PROGRAMMABLE SPEED CONTROL SYSTEM (PSCS): AN EFFICIENT APPROACH TO VARIOUS SPEED CONTROLS OF INDUCTION MOTORS

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ABSTRACT

Traditionally, in most application where variable speeds are required speeds are required, the obvious choice is the induction motor which is commonly used in every electromechanical conversion system. This paper presents various speed reference points implementation of computer based speed control system connected to an induction motor (AC fan) using an assembly coded microcontroller (AT89C51). We wrote codes in assembly language via notepad, which must be saved as .asm file. The saved file was built with an assembler (MIDI - 51) which generated three files; hex file, obj file and list file. The hex file was used for the simulation of the design in Proteus 6 professional. Once the system is on and the sensor detects the present room temperature, the constant speed mechanical load moves directly proportional to the detected temperature. We also found out that this system work in a sequential manner, one can never jump any digital input or key in wrong inputs.

Keywords: Computer based speed control (CBCS), induction motors, microcontroller

INTRODUCTION

Presently, induction motors are used in every electronic device at home, in the industry, in the offices, even in the computer printers and artificial intelligent systems. In every electromechanical energy conversion, the torque speed of the system is always inversely proportional to the mechanical load which is classified into three [3];

1. Adjustable speed loads; example is robots
2. Constant speed loads; example is fans
3. Variable speed loads; example is cranes

[7]The major factor militating against the usage of the induction motor as a variable speed drive in the past could only be effected by varying both the voltage and the frequency of each so as to keep air gap flux constant and minimize overheating. In the past, this problem was tackled by the use of motor generator sets or inverters using thyristors (this is a form of electron tube that is used for switching purpose).This made the induction motor uncompetitive as a variable speed drive. This problem is being tackled here via digital logic circuitry, microcontroller and power electronics converter.

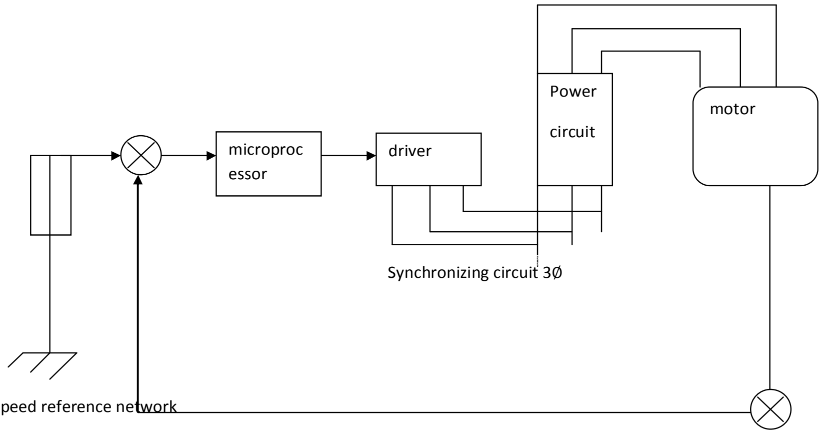


Figure 1. Induction motor CBCS speed control

The motor to be used for such a control strategy is usually fitted with a high resistance rotor, but under certain conditions, speed control of standard low resistance motor can be achieved using the equivalent circuit of the above diagram (fig 1) with frequency of line voltage and fixed value of slip frequency (Fsi), the power in any resistive element is proportional to Vs2 (stator voltage).therefore utilizing the following relationships.

$$Pem = Pag - Pr = (3RF - Fsl)(1/F3)(1\mathrm{r}^2).$$

$$Tem = Pem/w$$

We understood that torque T_{em} will be proportional to V_s for a value of rotor speed Nr determined by F and f_{sl} i.e $T_{em} = Kvs^2$

Where K = constant.

These equation shows that for loads requiring constant torque with speed, it is necessary to use a motor with high rotor resistance for a wide range of speed control. In its most basic form a thyristor controlled circuit which is represented by fig 1 can be divided into three parts[9].

I. .The power circuit
II. The drive on trigger circuit and
III. The controller

Which on its broadest sense consist of amplifier, Logic circuit and traducers. It should be noted at this point that microcontrollers can perform the function of logic circuits.

The speed reference network is basically a potentiometric network with zero ground reference, the position of the wiper arm dictates the particular desired speed. This particular desired speed is equivalent to a particular voltage. The function of the signal combination network is to compute this voltage with the adequate conditional voltage output from the Tachometer.

Electric Motor

An *electric motor* converts electrical energy into mechanical energy [8]. Most electric motors operate through the interaction of magnetic fields and current-carrying conductors to generate force. The reverse process, producing electrical energy from mechanical energy, is done by generators such as an alternator or a dynamo; some electric motors can also be used as generators, for example, a traction motor on a vehicle may perfom both tasks. Electric motors and generators are commonly referred to as electric machines.

Figure 2. Electric Motor [9]

Electric motors are found in applications like industrial fans, blowers and pumps, machine *tools, household appliances, power tools, and disk drives. They may be powered by direct current* (e.g., a battery powered portable device or motor vehicle), or by alternating current from a central electrical distribution grid or inverter. The smallest motors may be found in electric wristwatches. Medium-size motors of highly standardized dimensions and characteristics provide convenient mechanical power for industrial uses. The very largest electric motors are used for propulsion of ships, pipeline compressors, and water pumps with ratings in the millions of watts. Electric motors may be classified by the source of electric power, by their internal construction, by their application, or by the type of motion they give [6].

Induction Motor

An induction motor is an asynchronous AC motor where power is transferred to the rotor by electromagnetic induction, much like transformer action[3]. An induction motor resembles a rotating transformer, because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Polyphase induction motors are widely used in industry.

Figure 3. The Induction motor [5]

Currents induced into this winding provide the rotor magnetic field. The shape of the rotor bars determines the speed-torque characteristics. At low speeds, the current induced in the squirrel cage is nearly at line frequency and tends to flow in the outer parts of the rotor cage. As the motor accelerates, the slip frequency becomes lower and more current flows in the interior of the winding. By shaping the bars to change the resistance of the winding portions in the interior and outer parts of the cage, effectively a variable resistance is inserted in the rotor circuit. However, the majority of such motors have uniform bars. Motor speed can be changed because the torque curve of the motor is effectively modified by the amount of resistance connected to the rotor circuit. Increasing the value of resistance will move the speed of maximum torque down. If the resistance connected to the rotor is increased beyond the point where the maximum torque occurs at zero speed, the torque will be further reduced.

When used with a load that has a torque curve that increases with speed, the motor will operate at the speed where the torque developed by the motor is equal to the load torque. Reducing the load will cause the motor to speed up, and increasing the load will cause the motor to slow down until the load and motor torque are equal. Operated in this manner, the slip losses are dissipated in the secondary resistors and can be very significant. The speed regulation and net efficiency is also very poor.

Induction motors is further divided into

a. squirrel-cage motors and
b. wound-rotor motors.

Squirrel-cage motors have a heavy winding made up of solid bars, usually aluminum or copper, joined by rings at the ends of the rotor. When one considers only the bars and rings as a whole, they are much like an animal's rotating exercise cage, hence the name

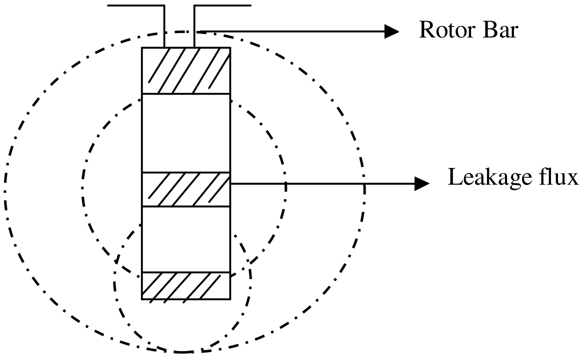


Figure 4. Squirrel-cage induction motor

In a **wound-rotor motor**, the rotor winding is made of many turns of insulated wire and is connected to slip rings on the motor shaft. An external resistor or other control devices can be connected in the rotor circuit. Resistors allow control of the motor speed, although significant power is dissipated in the external resistance. A converter can be fed from the rotor circuit and return the slip-frequency power that would otherwise be wasted back into the power system through an inverter or separate motor-generator[7].

The wound-rotor induction motor is used primarily to start a high inertia load or a load that requires a very high starting torque across the full speed range. By correctly selecting the resistors used in the secondary resistance or slip ring starter, the motor is able to produce maximum torque at a relatively low supply current from zero speed to full speed. This type of motor also offers controllable speed.

Where

φma = Air gap flux per pole
Fmr= peak rotor Mmf, ampere turns
dr = torque angle

For any speed wm < wms, the rotor and stator field remain stationary and a steady torque is produced for speed wm = wms ,the relative speed between the stator field and the rotor reverse and have a phase sequence opposite to that of the stator. The 3-phase rotor current produces a field which moves with respect to the rotor at the slip speed. Hence, the rotor field moves in space at the same speed as the stator field and a steady torque is produced. Since the direction of rotor current has reversed, the developed torque has a negative sign suggesting generator operation which is employed to produce regenerative braking.

The Microcontroller

A microcontroller is a computing device capable of executing programs (i.e. a sequence of instructions) and is often referred to as the brain or control center in a system since it is usually responsible for all computations, decision making, and communications [3].

In order to interact with the outside world, a microcontroller possesses a series of pins (electrical signal connections) that can be turned HIGH (1/ON), or LOW (0/OFF) through programming instructions. These pins can also be used to read electrical signals (coming form sensors or other devices) and tell whether they are HIGH or LOW.

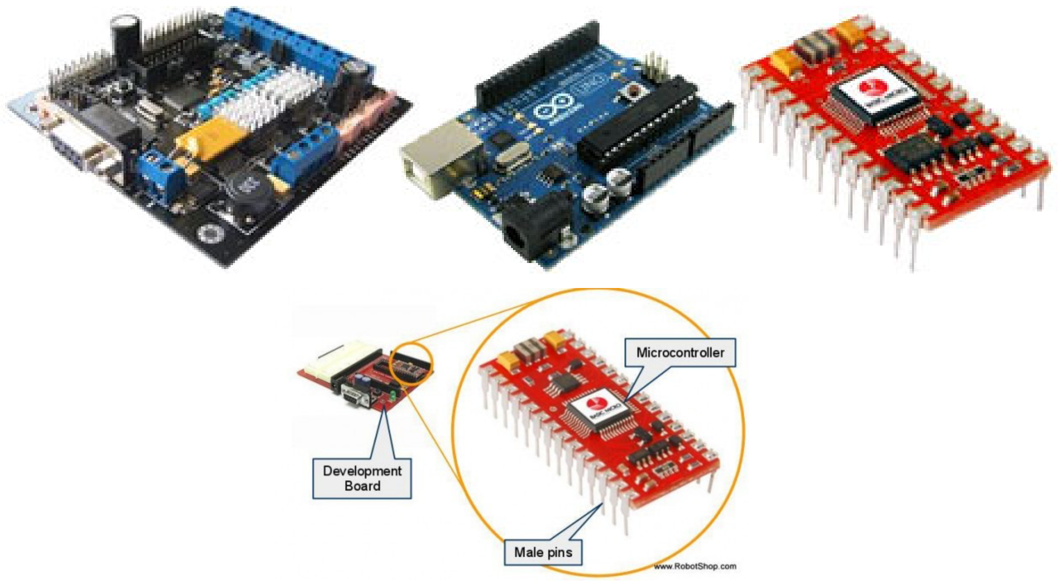


Figure 5. The micro controller

Most modern microcontrollers can also measure analogue voltage signals (i.e. signals that can have a full range of values instead of just two well defined states) through the use of an Analogue to Digital Converter (ADC). By using the ADC, a microcontroller can assign a numerical value to an analogue voltage that is neither HIGH nor LOW.

Programming the Microcontroller

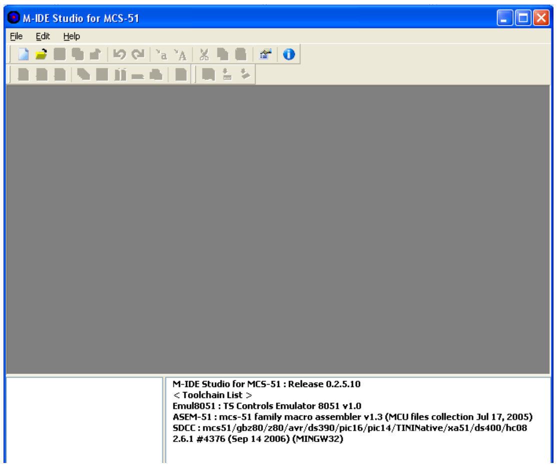
Being afraid of programming microcontrollers is getting old fashioned. Unlike the old days where making a light blink took advanced knowledge of the microcontroller and several dozen lines of code (not to mention parallel or serial cables connected to huge development board), programming a microcontro is very simple thanks to modern Integrated Development Environments (MIDE) that use up-to-ller date languages, fully featured libraries that readily cover all of the most common (and not so common) action, and several ready-made code examples to get beginners started.

Now-a-days, microcontrollers can be programmed in various high-level languages including C, C++, C#, processing (a variation of C++), Java, Python, .Net, and Basic. Of course, it is always possible to program them in Assembler (which was used to achieve this system) but this privilege is reserved for more advanced users with very special requirements (and a hint of masochism). In this sense, anyone should be able to find a programming language that best suit their taste and previous programming experience.

[8]MIDEs are becoming even simpler as manufacturers create graphical programming environments. Sequences which used to require several lines of code are reduced to an image which can be connected to other images to form code. For example, one image might represent controlling a motor and the user need only place it where he/she wants it and specify the direction and rotation per minute (rpm).

On the hardware side, microcontroller developments boards add convenience and are easier to use over time. These boards usually break out all the useful pins of the microcontroller and make them easy to access for quick circuit prototyping. They also provide convenient USB power and programming interfaces that plug right into any modern computer.

For those unfamiliar with the term,[11] a Development Board is a circuit board that provides a microcontroller chip with all the required supporting electronics (such as voltage regulator, oscillators, current limiting resistors, and USB plugs) required to operate. If you are not planning to design your own support circuit, buying a development board is preferable to simply getting a single microcontroller chip.



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M-IDE Studio for MCS-51 : Release 0.2.5.10
< Toolchain List >
Emul8051 : TS Controls Emulator 8051 v1.0
ASEM-51 : mcs-51 family macro assembler v1.3 (MCU files collection Jul 17, 2005)
SDCC : mcs51/gbz80/z80/avr/ds390/pic16/pic14/TININative/xa51/ds400/hc08
2.6.1 #4376 (Sep 14 2006) (MINGW32)
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Figure 8. MIDE programming environment

DISCUSSIONS

Application of electric motors revolutionized industry. Industry processes were no longer limited by power transmission using shaft, belts compressed air or hydraulic pressure. Instead every machine could be equipped with its own electric motor, providing easy control at the point of use, and improving power transmission efficiency. Electric motors applied in agriculture eliminated human and animal muscle power from such tasks as handling grain or pumping water. Household uses of electric motors reduced heavy labor in the home and making comfort and safety possible. Today, electric motors consume more than half of all electric energy produced. Induction motor being the major and commonly used type of electric motor which is applicable in every electronic devices and appliances nowadays; in the industry, in homes, offices, even in the computer printers and artificial intelligent systems like the robots [2], the need to control the speed of the mechanical loads attached to the induction motors by microcontroller for several reasons including high robustness, reliability, low cost, saving of *energy, high efficiency and lower maintenance requirement attracted us to this research work.*

Activities of the System Design

During the System design the following activities were undertaken.

a. Sub systems and major components were identified.
b. Any inherent concurrency was identified.
c. Sub-systems were allocated to processors.
d. A data management strategy was selected
e. A strategy and standards for human computer interaction were chosen
f. Code development standards were specified.
g. The control aspects of the application were planned
h. Test plans were produced.
i. Priorities were set for design trade-offs.
j. Implementation requirements are identified (for example, codes conversion).

Rumbaugh et al. (1991) proposed a similar list of activities, and equivalent activities for real time structured design were cited by Goldsmith (1993). The product of the system design process is not a detailed specification. It is rather a specification of the design context that can guide the developers as they make detailed design decisions regarding the design specification form from which construction will proceed [1].

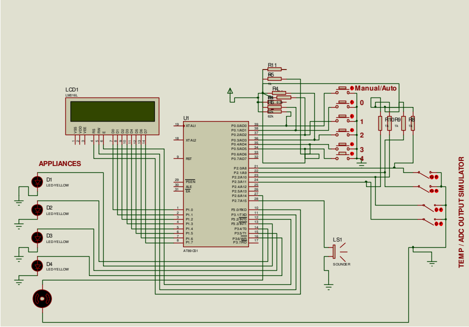

Figure 9: The System Circle

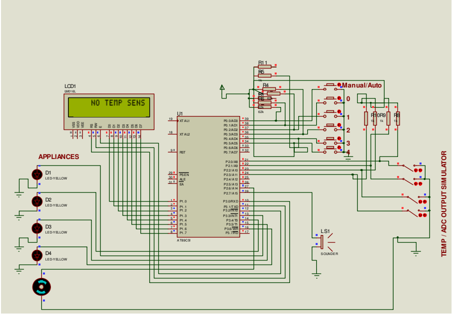

Figure 10: System at Initial Stage

Mode of Operation

After programming, building and burning (if we wish to construct a physical design with the micro- controller) but we are going to simulate the design which was done on ISIS professional 6 (fig 9) which provides the development environment for PROTEUS VSM, a revolutionary interactive system level simulator. This product combines mixed mode circuit simulation, micro-processor models and interactive component models to allow the simulation of complete micro-controller based designs. The present system comprises of one induction motor (in the fan), a microcontroller and other components which has been mentioned above which acts as the central processing unit that controls the whole activity of the system.

At the control circuit, the following three parameters should be adjusted.

I. Speed reference value in digital form from the comparator.
II. Control rate value (Deceleration and Acceleration) according to the temperature the atmosphere.
III. the voltage supplied to the comparator in accordance to the atmospheric temperature sense.

These values will be changed with the change in the value of the atmospheric temperature. In this design we used four speed reference values (speed 1, speed 2, speed 3 and speed 4). Once the system is on and the sensor might detect room temperature or the present temperature of the room otherwise the display unit will show *no temp sensed* therefore the speed of the induction motor is 0, at this stage the digital inputs is 1:1:1:1(figure 9).

If temperature between 28 degree and 0 degree Centigrade (room temp) is detected with digital inputs at 1:1:1:0, the induction motor (in the fan) will rotate at *speed 1* and the display unit will show *temp @ room; speed 1 = 500rpm as shown in the figure 11.*

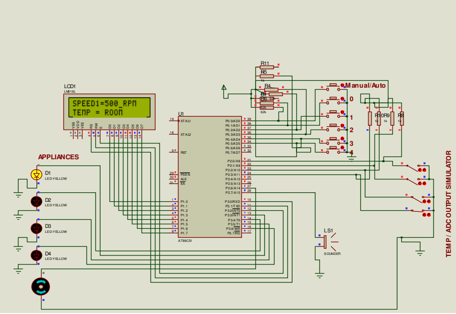

Figure 11. System at speed 1

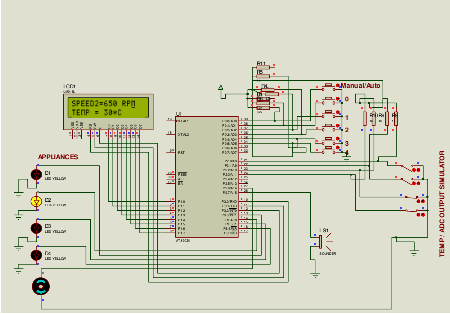

Figure 12. System at speed 2

If temperature between 29 degree and 35 degree Centigrade is detected with digital inputs at 1:1:0:0, the fan will rotate at *speed 2* and the display unit will show *temp 2; speed 2 = 650rpm as shown in the figure 12.* If the temperature between 36 and 40 is detected with digital inputs at 1:0:0:0, the fan will rotate at *speed 3* and the display unit will show *temp 3; speed 3 = 800rpmas shown in the figure 13.* If temperature 40 degree Centigrade and above is detected with digital inputs at 0:0:0:0, the fan will rotate at speed 4 and the display unit will show *temp 4; speed4 = 950rpmas shown in the figure 14.*

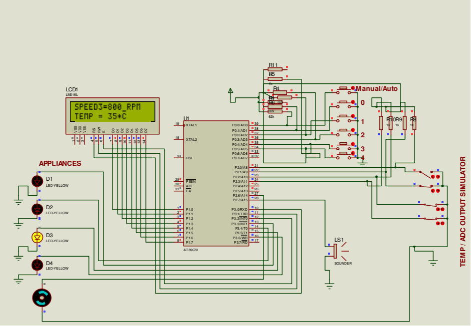

Figure 13. System at speed 3

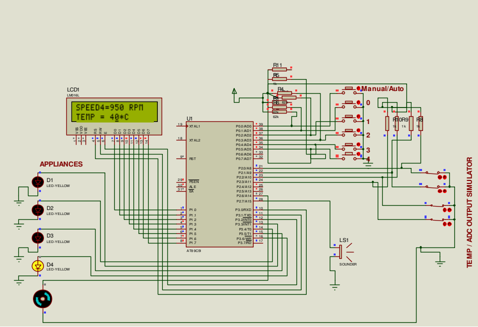

Figure 14. System at speed 4

This system work in a sequential manner that there is no way one can jump the digital inputs that is jumping from speed 0 to speed 4 or keying in wrong inputs. Example these are the digital inputs; at speed 1, the digital inputs are → 1110, if one mistakenly input 1101 or any other wrong inputs, the display unit will show *sensor error* .

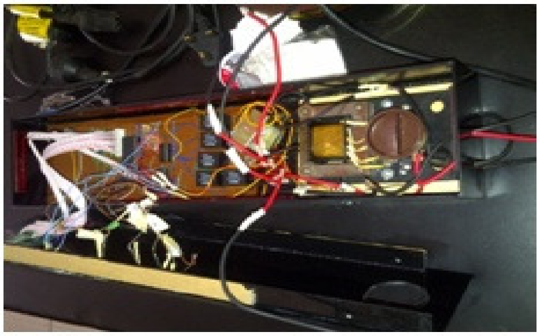

Figure 15. The constructed system

Figure 16. The packaged system

Figure 17. The system with the mechanical load (ceiling fan)

Review of Achievements

The development of this system which is capable of regulating the speed of the induction motor considering any mechanical loads either constant speed load or variable speed load or adjustable speed load is worthwhile. This system was developed due to the possibility of various speed controls of an induction motor using computer systems. At the end of this research, we were able to develop a simulated working prototype of a speed control system. This system has the ability to control the various speed levels of induction motors once it is properly connected, switched on with the right inputs. Finally, the prototype will aid those who wish to construct the system to start off without starting from the scratch.

Application Areas

CBCS will aid industry processes which were limited by power transmission using shaft, belts compressed air or hydraulic pressure. Instead every machine could be equipped with its own CBCS, providing easy control at the point of use, and improving power transmission efficiency. Automated Electric motors will be applied in agriculture eliminated human and animal muscle power from such tasks as handling grain or pumping water. Household uses of electric motors will also be automated reducing heavy labor in the home and make higher standards of living, convenience, Comfort and safety possible.

RECOMMENDATIONS

This research is highly recommended to construction companies, colleges, polytechnics and university students especially those in electrical/electronics and in computer science who wish to carry out more research in the area of a speed control systems. We believe that there is always a room for more improvement on this system. Much improvement can be made such that it can be widely used at homes, offices, churches and industries to control the speed of electrical gadgets using an induction motor.

CONCLUSION

This system was successfully implemented and constructed. During the course of implementation of this project, the system was tested for a while for perfect reliability. The result obtained has confirmed the achievement of the desired goal which was making it possible for manually operated induction motors considering any mechanical load to be computer based.

REFERENCES

[1]. Allworth, O. (2003). *Introduction to real-time software design.* Macmillan Round mill.

[2]. Anigbogu, S. O. (2003). *Fundamental principles of Artificial Intelligent and Expert.* Nimo: Charles and Patrick Ltd.

[3]. Balaji, F. (2000).*Embedded system design using 8031 microcontroller.* Pune: Frontline electronic.

[4]. Booch, G. (1996). *Object Solutions: Managing the Object-Oriented Project*. Redwood City, Califonia.

[5]. Dubey, G. K. (2002). *Power semi conductor controlled drives.* Englewood Cliffs: Prentice hall.

[6]. Carroll, J. & Moran,T. (1991). *Introduction to Special Issue on Design Rationale.* Human Computer Interaction 6, (pp 3-4)

[7]. Hubert, C. (2001). *Electric machines: Theory, Operations, applications adjustment and control.* McMillan, New York,

[8]. S. Okide, C., Ezekwe, N., Mberedogu, & Onuodu, F. (2011). *System Analysis, Design and Development.* Onitsha: Heroes publisher.

[9]. Rawshaw, B. (2000). *Power electronics-Thyristors controlled power for electric motors*. London: Chapman and Hall.

[10]. Bansler, J. P. & Bødker, K. (1991). A Reappraisal of Structured Analysis: Design in an Organizational Context. *ACM Transactions on Information Systems, 11*(2), 165-193.

[11]. Shneiderman, B. (1992). *Designing the User Interface.* Reading, MA: Addison-Wesley.