DESIGN OF AN INTELLIGENT POWER SUPPLY

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Electrical Engineering

By

CH SATISH KUMAR, ABHISHEK BHALOTIA & GANESH KUMAR

Department of Electrical Engineering
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Under the guidance of
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CONTENTS

National Institute of Technology
Rourkela

CERTIFICATE

This is to certify that the thesis entitled **"Designing an intelligent power supply"** submitted by **Ch. Satish Kumar (Roll No: 10602034), Abhishek Bhalotia (Roll No: 10602045) & Ganesh Kumar (Roll No: 10602047)** in the partial fulfilment of the requirement for the degree of **Bachelor of Technology** in **Electrical Engineering**, National Institute of Technology, Rourkela, is an authentic work carried out by them under my supervision.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other university/institute for the award of any degree or diploma.

06/05/2010

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ROURKELA

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Submitted by:

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CHAPTER I

INTRODUCTION TO POWER SUPPLY

[1]A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and most rarely to others. A power supply may include a power circulation system as well as primary or secondary sources of energy such as batteries, or low power computer instruments coupled with their sources, cells, solar power, etc. Constraints that commonly affect power supplies are:

(a) The amount of power they can supply

(b) How long they can supply it without needing some kind of re-fuelling or recharging

(c) How stable their output voltage or current is under varying load conditions

(d) Whether they provide continuous power or pulses and there

A regulated power supply or stabilized power supply is one that includes circuitry to tightly control the output voltage and/or current to a specific value. The specific value is closely maintained despite variations in the load presented to the power supply's output, or any reasonable voltage variation at the power supply's input.

Power Supplies are categorized as:

a) Linear Power Supplies: These power supply designs have simple design and construction but do become very bulky and heavy as the requirements are increased in terms of current or voltage. Voltage Regulation is very poor and can often yield low efficiency levels when used in conjunction with varying loads.

b)Switching Power Supplies: These power supplies implement switches like semiconductor diodes, Thyristors, IGBT, etc. in order to control the output from an AC source and have often complex control mechanisms associated with them. These power supplies are often very light and therefore used for most of the applications now days.

TRADITIONAL POWER SUPPLY

Early power supply systems were basically linear types which offer the benefit of mobility, portability and reliability. A battery is generally a combination of one or more electrochemical cell which is used to convert stored chemical energy into electrical energy. Dry cell batteries are commonly available which were manufactured by stacking a carbon plate, a layer of electrolyte paste and a zinc plate alternately until the desired total voltage is achieved. A linear power supply uses transformer to convert one voltage level to other voltage level that may be more or less. For dc voltage as an output rectifier is used. Pulsating current from rectifier is smoothened by capacitor. The voltage produced by an unregulated power supply will vary depending on the load and on variations in the AC supply voltage. To stabilize and adjust the output voltage regulator is used which will reduce the ripple and noise in the output dc current. Regulators also provide current limiting, protecting the power supply and attached circuit from over current.

For constant direct voltages, AC Rectified voltages were used which implemented diodes and vacuum tubes as their switching devices but these devices suffered from the fact that there is no control over conduction.

VARYING LOAD REQUIREMENTS

Load plays an important role in performance of any electrical systems like output voltage or current. Basically Electrical load is combination of resistance, inductance and capacitance.
In resistive load voltage and current phase are in same direction and produces heat and light out of electrical energy. Example of resistive load is mainly lights and heating system.
In Inductive load current wave form lags behind the voltage waveform. This type of load is generally motor and transformer.
In capacitive type load current waveform leads the voltage wave form. Examples of capacitive load are capacitors, wiring, cable, etc.
Two things which get affected by change in load is power factor and voltage regulation.
The power factor is defined as the ratio of real power flowing to the load to the apparent power. It is a measurement of how efficiently a facility uses electrical

energy. A high power factor indicates that electrical capacity is being utilized effectively .and a low power factor indicates poor utilization of electric power.

For pure resistive load power factor is unity and for pure inductive and capacitive load power factor is zero. Our electrical load is neither pure resistive nor inductive. It is always a combination of resistance and inductance. So power factor for industrial load is always less than one. It means that the circuit's wiring has to carry more current than what would be necessary with zero reactance in the circuit to deliver the same amount of (true) power to the resistive load. Lightly-loaded or varying-load inductive equipment such as HVAC systems, arc furnaces, moulding equipment, presses, etc., are all examples of equipment that can have a poor power factor. We should take care of low power factor because it means that they are using a facility's electrical system capacity inefficiently. It can cause equipment overloads, low voltage conditions, greater line losses, and increased heating of equipment that can shorten service life. Most importantly, low power factor can increase an electric bill with higher total demand charges and cost per kWh. Inductive loads, such as motors, will tend to reduce the power factor. Linear loads, such as lighting, will tend to increase power factor. Low lagging power factor conditions can result by the use of various combinations of the following common inductive devices.

- Induction motors, including motors that are parts of compressors on air conditioners, refrigeration systems, pump.
- Inductive loads of fluorescent ballasts
- Rectifiers providing a DC power supply
- Arc welders
- Solenoids
- Induction heaters
- Lifting magnets
- Small "dry-pack'' transformers.

In most cases, the addition of properly sized and applied capacitors can compensate for low lagging power factor conditions. Low leading power factor conditions usually occur as a result of too many fixed capacitors connected to the electric system during lower load (off-peak load) conditions. This condition can be corrected by installing automatic load sensing capacitors or by implementing manual procedure for disconnecting the capacitor when not needed.

Voltage regulation is defined as change is output voltage when load is applied or thrown off. it is generally defined in two ways

- Regulation down means change in output voltage when load current at any power factor is applied.
- Regulation up is defined as change in output voltage when load current given power factor is thrown off.

.If we consider the ideal case then power supplies should have constant voltage. But that is impossible to achieve. The main factors that can alter the output voltage are:

- The first reason is ac line voltage is not constant that alone can responsible for nearly a 20 percent change in the dc output voltage.
- Second reason that changes the dc output voltage is load resistance. This is due to fact that power supply has fixed internal resistance and if the load resistance decreases, then internal resistance of power supply drops more voltage. In electronics equipment load can change as circuit are switched on and off.

FIRING ANGLE CONTROL

Firing angle, or point during the half-cycle at which the SCR is triggered, determines the amount of current which flows through the device. It acts as a high-speed switch which is open for the first part of the cycle, and then closes to allow power flow after the trigger pulse is applied. There are 360 electrical degrees in a cycle; 180 degrees in a half-cycle. The number of degrees from the beginning of the cycle until the switch is gated ON is referred to as the *firing angle*, and the number of degrees that the SCR remains conducting is known as the *conduction angle*. The earlier in the cycle the SCR is gated ON, the greater will be the voltage applied to the load. A comparison between the average output voltages for an SCR being gated on at 30 degrees as compared with one which has a firing angle of 90 degrees leads us to conclude that *earlier* the SCR is fired, the *higher* the output voltage applied to the load. The voltage actually applied to the load is no longer sinusoidal, rather it is pulsating DC having a steep wave front which is high in harmonics. This waveform does not usually cause any problems on the driven equipment itself; In the case of motor loads, the waveform is smoothed by the circuit inductance. However, radio or television interference can occur. Often times the manufacturer of the SCR equipment will include an Electro-Magnetic-Interference (EMI) filter network in the control to eliminate such problems.

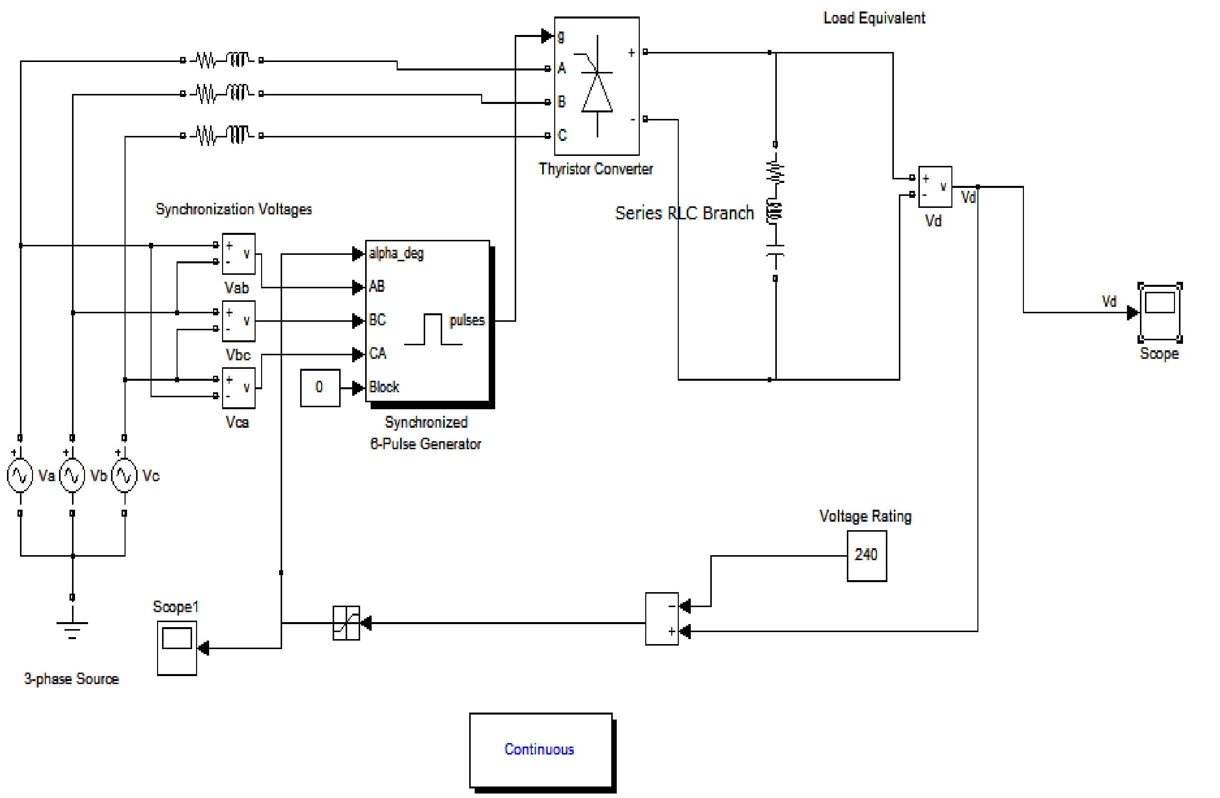
CHAPTER II

PID CONTROLLER IMPLEMENTATION

Switch-mode power converters, or switching converters, are increasingly popular devices for changing the level of electrical energy at the power output by use of a switching action. Digital Signal Processors (DSPs), as they fall in price and increase in capability allow for the economical use of advanced control algorithms and signal processing techniques to improve the quality of the switching converter output and are thus replacing Discrete Analog Components. The generated control signal for switch-mode power converters is pulse-width modulated (PWM) in order to apply the appropriate duty cycle to the switching transistor of the converter.

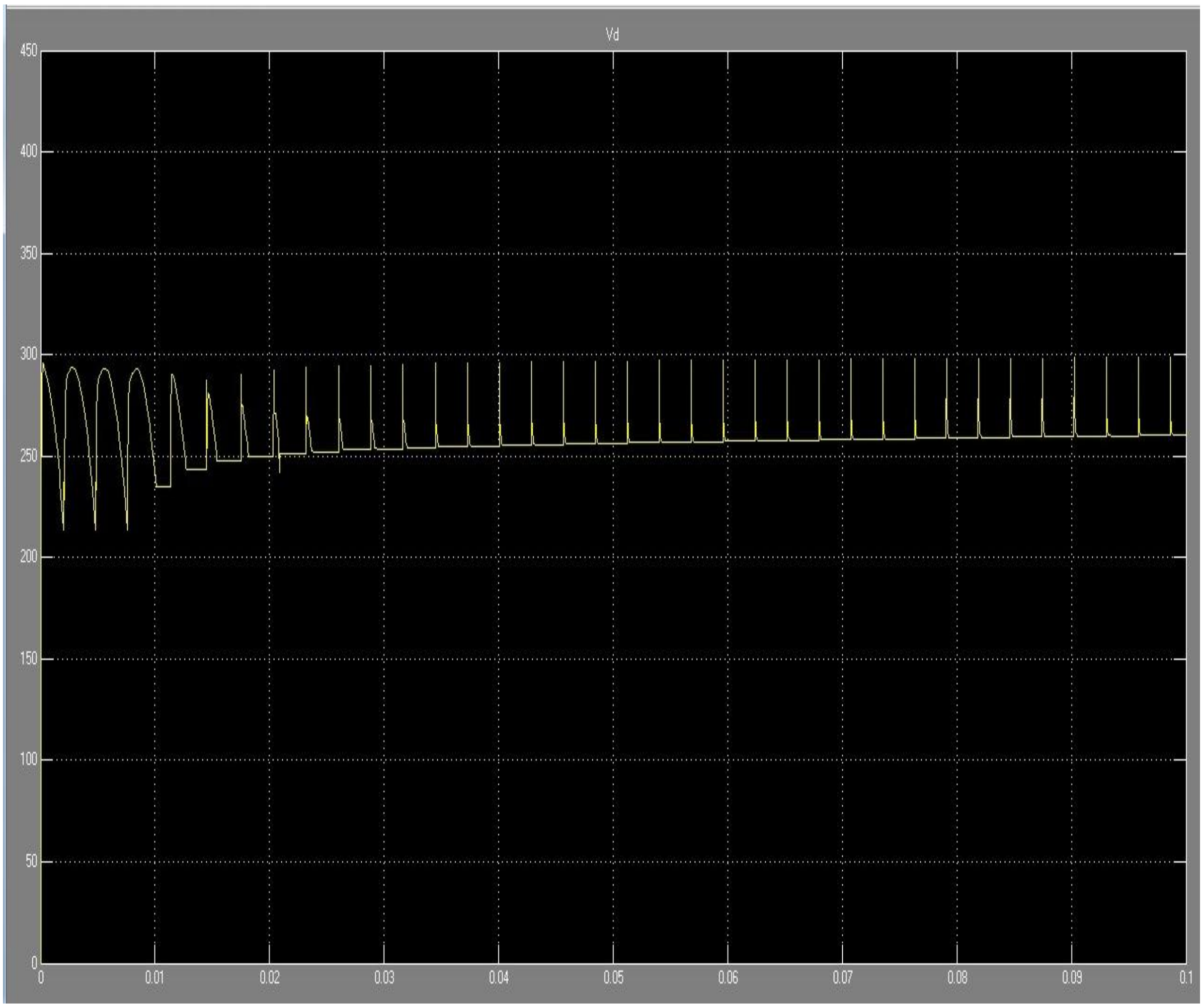
2. a CLOSED LOOP (WITHOUT CONTROLLER)

A power supply system was in its most rudimentary form was implemented using the firing angle control without having any controller in the feedback system. In this system, the error signal between the desired DC signal and the output from the converter system was calculated and was taken as the reference signal for generation of pulse signals to be used in the control signal of converter circuit.



Output Voltage : 240 V

OUTPUT:



The output of the system was observed for standard load specifications with Resistance= 10 ohms and Inductance=0.001H. The ideal output was set at 240V but the output couldn't be achieved because of the saturation characteristics of the feedback loop when implemented. Transient Stability of the system was also poor as there was no standard integral or derivative form which could take care of the sudden increase in error or the previous error encountered in the system.

2. b PID Controllers

PID action is an acronym for “proportional, integral, and derivative.” A PID controller is a controller that includes elements with those three functions. In the literature on PID controllers, acronyms are also used at the element level: the proportional element is referred to as the “P element,” the integral element as the “I element,” and the derivative element as the “D element.”

PID Controller Implementation

PID Control is the method of feedback control that uses the PID controller as the main tool. The basic structure of conventional feedback control systems is shown in following figure, using a block diagram representation. In this figure, the process is the object to be controlled. The purpose of control is to make the process variable *y* follow the set-point value *r*. To achieve this purpose, the manipulated variable *u* is changed at the command of the controller. In some applications, however, a major disturbance enters the process in a different way, or plural disturbances need to be considered. The error *e* is defined by *e* = *r* – *y*. The compensator *C(s)* is the computational rule that determines the manipulated variable *u* based on its input data, which is the error *e.* The last thing to notice is that the process variable *y* is assumed to be measured by the detector, which is not shown explicitly here, with sufficient accuracy instantaneously that the input to the controller can be regarded as being exactly equal to *y*.

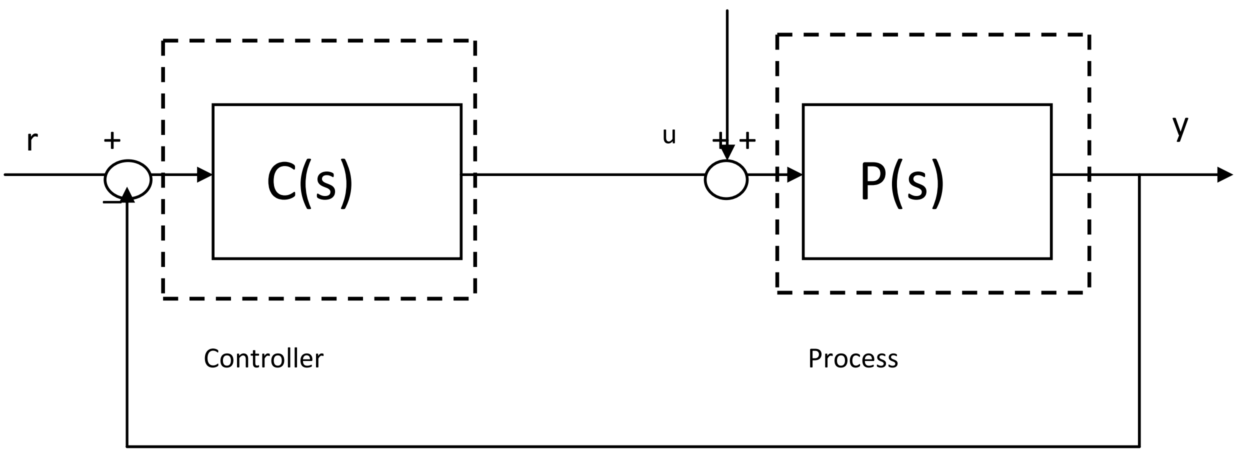


Figure: PID Controller Basic Outline Diagram

The transfer function *C(s)* of the PID *controller is*

$C(s) = K_P (1+ (1/T_I s) + (T_D D(s)))$

given the condition that all the three elements are kept in action. Here, and *T* are positive parameters, which are respectively referred to as “proportional gain,” “integral time,” and “derivative time,” and as a whole, as “PID parameters.” *D(s)* is called the “approximate derivative.” The approximate derivative *D(s)* is used in place of the pure derivative *s*, because the latter is impossible to realize physically. γ is a positive parameter, which is referred to as “derivative gain.” The response of the approximate derivative approaches that of the pure derivative as γ increases. It must be noted, however, that the detection noise, which has strong components in the high frequency region in general, is superposed to the detected signal in most cases, and that choosing a large value of γ increases the amplification of the detection noise, and consequently causes malfunction of the controller. This means that the pure derivative is not the ideal element to use in a practical situation. It is usual practice to use a fixed value of γ, which is typically chosen as 10 for most applications. However, it is possible to use γ as a design parameter for the purpose of, for instance, compensating for a “zero”.

Tuning of PID Controllers

Selecting optimal values for the P and D parameters of a closed loop control system is usually an iterative process. This process is called PID tuning.

Before tuning begins, verify that all components of the control loop operate correctly. Test input processing tasks to verify that the measurements of system output are sampled correctly. Test output procedures to verify that the control output is correctly scaled. Verify that the PID controller processes the sampled input and produces an output sequence which is consistent with the input. If possible, verify that the system responds correctly to its control input.

Knowing that the components work individually still does not guarantee that they will work together. How do you establish initial parameter settings and evaluate closed loop operation without driving the actual system? You can use the multi-tasking capabilities of DAPL to simulate the essential characteristics of your system under closed loop control, using the PID parameters that you specify. Then, when you are satisfied that the settings are reasonable, you can disconnect the simulated system and connect the real system in its place.

The DAPL commands provided simulate the response of an inertial third-order linear system under closed loop PID control. The simulated system samples its control input from analog input channel 0 and sends its output level to analog output channel 0. The PID controller samples its input from analog input channel 1 and produces a control output on analog output channel 1. A sample time of 1/10 second is used both for the PID controller and for the simulated system.

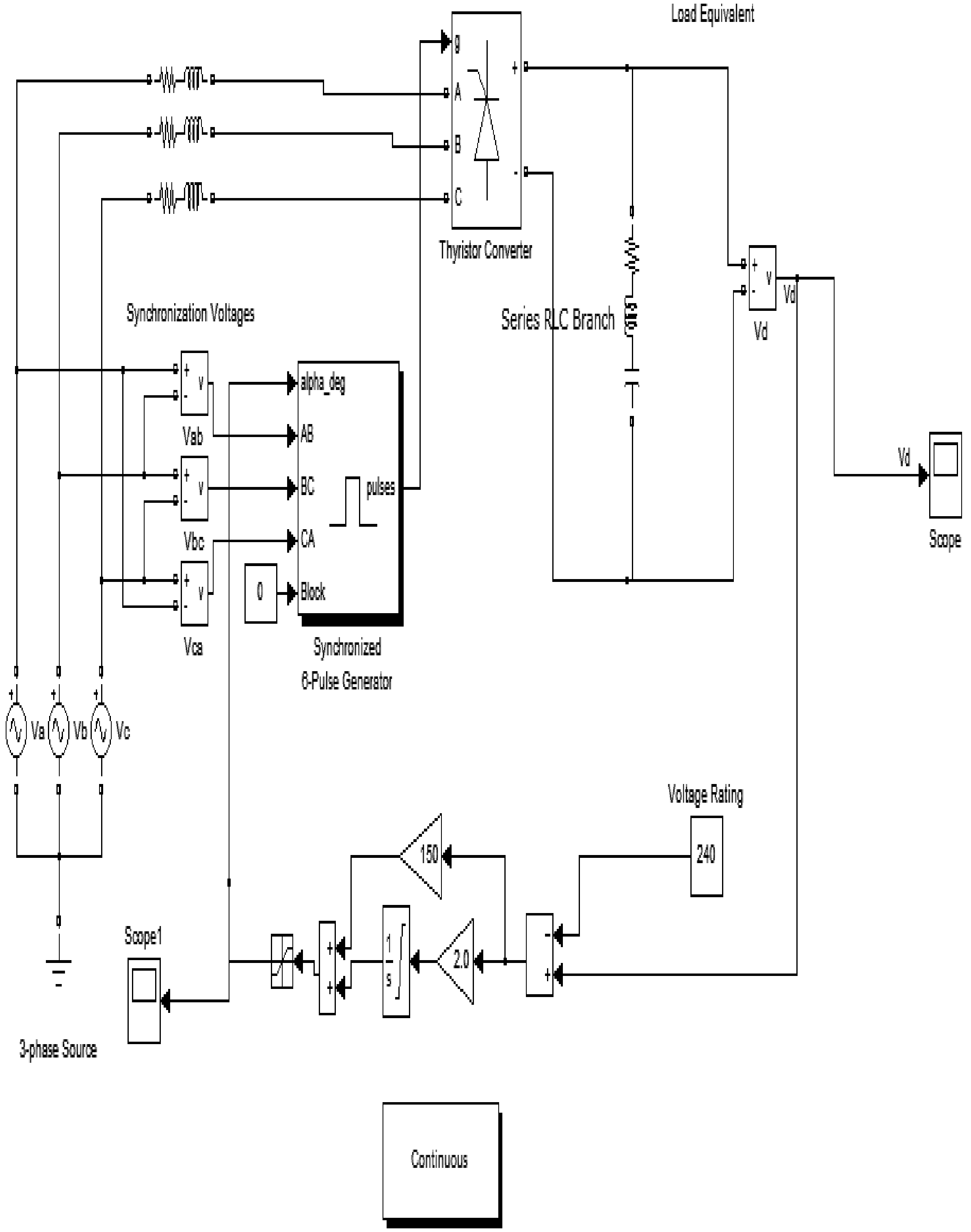
MATLAB SIMULATION OF CIRCUIT

PID control action is implemented in power design problem in order to control the firing angle of thyristor resulting in a switched mode power supply unit for the load which results in a stable DC output. In the Simulation Circuit used for implementation, a PID controller is used in conjunction with the error signal generated by the difference between the output DC voltage and the constant voltage required by the circuit and this modified error voltage after passing through the controller is sent to a saturation box wherein the limits of firing angle are set. The error signal generated thereon is fed to a PWM firing pulse converter which is synchronized so as to generate gating pulses for six thyristor in the three arms of bridge rectifier used along with the input and thus the output is stabilized.

In this circuit, a PI controller is used in the feedback in order to control the firing angle to the thyristor assembly. The input voltages are used for generation of synchronization voltages so that the ignition is proper and stability is high in case of feedback loop.

Delay Angle for Firing Pulse is generated by varying the alpha angle parameter in the PWM generator block. In the firing pulse block, PI controller is implemented owing to the fact that most of the industrial applications don’t involve the usage of derivative controller because of their high costs and the compounded effect that a system noise will have on the performance of converter circuit in case of a derivative controller.

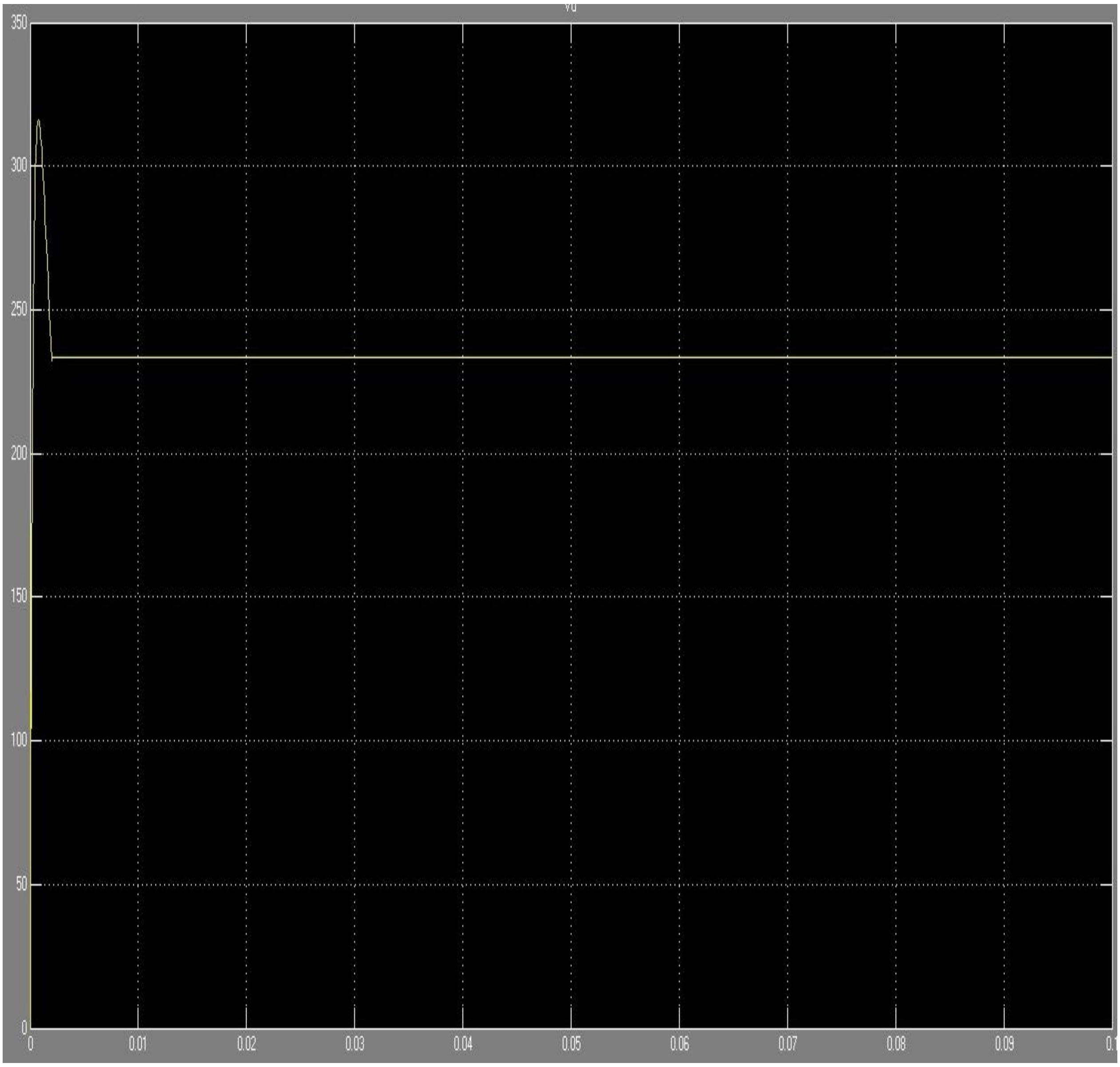
A saturation block is provided next to controller in order to limit the thyristor from entering the inverter state and to limit the value of firing angle between 5^o to 180^o which is the threshold limit for the operation in rectifier mode.



Output Voltage : 240 V

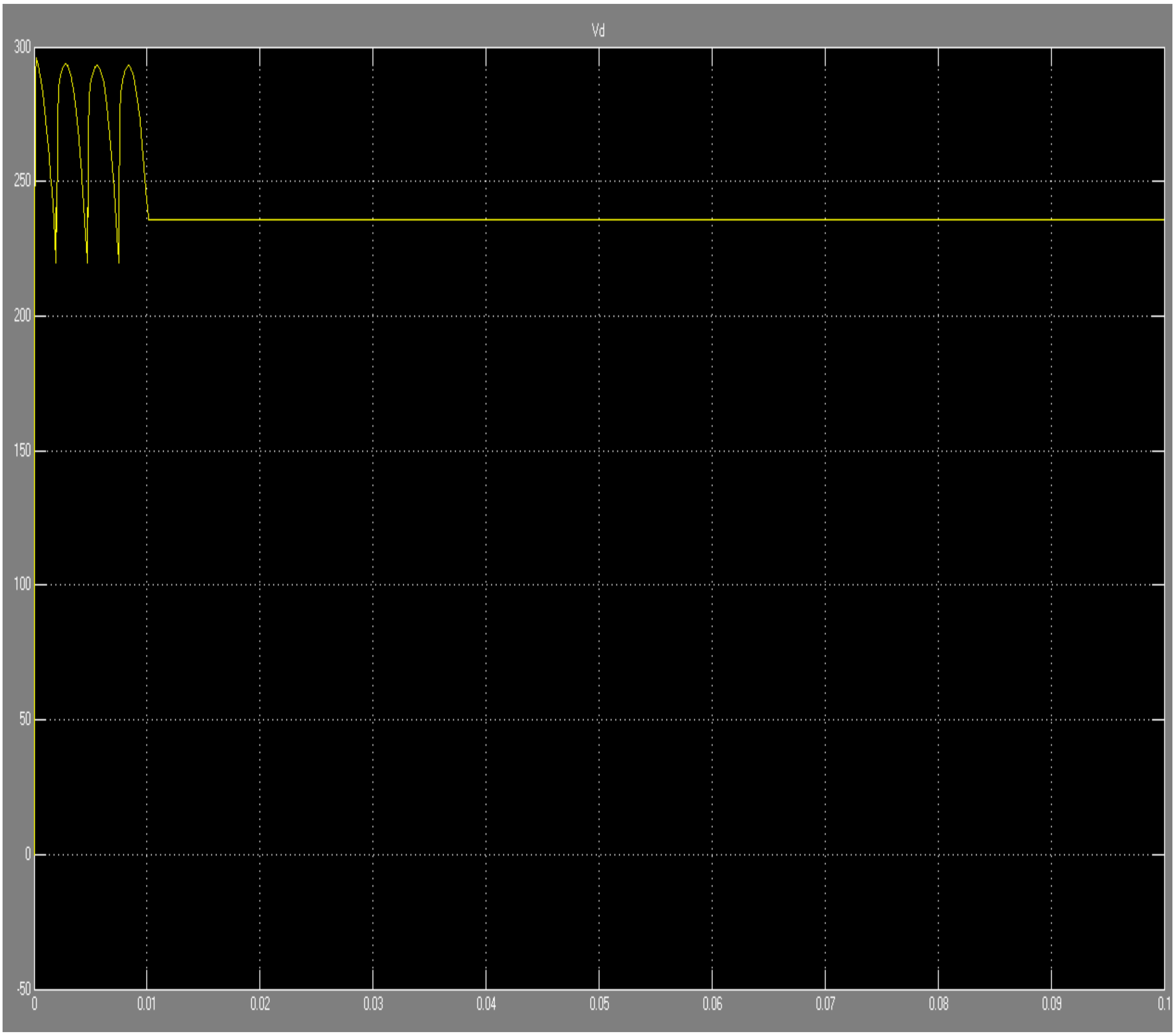
OUTPUT CHARACTERSTICS AND PERFORMANCE EVALUATION

For an output load requirement of 240 Volts and a Load Specification of R=10ohm, L=0.0001H and Capacitance= 10^{-3} F

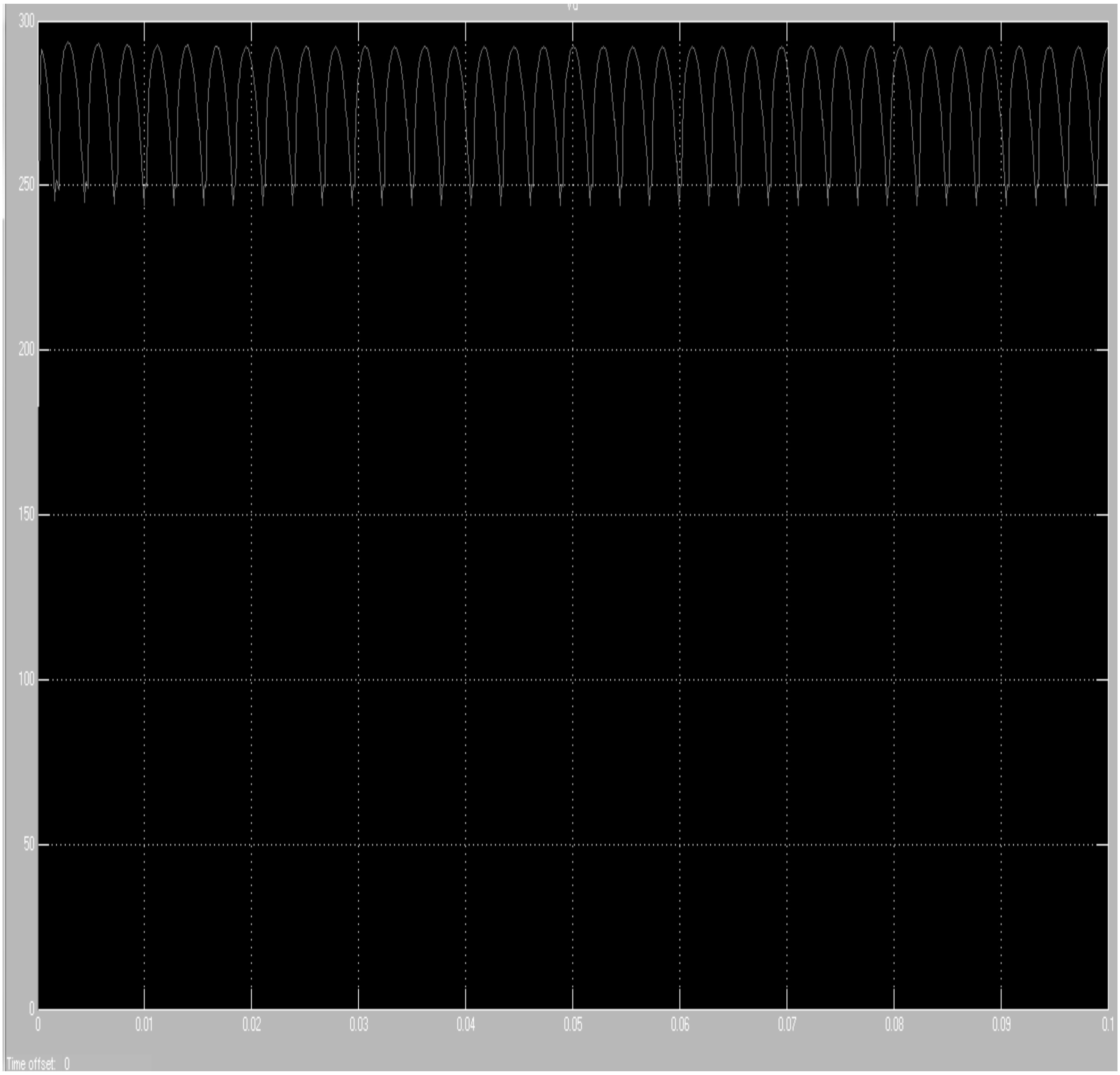


For an output load requirement remaining the same, the variation in output voltage can be due to sudden or slow variation of load. To observe the effect, output voltage waveform of the circuit is studied for changed load and also for transient variation in load i.e. sudden change in load of the circuit.

For an output load requirement of 240 volts, with change in load, the output suffers minor variation in the form of ripples but do try to attain the steady state point after suffering a few cycles of variation in the form of sinusoidal ripples.



The ruggedness of the system is also tested when minor variations in output requirements of the system i.e. when the output voltage is changed from 240V to say 270V suddenly and the output of the system is also to be adjusted for variations in load simultaneously i.e. an extra load is suddenly brought in parallel with the existing load as well. The output curve shows clearly that tuning of PID controller is necessary in order to minimize the harmonic and ripple content of system output.



LIMITATIONS OF PID CONTROL

Integral windup

PID controllers do suffer from a severe problem, known as Integral windup which mainly refers to the accumulation of error in the circuit in case of a severe fault in the system which can lead to just attenuation of error in the power supply leading to even wider fluctuations. This problem can be avoided by adopting means of switching between controller modes in case of errors in the system or by adopting some manual control mechanism which will result in handover of controller modes.

Freezing the integral function in case of disturbances

In a situation or application wherein the set point of the system is likely to get disturbed by some changes in the system load configuration for like, a sudden very heavy load is displaced on the output side of the power supply system, the set-point does fluctuate from the desired or pre-set one which can also result in loss of stability of the system. Integral function in the controller can lead to trouble in such cases by causing a positive error sign instead of the contrary leading to even wider fluctuations and variations in the circuit.

Replacing the integral function by a model based part

During most of the application of PID controllers, the time response is almost known and it is advantageous to simulate such a time response with some model and calculate parameters on the basis of actual response of the system.. For instance, in an electrical furnace, the ambient temperatures and the resulting temperature diagrams of the output can be used to characterize the electrical properties of the whole process and find out the various parameters associated with the process. A series of filters is used to obtain the setpoint of the temperatures by deducting the set-point of temperature by the ambient temperature through some co-efficient of the process. Such results can be employed in case of electrical circuits in order to model the integral model of the system which does prevent in integral windup of the system and other complexities usually associated with PID controllers. Such controllers work almost perfectly in open loop conditions and therefore are more reliable even in circumstances wherein the feedback of the system doesn’t count too much. This sort of procedure is helpful in certain situation, for example in our case in case the sensor (output voltage sensor) fails for some time due to some internal calibration error or some device damage owing to operating conditions, then the system needs to be redundant enough in order to carry out the task on its own without taking the help of the feedback system which is malfunctioning.

Derivative of output

Sometimes, PID controllers do start measuring the derivative of the output rather than that of errors which might lead to erroneous results in the control circuitry and leads to stabilization of the circuit. In such conditions, it is extremely important to ensure that the sign of the derivative of output is same as that of derivative of error or else instead of diminishing the error, it might get amplified leading to voltage shoot out in the output.

Set-point ramping

To avoid the discontinuity in the step change function of PID controller, Set point of PID controller is shifted from its old value to a new modified value in accordance with a ramp control signal generated by the control circuit of the whole system and maintains the stability of the set point of the system.

Set-point weighting

Set-point weighting utilizes multiple numbers of controllers depending upon the errors that occur in a given paradigm. Error in integral term is of prime concern because it affects the steady state stability and error prediction of the system. This sort of constraint do affect the set point of controllers although when it comes to countering disturbances and noises in the system, the response is almost unaffected by such sort of adjustments.

CHAPTER III

FUZZY LOGIC IMPLEMENTATION

INTRODUCTION TO FUZZY LOGIC

Fuzzy logic was first initiated in 1965, by Lotfi A. Zadeh, professor for computer science at the University of California in Berkeley. Fuzzy Logic (FL) is a multivalent logic that allows intermediate values to be defined between conventional evaluations for example true/false, yes/no, high/low, etc. Opinions like rather tall, fullness or very fast can be formulated mathematically and processed by processors, in order to apply a more human-like way of observing things in the programming of micro-processor or computers .Fuzzy systems can be treated as an alternative to traditional notions of set membership and logic that has its origins in ancient Greek philosophy.

Fuzzy logic and probabilistic logic are mathematically similar and both truth values range lies between 0 and 1 – but conceptually distinct, due to different versions. Fuzzy logic relates to "degrees of truth", where as probabilistic logic corresponds to "probability"; as these differ, fuzzy logic and probabilistic logic gives different models of the same system.

The range of both the theories lies between 0 and 1 and hence may appear similar at first. Let us consider there is a box containing 3 books of capacity 10 books. Then there may be two concepts: Empty and Full. The meaning of each of these can be represented by a certain fuzzy set. The box can then be defined as being 0.7 empty and 0.3 full. The concept of emptiness would be subjective and hence would depend on the observer or designer. There may be another observer or designer might equally well design a set of membership function where the box would be considered as full for all values down to 5 books. It is essential to realize that fuzzy logic uses truth degrees as a mathematical model of the blurriness phenomenon while probability can be defined as the mathematical model of randomness. A probabilistic setting would first define a scalar variable for the fullness of the box, and second, conditional distributions describing the probability that by giving specific fullness level someone would call the box full. This model, however, has no sense without accepting the fact that occurrence of some event such that after a few minutes or time, the box will be half empty. The conditioning can be achieved by having a unique observer that randomly selects the quantity for the box, a distribution over deterministic observers, or both. Consequently, probability and fuzziness are not related to each other.

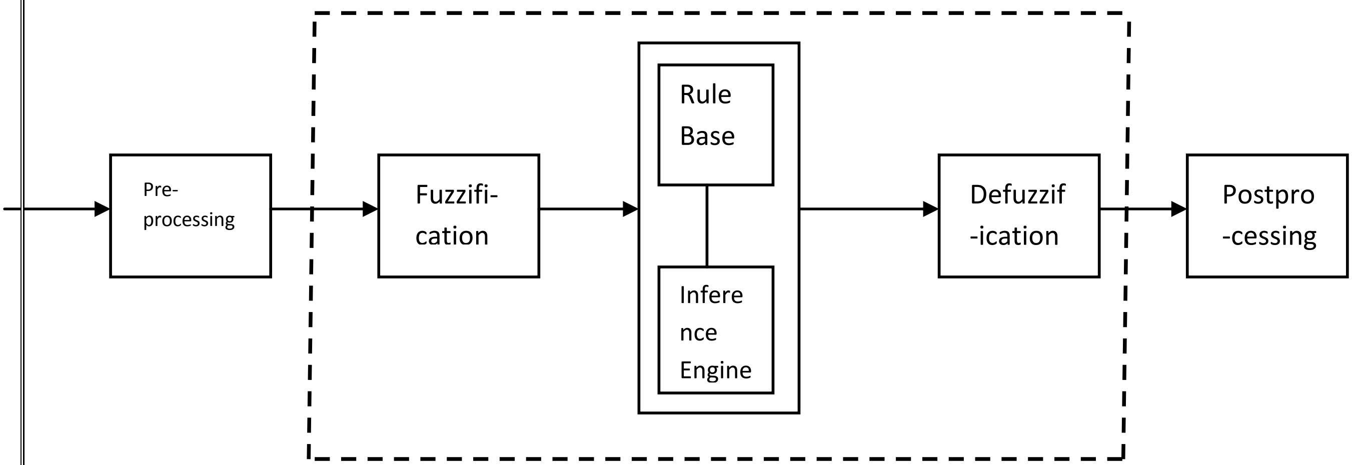
FUZZY LOGIC CONTROLLER

We have to design a controller instead of PID controller which increases the system efficiency and reduces the harmonic content in the output load.
Fuzzy logic controller is based on fuzzy logic which includes rules.
The collection of rules is called rule base which is generally in the form of *if - then* format. The if-side is known as the *condition* part and *then* side is called the *conclusion*. The condition part is also known as antecedent and conclusion can also be denoted as *premise*.

The rule base can be of any type for example:
If error in voltage is ZE and change in error is PM then output is PM
If error in voltage is NB and change in error is PS then output is NB.
Where NB-negative big, ZE=zero, PM-positive small and PS= positive small

STRUCTURE OF FUZZY CONTROLLERS

The controller structure is being given below which denotes all various blocks which forms the fuzzy controller.



Fuzzy controller

FUZZY CONTROLLER PROCESS FLOW

Pre-processing (Normalisation of Input)

The input obtained after measurement is often hard or crisp, so proper pre-processing of input data is being done. It includes various process like-

- **Quantisation** in association with sampling or rounding to nearest integers;
- **Normalisation** or scaling onto a particular, standard range of input and output;
- **Filtering** is being done in order to remove noise and harmonics;
- long term or short term tendencies can be obtained by **averaging**;
- A combination of several measurements to find key indicators;
- **Differentiation** and **integration** or their discrete equivalences or the output.

Fuzzification:

Fuzzification is the first block of the controller which converts each part of input data to degrees of membership by a lookup in one or various membership functions. The fuzzification block thus matches the input data with the conditions of the rules given by the rule base (explained below) to find out the degree to which the condition of each rule matches that particular input instance. Each linguistic term has a degree of membership assigned that applies to that input variable.

Membership Function:

The membership function is the abstraction of the index function in classical sets. In fuzzy logic theory, the degree of truth is represented as a prolongation of rating. There is always a confusion prevails between Probability theory and degree of truth but both these theories are completely different, because fuzzy truth represents membership in mistily defined sets, where as probability theory depends on likelihood of some event or condition.

Membership functions on *X* represent fuzzy subsets of *X*. The membership function which represents a fuzzy set $\tilde{A}$is generally denoted by μ_A. For an element *x* € *X* (belongs to *X*), the value $\mu_A(x)$ is known as the *membership degree* of *x* in the fuzzy set $\tilde{A}$.The membership degree $\mu_A(x)$ quantifies the grade of membership of the element *x* to the fuzzy set $\tilde{A}$.The value 0 means that *x* is not considered as the member of the fuzzy set; the value 1 means that *x* is fully or completely a member of the given fuzzy set. The values between 0 and 1 characterise fuzzy members, which corresponds to the fuzzy set only partially.

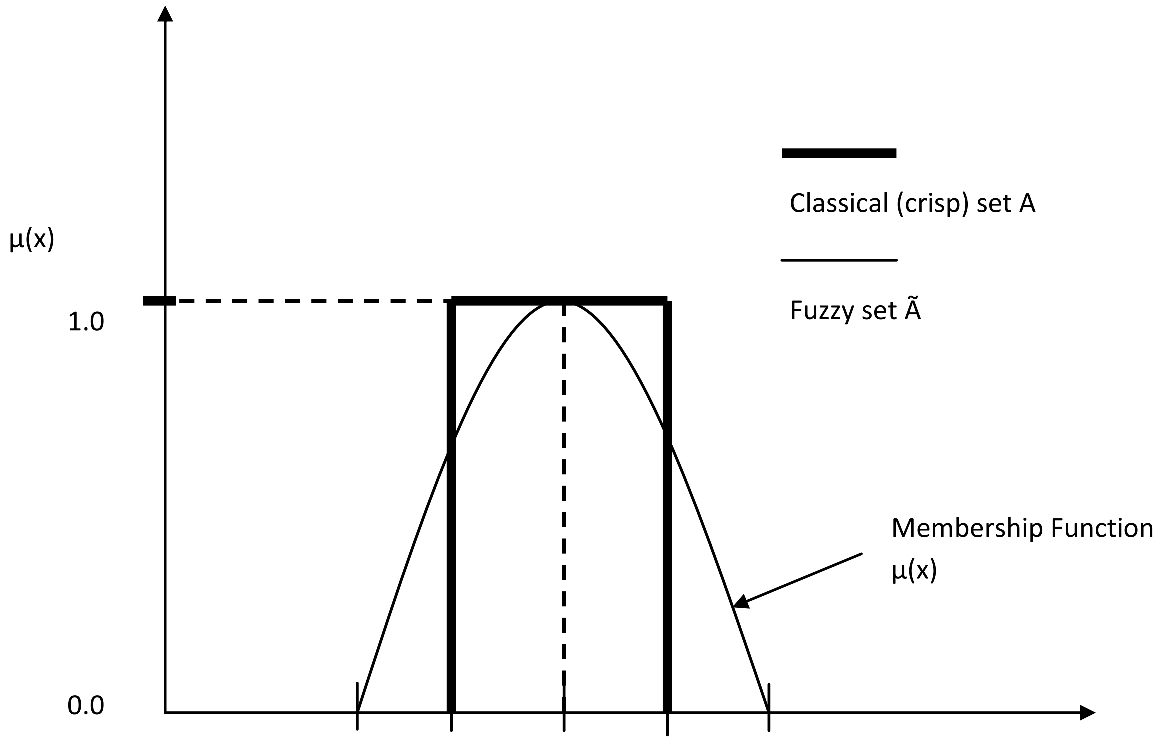
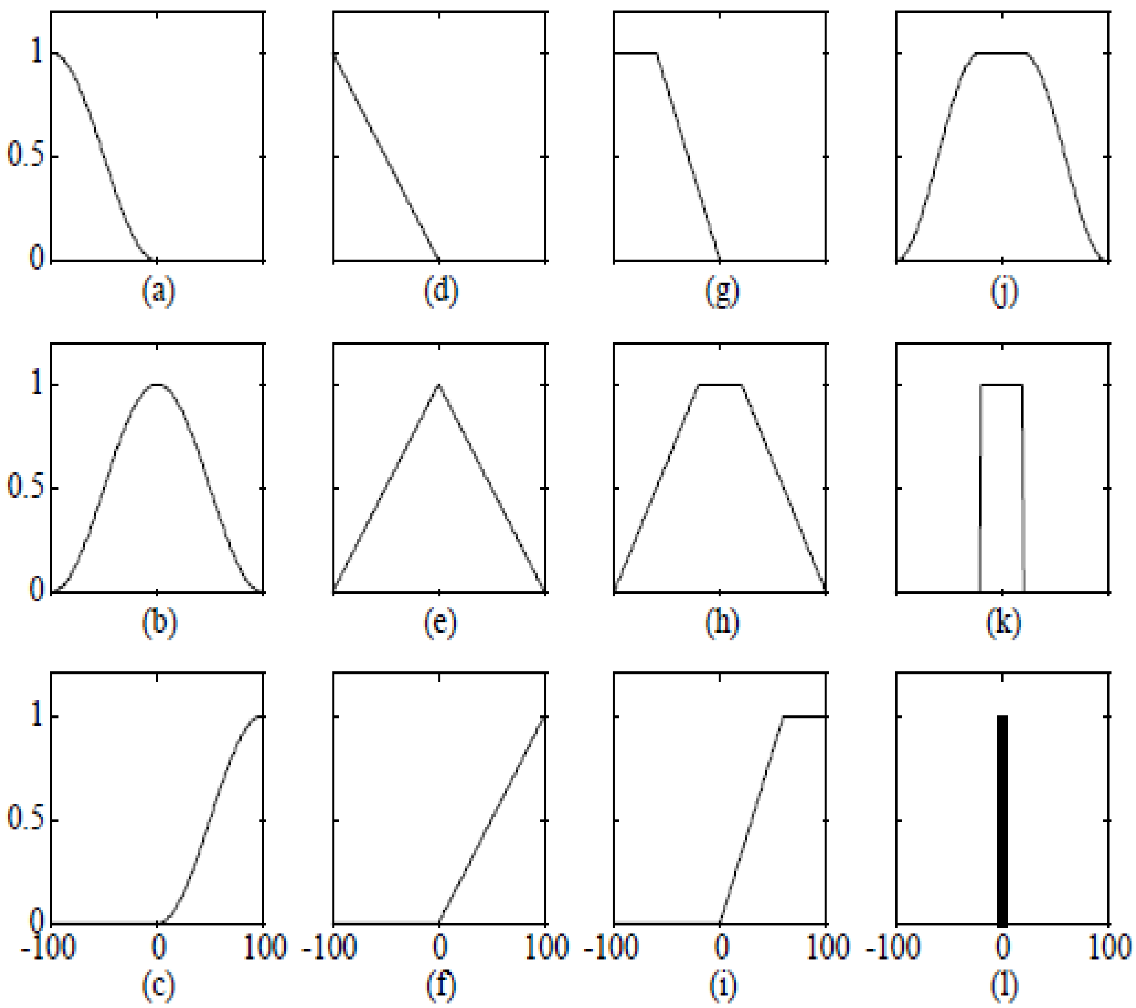


Diagram of a typical membership function



Examples of various membership functions: (a) s-function, (b) π- function, (c) Z- function, (d-f) triangular editions, (g-i) trapezoidal editions, (j) flat π-function, (k) rectangular and (l) impulse or singleton.

RULE BASE

The rules can be used with multi variables both for conclusion and condition. So it can be used for both single input single output system and as well as multi input multi-output systems. A fuzzy controller needs two variables error and change in error.

Let

- **e**=error
- **ce**=change in error
- **du**=change in firing angle

Linguistic fuzzy sets are defined as below

- **Z**= zero
- **PS**=positive small
- **PM**=positive medium
- **PB**=positive big
- **NS**=Negative small
- **NM**=Negative medium
- **NB**=Negative big

The rules for the particular problem are given by:

- If **e** is **NB** and **ce** is **NB** then **du** equal to **NB**
- If **e** is **NB** and **ce** is **NM** then **du** equal to **NB**
- If **e** is **NB** and **ce** is **NS** then du equal to **NB**
- If **e** is **NB** and **ce** is **Z** then du equal to **NB**
- If **e** is **NB** and **ce** is **PS** then du equal to **NM**
- If **e** is **NB** and **ce** is **PM** then du equal to **NS**
- If e is **NB** and **ce** is **PB** then du equal to **Z**
- If e is **NM** and **ce** is **NB** then du equal to **NB**
- If e is **NM** and **ce** is **NM** then du equal to **NB**
- If e is **NM** and **ce** is **NS** then du equal to **NB**
- If e is **NM** and **ce** is **Z** then du equal to **NM**
- If e is **NM** and **ce** is **PS** then du equal to **NS**
- If e is **NM** and **ce** is **PM** then du equal to **Z**
- If e is **NM** and **ce** is **PB** then du equal to **PS**

- If e is **NS** and ce is **NB** then du equal to **NB**
- If e is **NS** and ce is **NM** then du equal to **NB**
- If e is **NS** and ce is **NS** then du equal to **NM**
- If e is **NS** and ce is **Z** then du equal to **NS**
- If e is **NS** and ce is **PS** then du equal to **Z**
- If e is **NS** and ce is **PM** then du equal to **PS**
- If e is **NS** and ce is **PB** then du equal to **PM**
- If e is **Z** and ce is **NB** then du equal to **NB**
- If e is **Z** and ce is **NM** then du equal to **NM**
- If e is **Z** and ce is **NS** then du equal to **NS**
- If e is **Z** and ce is **Z** then du equal to **Z**
- If e is **Z** and ce is **PS** then du equal to **PS**
- If e is **Z** and ce is **PM** then du equal to **PM**
- If e is **Z** and ce is **PB** then du equal to **PB**
- If e is **PS** and ce is **NB** then du equal to **NM**
- If e is **PS** and ce is **NM** then du equal to **NS**
- If e is **PS** and ce is **NS** then du equal to **Z**
- If e is **PS** and ce is **Z** then du equal to **PS**
- If e is **PS** and ce is **PS** then du equal to **PM**
- If e is **PS** and ce is **PM** then du equal to **PB**
- If e is **PS** and ce is **PB** then du equal to **PB**
- If e is **PM** and ce is **NB** then du equal to **NS**
- If e is **PM** and ce is **NM** then du equal to **Z**
- If e is **PM** and ce is **NS** then du equal to **PS**
- If e is **PM** and ce is **Z** then du equal to **PM**
- If e is **PM** and ce is **PS** then du equal to **PB**
- If e is **PM** and ce is **PM** then du equal to **PB**
- If e is **PM** and ce is **PB** then du equal to **PB**
- If e is **PB** and ce is **NB** then du equal to **Z**
- If e is **PB** and ce is **NM** then du equal to **PS**
- If e is **PB** and ce is **NS** then du equal to **PM**
- If e is **PB** and ce is **Z** then du equal to **PB**
- If e is **PB** and ce is **PS** then du equal to **PB**
- If e is **PB** and ce is **PM** then du equal to **PB**
- If e is **PB** and ce is **PB** then du equal to **PB**

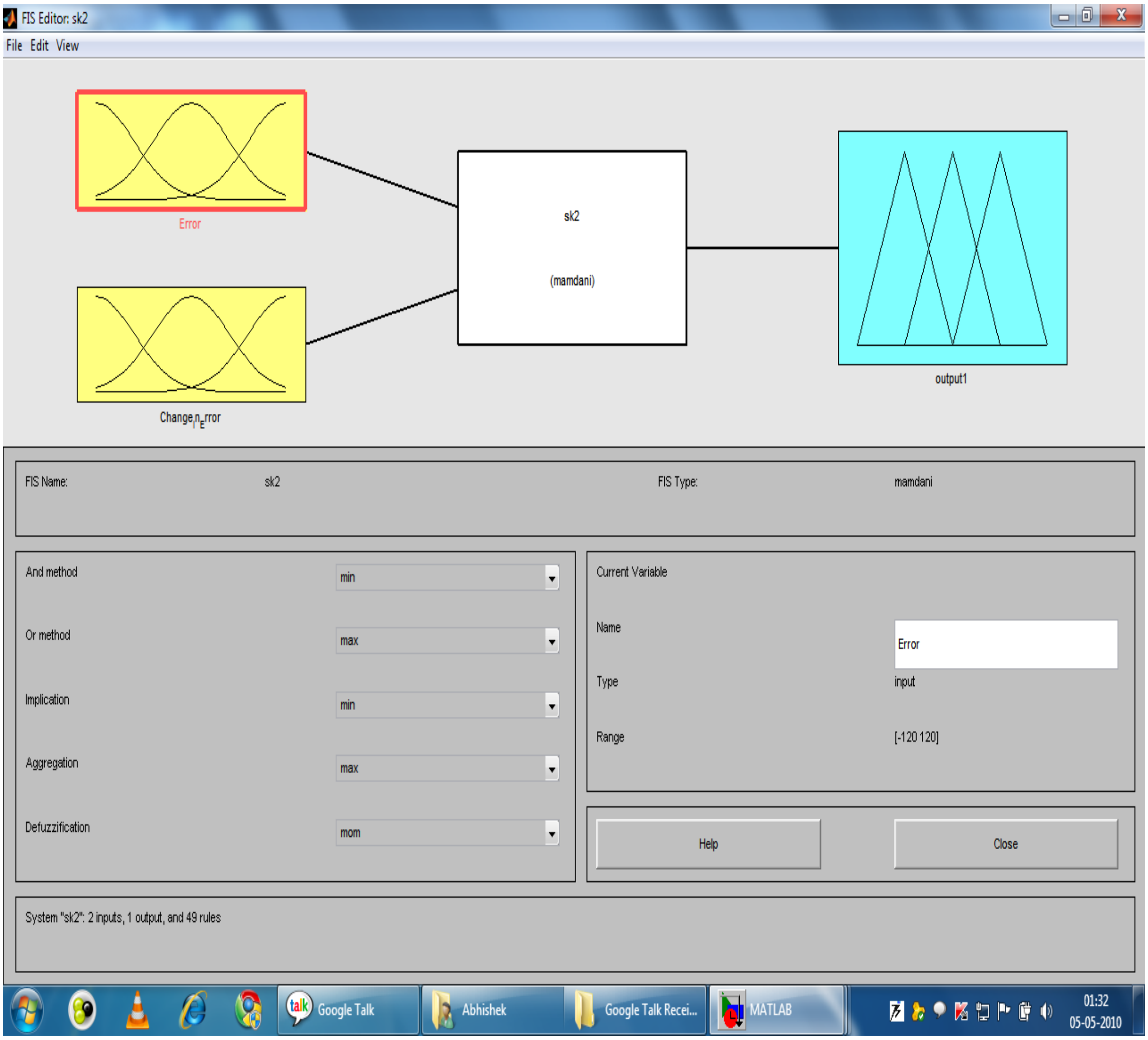
du / ce \ e	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

Rule Matrix for Fuzzy voltage control

Designing a Fuzzy controller Using Matlab

Creating “.fis “file

Step-1 opening FIS editor from the fuzzy tool box:

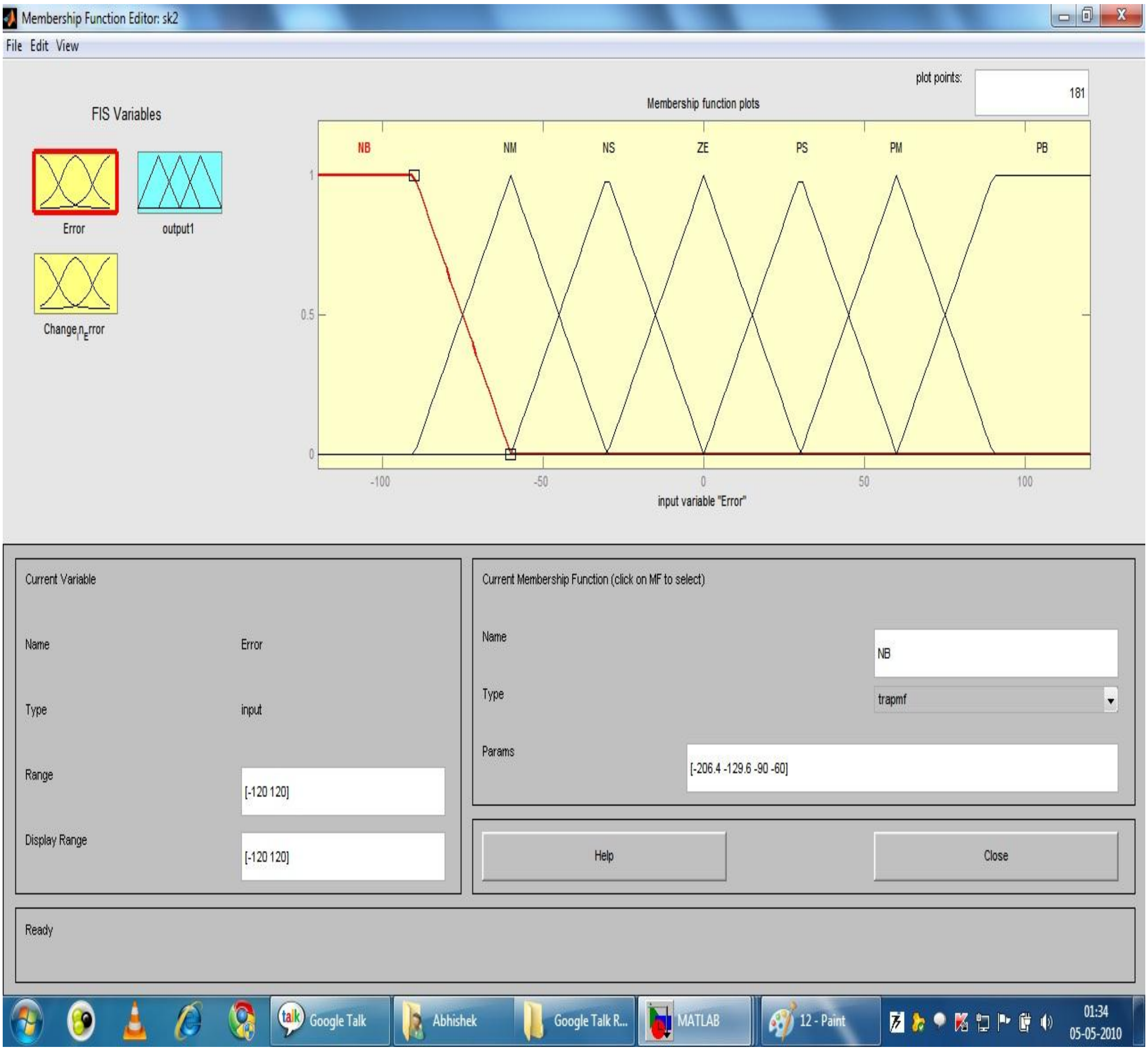


Step-2: defining Inputs and outputs

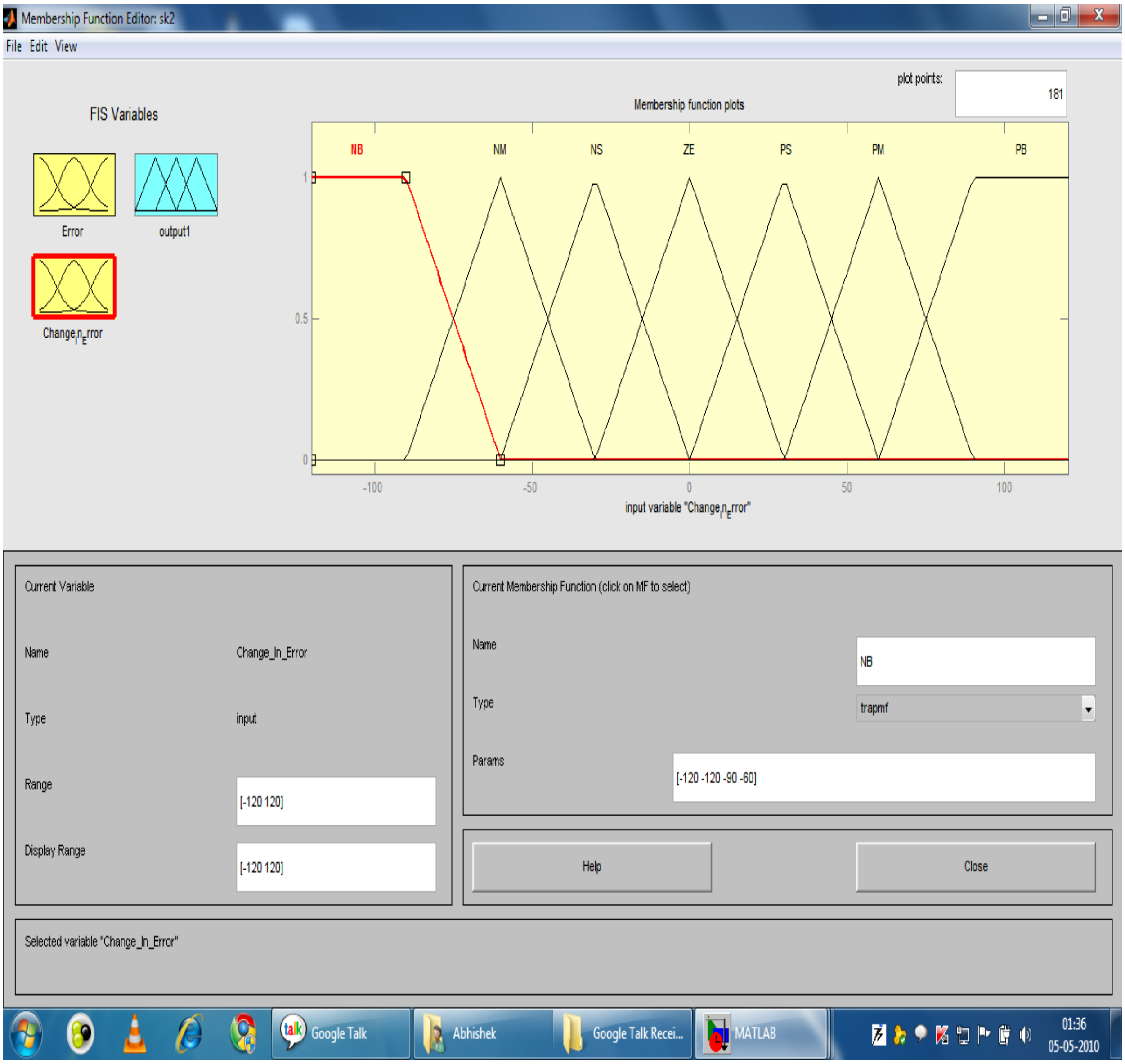
I-Defining Inputs: there are two inputs the Fuzzy controller a)error in the voltage and b)change in error

- Assigning Membership functions to the input variables.

a) For Error in the voltage

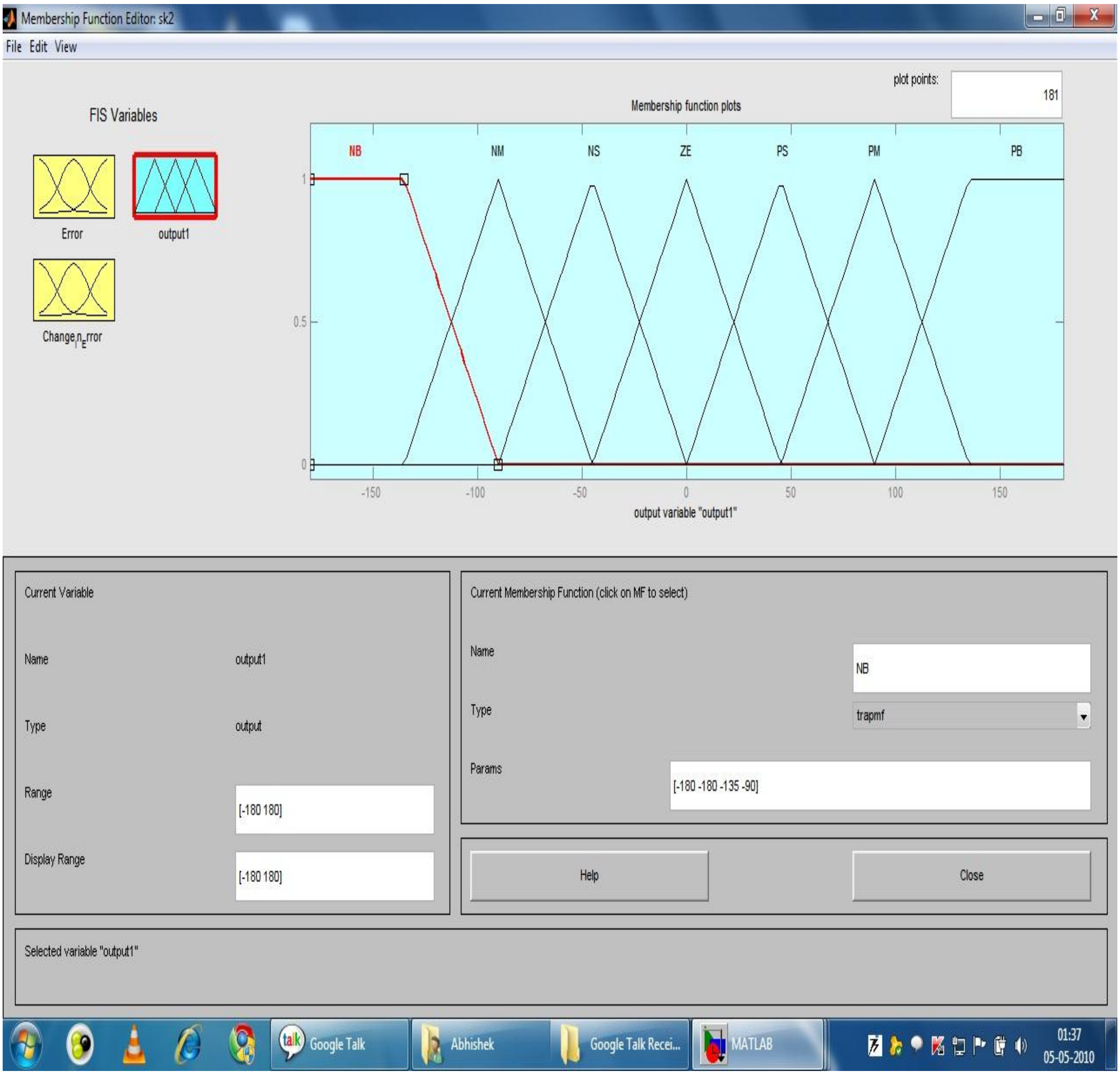


b) For change in Error

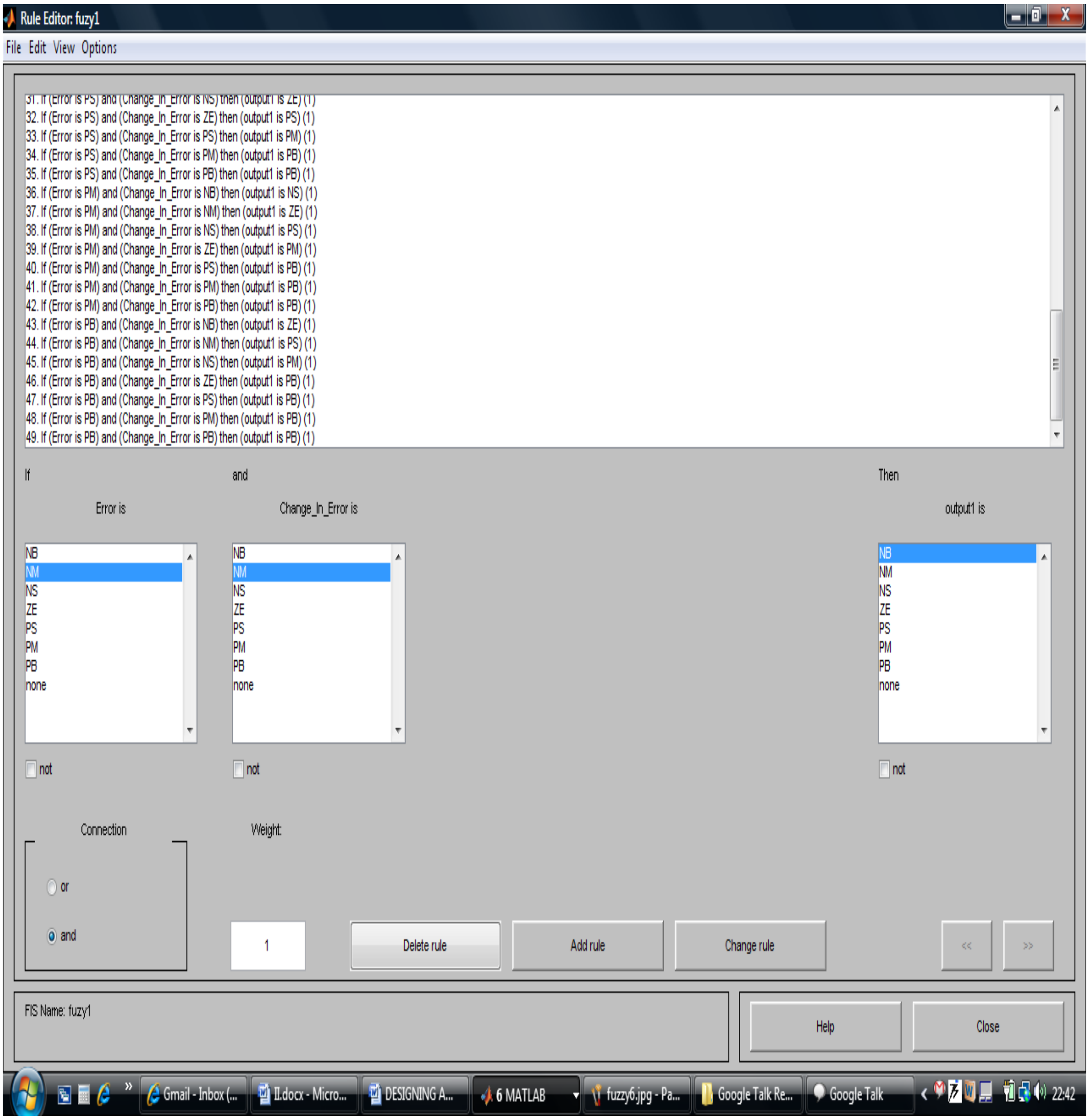


I-Defining Output: for the particular voltage control we have only one output du which is used to control the firing angle of the Thyristors.

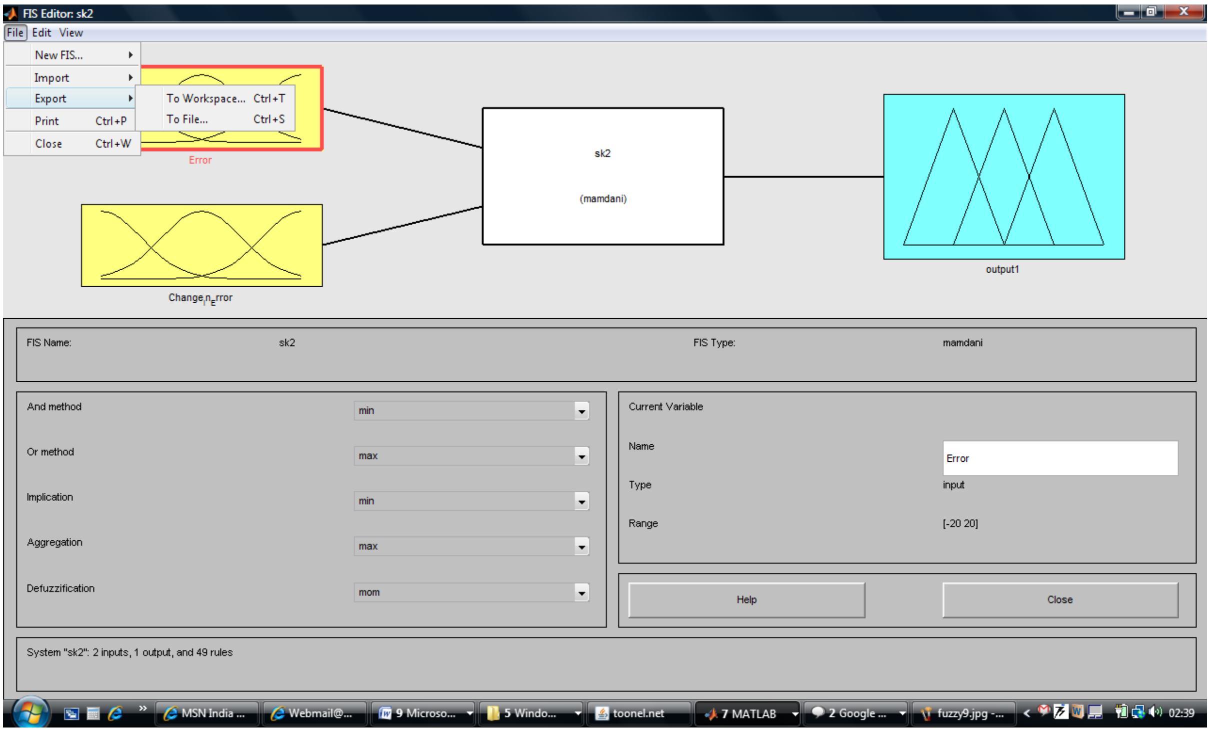
- Assigning Membership functions to Output variables:

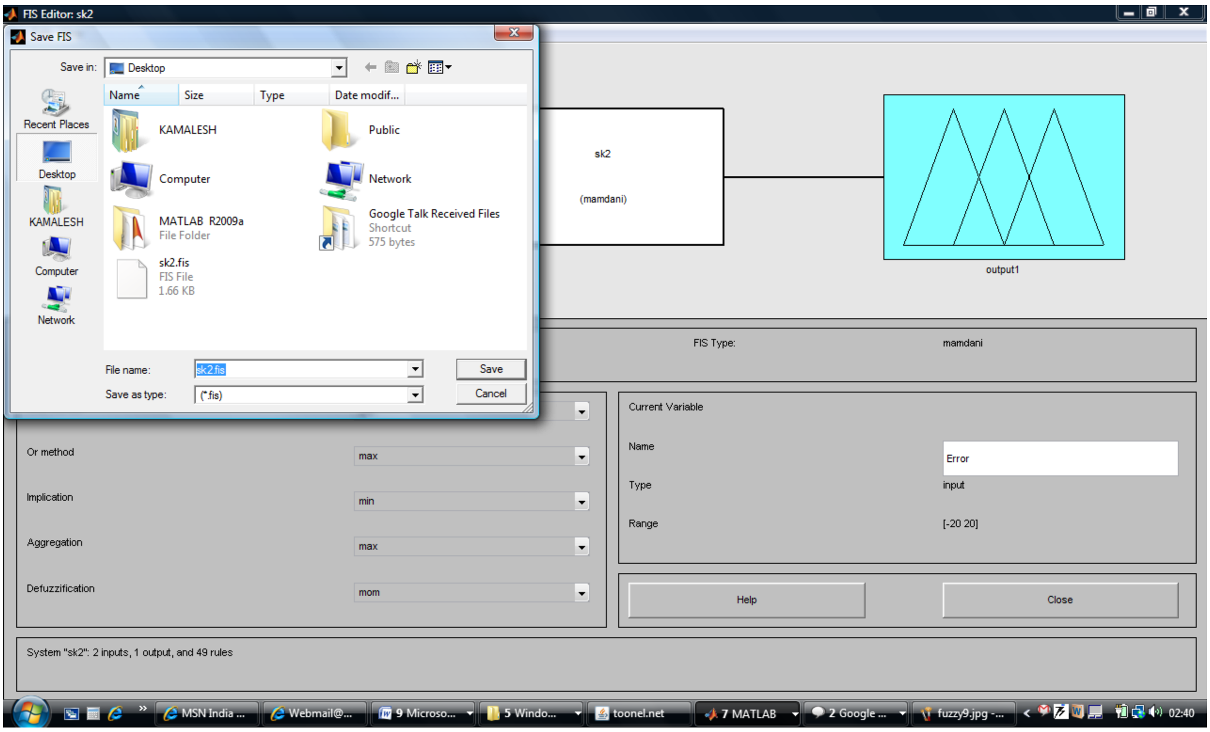


Step-3: Defining Rule Base for the fuzzy controller

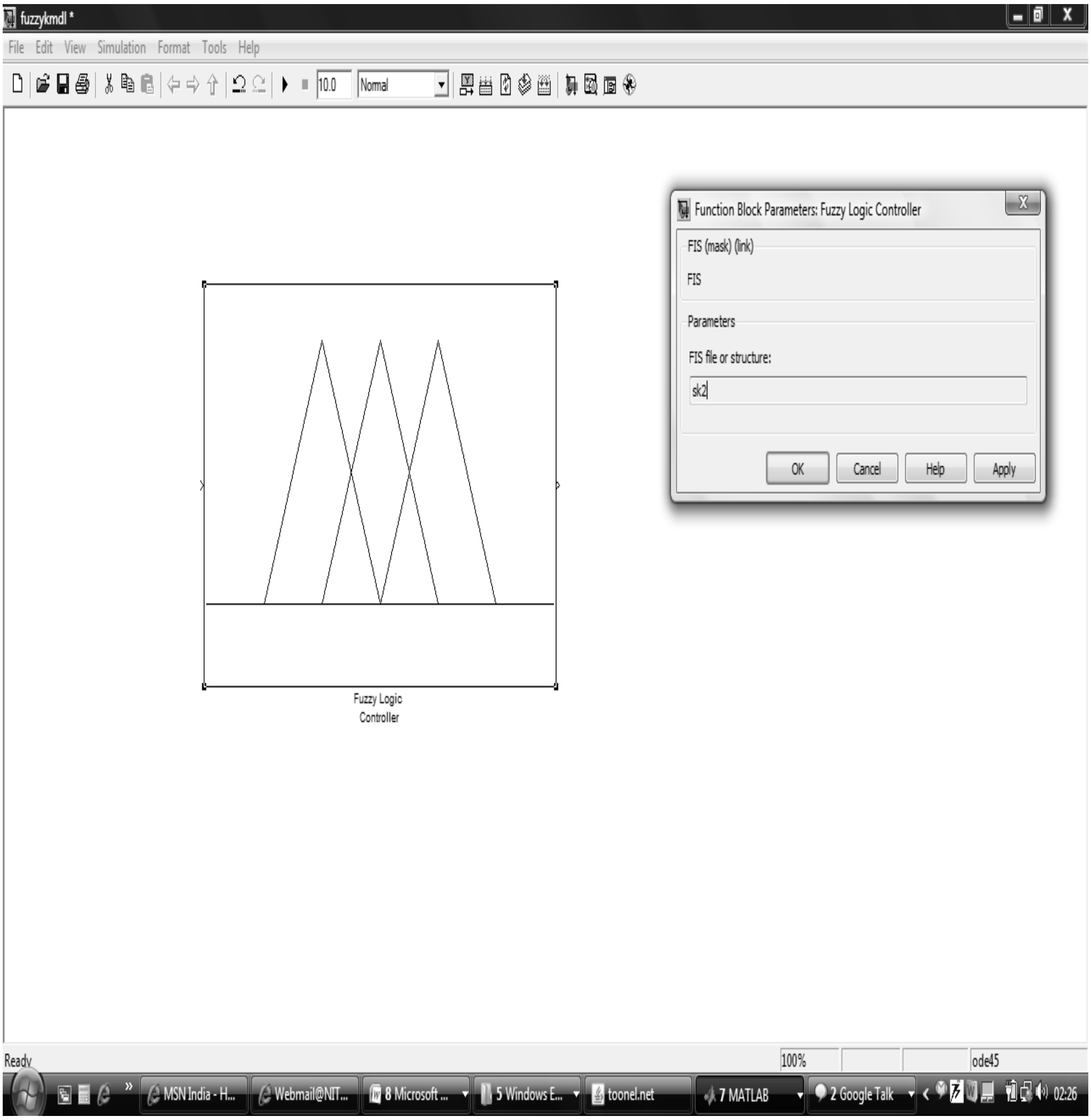


Step-4: saving the FIS editor in .fis format



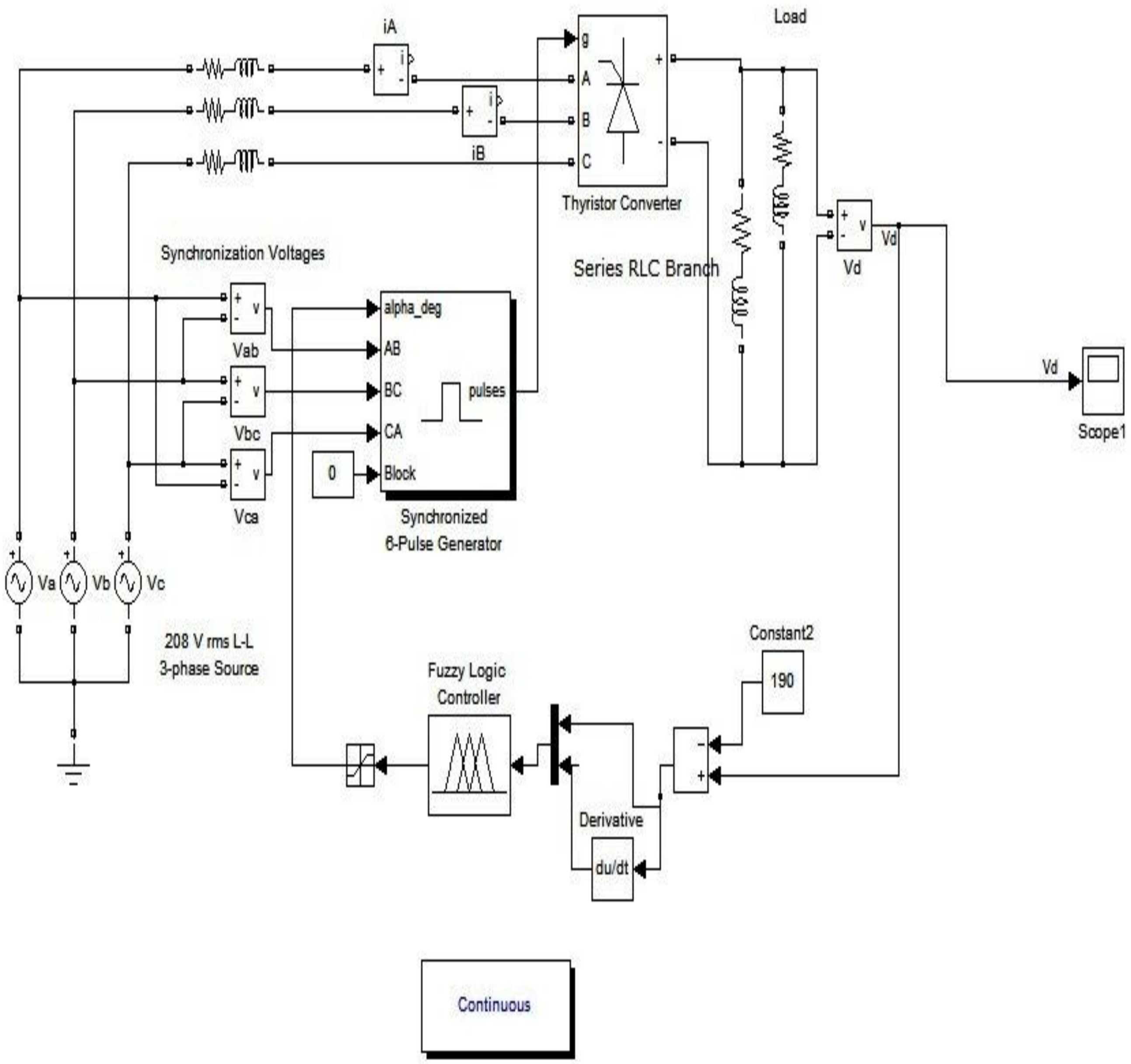


Step-5: loading ‘sk2.fis’ in the fuzzy controller

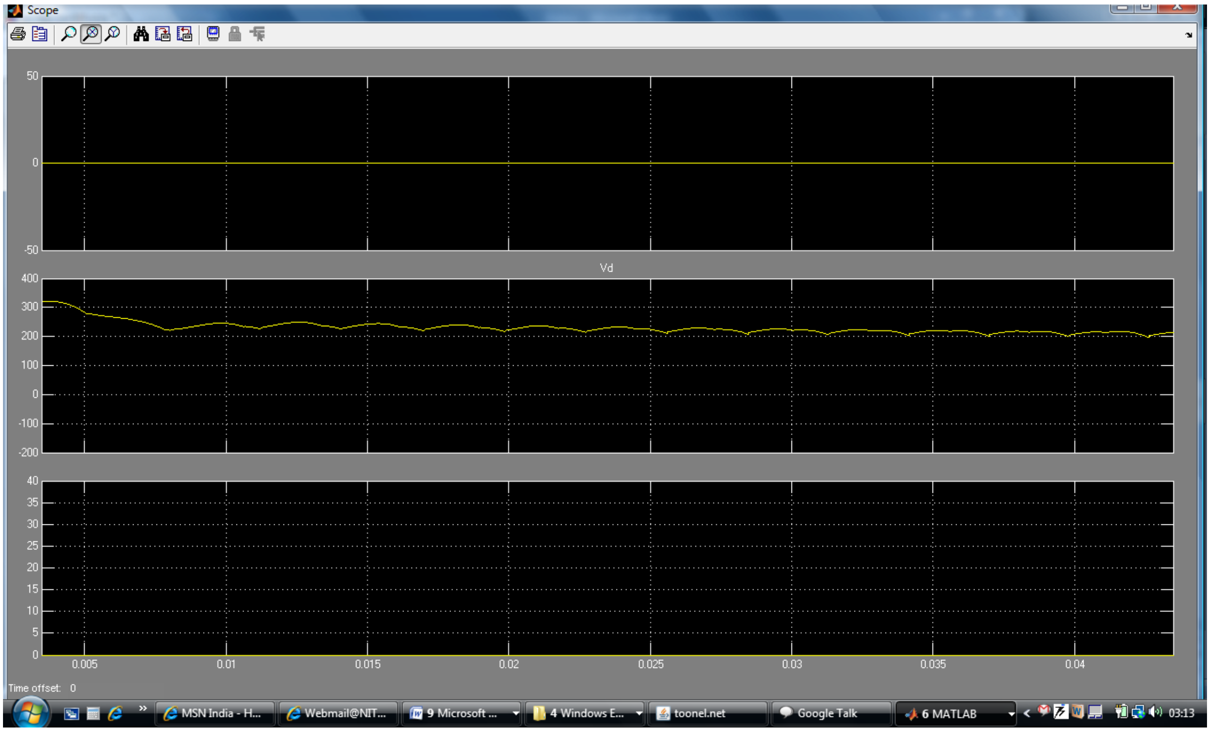


MATLAB SIMULATION OF FUZZY CONTROLLER

In this circuit, a fuzzy controller is used in the feedback in order to control the firing angle to the Thyristors assembly. In the fuzzy controller the membership function used is triangular function and for Defuzzification Mom method is being used. The rest of the process is similar to that implemented for a PID controller except the fact that PID controller has been replaced by fuzzy controller.



OUTPUT: the output ripples can be reduced with the fuzzy controller and the output obtained is smooth. When the load changes take place while implementing the fuzzy controller, the output voltage has the retentivity to stay at the same levels without inducing any harmonics or noise in the system and adapts very well even in case wherein the load requirement in terms of voltage and current is changed along with the load change of the system, making the system more robust to change. The stabilization time is comparatively a bit higher in comparison to PID controllers owing to computational delay involved in Fuzzy System.



LIMITATIONS OF FUZZY CONTROL

Although there are many advantages associated with fuzzy controllers in terms of stability and transient response of system, Fuzzy controllers do have certain disadvantages when it comes to implementation of controllers in feedback loop. In my view, one of the major Disadvantages of this approach is that the use of so much arbitrary non-linear truncation and jagged interpolation makes the resulting overall system highly resistant to any concise mathematical analysis or characterization, and the results of piece-meal testing would not necessarily reveal all the potential operating characteristic of the entire system

CHAPTER IV

CONCLUSION

With fuzzy controllers the harmonic content and thus ripple factor can be reduced. During our analysis it is observed that in case of PID controller, as the load is varied, the output voltage remains stable up to certain extent but as load is increased further, the output voltage becomes more unstable and it fluctuates a lot, which is undesirable to the Equipments connected to the power supply.With fuzzy controllers the variation in the output voltage can be minimised to a greater extent and the power supply remains constant irrespective of the load change. Thus intelligence to the power supply is added with fuzzy controller.

The main advantage of Fuzzy Controllers is that it is capable of being used with a nonlinear system which requires more ruggedness and flexibility of the controller. These controllers do require a pre-existing knowledge base and involves complex mathematical operations which make the process a bit slower when compared with their earlier counterparts. This was vividly demonstrated when the performance of closed loop using fuzzy controller as well as PID controllers as an example of classical controller.
PID controllers as well as most of earlier controller had an advantage of possessing a limited number of parameters i.e. only three in case of a PID controller. Control System shows good result in terms of response time and precision when these parameters are well adjusted. Fuzzy Controllers have a lot of parameters; to make a choice of rule base and selecting parameters of membership function. A fuzzy controller when provided makes the system a properly settled compared to PID controller. The performance of system is heavily dependent upon the choice of parameters of the system and when properly selected, the response of the system is quite good in time domain. The fuzzy controlled system is very sensitive to the distribution of membership function but not to the shape of membership function. Fuzzy controlled system doesn’t have much better characteristics in time domain than PID controlled systems. In our case, the fuzzy controlled power supply showed more rugged characteristics when subjected to fluctuations in voltage and current requirements of the load whereas PID required lots of tuning when used in the same context.

CHAPTER V

BIBLIOGRAPHY

1. *Malmstadt, Enke and Crouch*, Electronics and Instrumentation for Scientists, The Benjamin/Cummings Publishing Company
2. Intelligent Power Supply Controller by *R.S. Rumrill and CA Hayward*, IEEE Publications
3. Design of Fuzzy Learning Fuzzy Controllers by *C.W.Tao and J.S.Taur*, IEEE Publications
4. PID Control, *M.Araki* , Scribd
5. PID Control System Analysis, Design and Technology by *K.H. Ang and Y.Li*, IEEE Control Transactions
6. Comparison of Fuzzy and PID Controllers for Thyristor Controlled Series Compensator by *U.Yolac and T.Yalcinov,* Department of Electrical and Electronics Engineering, Nigde University
7. Tuning of Fuzzy PID control, University of Denmark Publication
8. DC Power Production, Delivery and Utilization, An EPRI White Paper