DESIGN, CONSTRUCTION AND TESTING OF A THREE-PHASE LOW VOLTAGE POWER SUPPLY

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ABSTRACT

This study aimed to design, construct and test a three-phase low voltage variable power supply for EE/ECE laboratory with the following components: three-phase high voltage power supply of 220VAC, low voltage variable three-phase AC power supply with an output of 3V, 4.5V, 6V, 9V, 12V and DC output of 12V, +5V, 1.25V 12V. All outputs except the 220VAC are provided with over current circuit protection to protect the circuit and the component from overload and accidental short circuit. The parameters tested are the phase angle, (for AC output voltage only), output voltage, and maximum load current for both DC and AC output. After testing the power supply, the results show that all data have met the requirements with an acceptable level of error. This indicates that the design is valid, reliable and accurate and that the power supply was satisfactorily made and very adoptable to the needs of the EE/ECE Laboratory.

INTRODUCTION

Background of the Study

Most electronic equipment require DC voltages for their operation. These can be provided by batteries or by internal power supplies that convert alternating current available at the home electric outlet, into regulated DC voltages. The first element in an internal DC power supply is a transformer, which steps up or steps down the input voltage to a level suitable for the operation of the equipment. A secondary function of the transformer is to provide electrical ground insulation for the device from the power line to reduce potential shock hazards. The transformer is then followed by a rectifier, normally a diode. In the past, vacuum diodes and a wide variety of different materials such as germanium crystals or cadmium sulfide were employed in the low-power rectifiers used in electronic equipment. Today silicon rectifiers are used almost exclusively because of their low cost and their highreliability from(http://encarta.msn.com/encyclopedia_761566928 2/electronics.html).

Rectifiers are important because after all, the AC has to get converted to DC. They are essential elements in switching power supplies, but for regular "linear" power supplies, SLOW diodes are preferred. Slow diodes are created by placing small capacitor circuits across the diodes, which greatly reduces radiated noise from (http://www.passlabs.com/downloads/articles/powersupply.pdf).

Some companies developed power supply with similar features as this present design. Hamden developed AC, DC Power Supply model BPS 103A with the following features 0 128Vdc 6A max, 0 140Vac 6A max, 0 220 3 phase, 9A max, 220Vac 3 phase, 15A max, 0 150Vdc 1A max and 110V single phase 15A maximum. Lab Volt EMS 8621 power supply has 120/208, three phase 15A maximum, 0 120V/208V 5A maximum, three phase 0 120V, 8A DC. This power supply however, does not have the electronic over current protection and variable step voltage which are present in the developed design. The Lab Volt EMMS 8621 power supply is applicable only to a very high power voltage which is dangerous for students' use and cannot be used in low voltage application.

The design, fabrication, and evaluation of a Three-Phase Low Voltage Power Supply is designed specifically for low voltage current application suitable for laboratory experiments in Circuit 1 and 2 and in Industrial Electronics.

The College of Engineering of Central Philippine University (CPU) is composed of five departments namely: Chemical Engineering, Civil Engineering, Electrical and Electronics and

Communication Engineering, Mechanical Engineering, and Software Engineering. The college has a total enrolment of 1,250 students for First Semester School Year 20042005, with 40 faculty members; both fulltime and parttime and 4 staff members. The Philippine Accredited Association of Colleges and Universities (PAASCU) accredited the four Programs of the College as level III Center of Development 1 and were granted a 5 year accreditation status.

Recently the four programs of the college were reaccredited and one of the basic equipment required by the accreditors is the low voltage 3-phase variable power supply with complete switching and protection. Since the college does not have this equipment, a Lab Volt is used for the laboratory experiments. However, the Lab volt is very expensive; it costs about more than a million per unit which allows only one group of students to perform a specific experiment. Because of this, it was decided to design an equipment for the EE Power Laboratory. Most of the students using this equipment are in their 3rd to 5th years.

Fabrication of the equipment will not only facilitate efficient and convenient conduct of experiments but will also add equipment in the EE Power Lab thus meeting the requirements of PAASCU. Developing and fabricating a three phase low voltage power supply will provide students in Basic Electrical Engineering (Circuit I and II) and Industrial Electronics (EE512) and EE/ECE professors with a low cost power supply. Its major parts include: 220 VAC 3 phase source voltage, 220 VAC 3 phase output voltage, the low voltage 3 phase variable power supply, the DC power supply with regulated output of 5V fixed, +12V and 12V fixed and the + 1.25V to +12V and 1,25V to 12V variable, Over current circuit protection, LED display, six position selector switch, Toggle switch and variable resistor.

Objectives of the Study

The main objective of the study was to design, fabricate and evaluate of a 3 - phase low voltage power supply for EE Power Lab.

Specifically it aimed:

1. To develop the basic Block Diagram of the circuit board
2. To integrate each discrete component based on the block diagram
3. To calculate the component values, and determine the circuit and active component parameters
4. To test the designed circuit and evaluate the result and do some modification, if necessary
5. To construct the actual circuit board, and
6. To conduct final testing and evaluation of the circuit board.

Scope and Limitation of the Study

This power supply is primarily designed for electrical and electronics experiments specifically in Basic Electrical Circuit (Circuit I and II) and Industrial Electronics laboratory experiments. Power supply capacity is set to a maximum load current of 1 Ampere (both AC and DC) and the output voltage is specified depending on the availability of component. For this design, the output voltages for both DC and AC were specified and limited to its specifications. It cannot be operated beyond its maximum operating current for it will cause tripping off of the device to protect the active component inside the power supply.

The circuitry of a power supply is designed based on its specifications and limitations. The DC power supply circuit with variable output has a maximum current of 1A and has an output voltage of +1.25V-to-12V Vdc regulated, 12V fixed regulated, +5V fixed regulated. The AC inner supply circuit has a maximum output voltage of 220VAC, variable low voltage AC of 3V, 4.5V, 6V, 9V, and 12V with LED display. All output voltages have over current circuit and fuse protection.

Significance of the Study

The outcome of this study will benefit the School Administrators, EE/ECE department, teachers, students, and other schools which offer related or the same course but cannot afford to buy expensive equipment.

METHODOLOGY

Conceptualization of the Design

The design was started, by drawing the block diagram of a given system shown in Figure 1 below. The simplified block diagram of the 3 - Phase Low Voltage Power Supply are composed of eight blocks labeled with a name that corresponds to its specific function and operation.

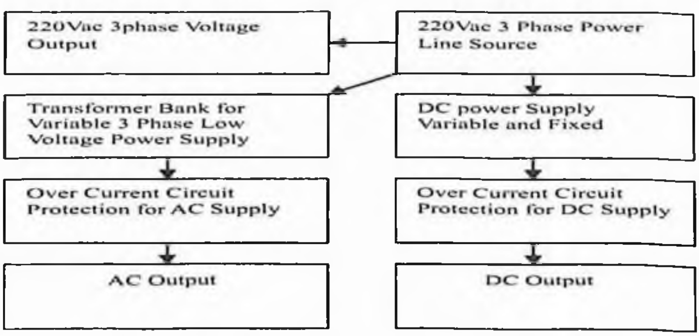

Figure 1. Block Diagram

The block diagram has eight major components namely: the regulated power supply both fixed and variable, the transformer bank with step down voltage from 220 VAC to a variable 3V, 4.5V, 6V, 9V, and 12VAC voltage, the over current circuit protection for both AC and DC, the 220V AC output voltage directly connected to a 220VAC 3 phase line, and the low voltage DC and AC output. The regulated DC power supply design is an IC voltage regulator with variable and fixed output voltage (Figure 2).

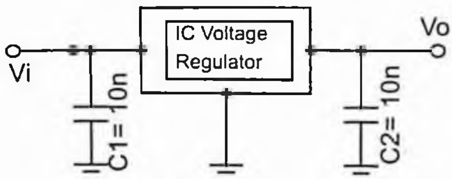

Figure 2. Fixed IC Voltage Regulator

The circuit shown in Figure 2 is a schematic diagram of a fixed IC regulator; the output voltage is depending on the IC used. A +5V regulator output only used 7805, for -12V, used 7912, for +12V, used 7812. The capacitor connected to the input and output terminals are used to filter out harmonics produced by the active component and the high frequency interference.

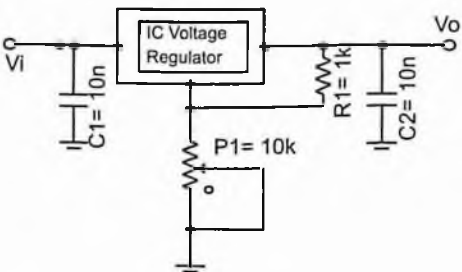

Figure 3. Variable IC Voltage Regulator

For the variable IC regulator shown in Figure 3, the output voltage is from 1.25V to 37 V with built-in over current circuit protection. For fixed IC regulator, the output voltage is being specified based on their rating and has also a built over current circuit protection.

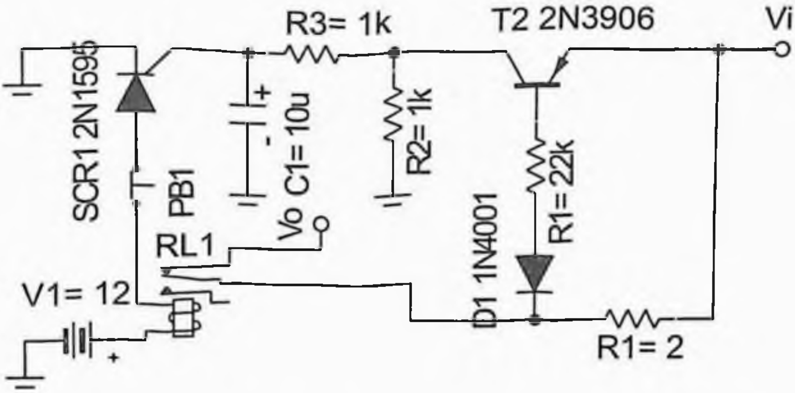

Figure 4. Over Current Circuit Protection

The over current circuit protection shown in Figure 4 is carefully designed to limit the operating current to approximately 1 ampere and for the protection of the transformer bank and the main component, specifically the active components like the transistors and IC voltage regulator.

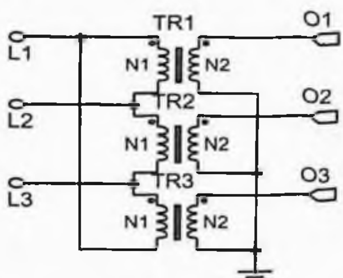

Figure 5. Three-Phase Transformer Bank

Shown in Figure 5 is the transformer bank used to step-down the voltage from 220VAC to 3V, 4.5V, 6V, 9V, and 12VAC using the Delta-to-Wye connection.

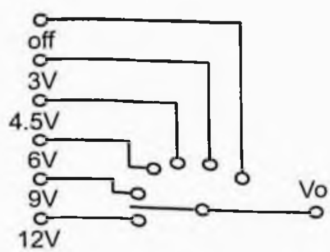

Figure 6. Six Position Selector Switch

Shown in Figure 6 is the rotary switch used to select the variable AC supply output to 3V, 4.5V, 6V, 9V, and 12VAC, and the circuit which is the overcurrent circuit protection. Relay (RL1) is used to automatically switch on and off the output terminal, T2 is the pnp transistor used to sense the error voltage and trigger the relay on by triggering the gate terminal of SCR1, and the 2 ohm resistor R1 controls the maximum operating current. When the voltage across R1 is equal or greater than 2V, the transistor T2 will turn on thereby triggering the SCR1 to cause the relay on. The Pb1 is the push button used to reset the supply whenever there is an overload in the power supply.

MAJOR FINDINGS

The source voltage required by the design is 220VAC, however, the actual testing supply voltages were 210.8V, 211.5V, 211.3V for phase 1, phase 2, and phase 3, respectively (Table 1). The secondary AC output voltage as shown in Table 2 is slightly lower compared to the required voltage based on the design, but this is beyond the researchers' control since it is dependent on the voltage produced by the utility company. However, these values are tolerable and can be used for testing and evaluation with a minimal amount of deviation from the expected value. Since the AC voltage is not regulated, the output may vary depending on the variation of the line voltage. The output of the regulated power supply is capable of maintaining the output voltage within a tolerable limit even if the source voltage varies (Table 3). Based on the results, all data have a small variation. One reading had a 6.53% error, but this is tolerable and can be corrected if the output required is only 12V or less.

Table 1. Source Voltage Reading

Expected Value per Phase	Measured Value		
	Phase 1	Phase 2	Phase 3
220VAC/60Hz	210.8V	211.5V	211.3V

Table 2. AC Output Voltage Reading

Expected Value per Phase	Measured Value (V)			% Difference		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
3	3.09	3.07	3.07	−3	−2.33	−2.33
4.5	4.56	4.58	4.57	−1.33	−1.77	−1.55
6	6.06	6.08	6.07	−1	−1.33	−1.16
9	8.97	9.01	8.99	0.33	−0.11	0.11
12	11.88	11.95	11.92	1	0.42	0.66

Table 3. DC Output Voltage Reading

Expected Value	Measured Value (V)	% Difference
+5	5.04	–0.8
+12	12.03	–0.25
–12	–11.87	1.08
+1.25 15	+1.253 15	–0.24 0
–1.25 –15	–1.268 –15.98	–1.44 –6.53

The load currents of 0.6A for AC and 0.7A for DC presented in Table 4 are more than enough for the required laboratory experiments, because these laboratory experiments were designed for low current (normally from 10mA 100mA load current).

Table 4. Current Reading

Maximum Load Current	Expected	Measured	% Difference
AC	1A	0.6A	40%
DC	1A	0.7A	30%

The resulting phase angle shown in Table 5 is approximately 120 degrees for each phase, which only shows that the lines are balanced when the power supply was tested. The phasing of the three-phase low voltage power supply depends on the source voltage.

Table 5. Phase Angle Measurements

Expected Value per Phase	Measured Value		
	Phase 1	Phase 2	Phase 3
120 degrees per phase	116.47^0	121.76^0	116.47^0

CONCLUSION AND RECOMMENDATION

Conclusion

After testing different blocks, the results show that all data have met the requirements with an acceptable percentage error indicating that the design is valid, reliable and accurate. It can be concluded further that it was satisfactorily made and very adaptable to the needs of the EE/ECE Laboratory.

Recommendation

Based on the results of the test, it is recommended that the current capability of the power supply be increased. The 2 ohm resistor five Watt connected to the over current protection circuit) should be changed to less than 2 ohms and the transformer bank should be changed to 2 A rating. The load current capability of the power supply normally depends on the rating of the transformer used for AC voltage output and for DC output voltage, addition of series pass transistor and also the transformer rating must be higher depending on the maximum load current.

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