the over-voltage, the conduction angle is reduced and firing angle will be increased using PIC. The output current also changes with the change in the output voltage. But when the over-current condition occurs, the PIC will make the system to supply the fix value of current.

III. EXPERIMENTAL RESULTS

The DC-UPS having ratings 415 V, 3-Ø, 50 Hz AC input and 405 V, 25 A DC output has been developed and tested. The experimental results are shown below:

Fig8 shows the output voltage ripple as 4.06 V which is less than the 2% of the output voltage,

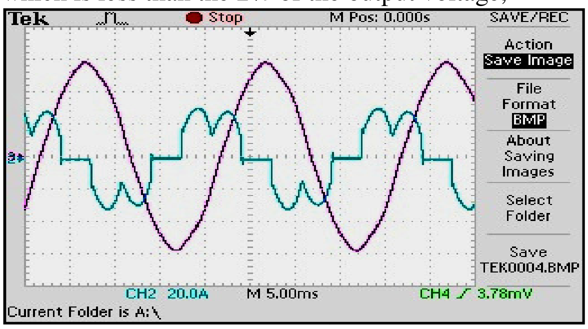


Fig6. Input phase current and input current (Scale: X-axis 5 ms per div and Y-axis 20 A per div and 100 V per div)

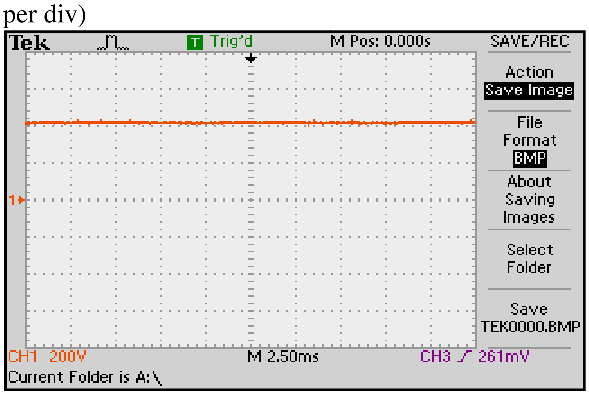


Fig7. Output Voltage waveform (Scale: X-axis 2.5 ms per div and Y-axis 200 V per div)

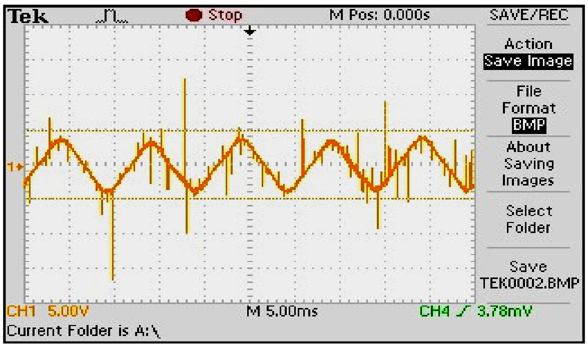


Fig8. Voltage ripple in the output voltage 4.06 V(Scale: X-axis 5 ms per div and Y-axis 5 V per div)

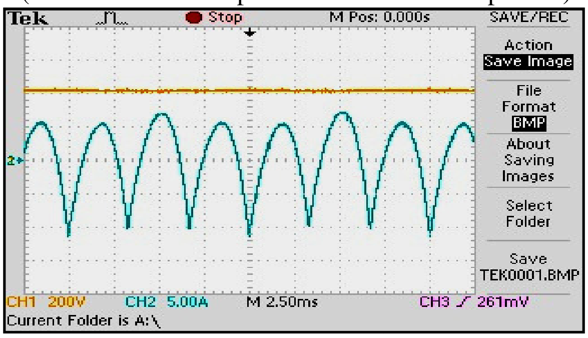


Fig.9 Pulsating DC Output (Scale: X-axis 2.5 ms per div and Y-axis 200 V per div)

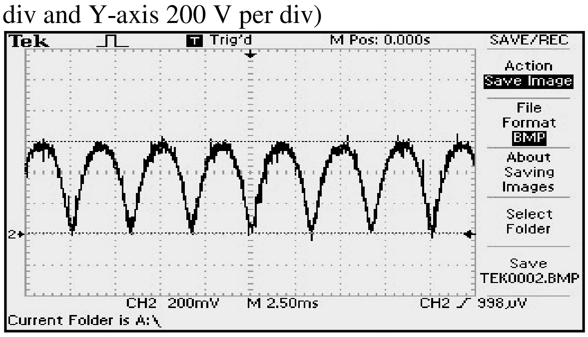


Fig10. Output current measured across DCCT, Transformation ratio 1/2000 (Scale: X-axis 2.5 ms per div and 200mV per div)

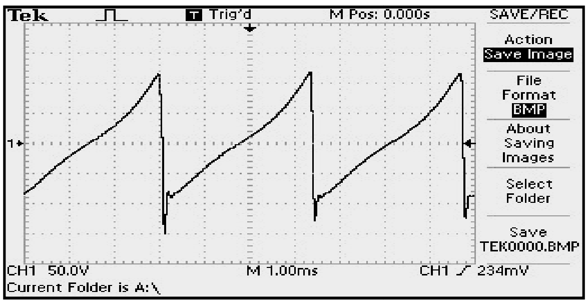


Fig10. Voltage across inductor (Scale: X-axis 1 ms per div and 50 per div)

Table II. Experimental Results at No Load and Full Load

Paremeter	**At No Load**	**At Full Load**
Input Line-to-Line Voltage	415 V	415 V
Input Line Current	0 A	20.5 A
Output Voltage	405 V	405 V
Output Current	25 A	25 A

IV. CONCLUSION

The output voltage regulation less than 2% is achieved. The efficiency and reliability of the developed DC-UPS is higher. This DC-UPS is suitable for the several applications such as Railway Battery Charger. In this case, the input power factor is poor which is around 0.8. With the 12-pulse rectifier or incorporation of the PFC before rectifier, the power factor near to unity can be achieved.

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