ELECTRIC SPRING ON VOLTAGE, POWER STABILITY AND POWER FACTOR CORRECTION

A dissertation
submitted in the partial fulfillment of the requirement for the Award of the Degree of
MASTER OF TECHNOLOGY
In
ELECTRICAL ENGINEERING
(With specialization in Power System Engineering)
Of
Assam Science & Technology University
Session: 2019-2021

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DECLARATION

I hereby declare that the work presented in the project "**ELECTRIC SPRING ON VOLTAGE, POWER STABILITY AND POWER FACTOR CORRECTION"** is here by accorded for the degree of " **MASTER OF TECHNOLOGY**" in **Electrical Engineering,** with Specialization in **Power System Engineering**, submitted to the Department of Electrical Engineering, Assam Engineering College, Guwahati in authentic record of my own work carried out under the supervision and guidance of Dr. Purobi Patowary, Professor, Department of Electrical Engineering, Assam Engineering College, Guwahati.

The matter embodied in this project has not been submitted by me for the award of any other degree.

Date: Amlan Jyoti Kashyap

Place: (Roll No.-190620032002)

ASTU Regn No.298506219 of 2019-2020

<u>CERTIFICATE FOR APPROVAL</u>

This is to certify that the project entitled **"ELECTRIC SPRING ON VOLTAGE, POWER STABILITY AND POWER FACTOR CORRECTION"**, undertaken by Amlan Jyoti Kashyap (ASTU Roll No.190620032002), M.Tech 4th semester student of the Department of **Electrical Engineering**, Assam Engineering College, Guwahati 13, is a work carried out by him during the academic year 2019-2021 under my supervision and guidance.

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CERTIFICATE OF ACCEPTANCE

This is to certify that Amlan Jyoti Kashyap (Roll No. 190620032002), an M.Tech. 4^{th} semester student of the Department of Electrical Engineering, Assam Engineering College, has submitted his dissertation on **“ELECTRIC SPRING ON VOLTAGE, POWER STABILITY AND POWER FACTOR CORRECTION”,** in partial fulfillment for the award of the degree of **Master of Technology** in **Electrical Engineering** with specialization in **Power System Engineering** under **“Assam Science and Technology University”.**

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## ACKNOWLEDGEMENT

First, I would like to thank my guide Dr. Purobi Patowary, Professor, Assam Engineering College, Guwahati for utmost supervision, guidance, help and encouragement throughout the project work.

I would like to express my sincere gratitude to Dr. Aroop Bardalai, Professor and Head of Electrical Engineering Department, Assam Engineering College and our M.Tech course coordinator Dr. Bani Kanta Talukdar, Professor, Electrical Engineering Department, Assam Engineering College for their help and encouragement in doing the project work during my entire period of study.

I am very much grateful to all the faculty members and staff members of Electrical Engineering Department of Assam Engineering College for encouraging and helping me to conduct my project in every aspect.

At last, but not the least, I would like to thank my all friends who are directly or indirectly involved in the fulfillment of my project work.

Date: Amlan Jyoti Kashyap

Place:

ABSTRACT

DSM (Demand Side Management) has been used successfully as a technique to limit the effects of environmentally sustainable power supply discontinuity. To carry out the DSM (Demand Side Management), various techniques such as direct burden management, load forecasting, energy stockpiling, and so on are used. However, they cannot be used in a progressive manner, as load preparation, or in a nosy manner, as direct strain management.

Another method for dealing with DSM (Demand Side Management), in particular, the Electric Spring (ES), which can provide voltage and power continuously, was previously introduced. The researchers used only receptive pay to provide continuous voltage support and load shedding for non-basic loads. In this study, a hybrid algorithm for controlling an electric spring circuit with improved power factor correction efficiency is created.

The ‘input-voltage-input-current' control architecture is contrasted with conventional 'input-voltage' control in Electric Spring as a sharp response to the problem of voltage and power instability relevant to power source driven frameworks. It was discovered that using solitary gadget voltage & control guideline & power condition advancement could be accomplished by leisure & equipment in-circle copying. It was also shown that ad hoc control architecture outperforms conventional Electric Spring with only reactive power infusion.

It will be a one-of-a-kind DSM (Demand Side Management) arrangement that could be carried out without relying on data and communication technologies.

LIST OF FIGURES

CHAPTER-1
INTRODUCTION

Electric Spring (ES) a new technology was introduced by Rui et al in 2012. The use of the spring will be to provide voltage support, power factor correction of the system.
The RMS Voltage on the receiving side should be always maintained at the desired level for good performance of the loads. However, certain problem occurs with the under voltage and overvoltage in the system.

1.1 MOTIVATION

The ‘input-voltage-input-current' control architecture is contrasted with conventional 'input-voltage' control in Electric Spring as a sharp response to the problem of voltage and power instability relevant to renewable power source driven frameworks. It is found that employing a single device for voltage control and power quality enhancement could be achieved by use of electric spring. It was also shown that ad hoc control architecture outperforms conventional Electric Spring with only reactive power infusion. It will be a one-of-a-kind DSM (demand side management) arrangement that could be carried out without relying on data and communication technologies.

1.2 OPERATION OF ELECTRIC SPRING

An electrical load with a poor power factor draws more current than a load with improved power factor for the same amount of useful power transferred and can put unnecessary strain on the electrical distribution network. By improving the power factor, we can reduce the electricity bills and improve the performance. It is analogous to the property of mechanical spring (property of elongation and compression of the mechanical spring)

Electric springs, may shape savvy loads that can be used to regulate the voltage at the function of the distribution framework to which it is connected. The use of ES (Electric Spring) is an innovative approach for circulated voltage control while all achieving effective DSM by regulation of noncritical burden due to shifts in discontinuous sustainable power sources (for example, wind). However, to illustrate the feasibility of such electric springs when implemented in massive statistics around the power framework. The use of electric spring can be used to regulate the voltage and also to improvise the power factor at the load side and it is a demand side management control.

1.3 ORGANISATION OF THE THESIS

The report is organized into five chapters which are followed by an introduction to ES for Voltage and Power Factor Correction and Power Stability

Chapter 1: Introduction to electric spring and motivation.

Chapter 2: Reviews the previous work done by researchers on Power Stability and Power Factor Correction and Electric Spring for Voltage.

Chapter 3: This chapter is devoted to an explanation of electric spring and circuits.

Chapter 4: Shows the introduction of fuzzy logic and block diagram.

Chapter 5: Experimental results, simulation study and comparison of results.

Chapter 6: Conclusion and future scope.

1.4 OBJECTIVE OF THE THESIS

The objectives of this thesis are:

1. To conduct a comprehensive review of the literature and apply the concept of electric springs for power factor correction and power as well as voltage stability.

2. Improving the power factor, rms voltage, active power and reactive power using fuzzy logic.

CHAPTER-2
LITERATURE SURVEY

[1] Electric spring (ES), another genius network invention, has previously been used for providing voltage and power stabilisation in a pitifully controlled/independent sustainable power source driven lattice, according to Jayantika Soni et al. Another control mechanism is seen for the use of ES in noncritical structure burdens such as electric radiators, coolers, and focal cooling framework. This control scheme will most likely include a power factor remedy of framework, voltage support, and power balance for simple loads, for example, the structure's protection framework, not-withstanding the existing power stabilisation and voltage characteristics.

[2] Congchong Zhang and colleagues stated that Control schemes should be granulated down at every pace to sub-transmission systems to conduct controllable burdens for recurrence guideline in transmission organizations in a realistic fashion, since burdens in transmission systems are usually conglomeration of lower voltage systems. Expenses for pressures participating in recurrence and voltage guideline should also be considered. For Electric Spring aggregators to get new running & reactive power setpoints by providing data to neighbours, a distributed improvement that expects to reduce expenditures and executes both recurrence & voltage guideline is obtained. Reenactment shows that ES aggregators can benefit required running energy reaction and direct recurrence while keeping transport voltages within reasonable limits with minimal expenses under control scheme.

[3] Nilanjan Ray Chaudhuri and colleagues stated the use of 'ES' is an innovative approach for distributed voltage regulation while still achieving effective DSM through a tweak of noncritical loads due to fluctuations in discontinuous sustainable power sources (for example wind). The verification of the concept was successfully demonstrated on a simple 10 kVA test platform equipment. Nonetheless, to show the sufficiency of such ES when applied in massive quantities through the power framework.

[4] Neethu S. Nair, MTech Scholar, and colleagues indicated electric springs are a relatively new concept for improving the stability of future-savvy lattices using renewable energy sources. Electric springs, in conjunction with noncritical loads, may shape savvy loads that can be used to regulate the voltage at the function of the distribution framework to which it is connected. Simulink is used to implement an electric spring in this paper. The adequacy of the electric spring in controlling mains voltage is checked by observing voltage waveforms with and without the electric spring.

[5] Rana Abou Hashem, Ahmed Massoud, Sara Al-Sharm, Yasmin Soliman, et al., stated that the ES concept has been based on the mechanical spring concept. Electric springs could be used in an alternating current or direct current framework for DSM, energy management, and power condition growth. DC ES is installed in a DC system and combined with non-basic loads (for example, thermostatically regulated loads such as cooling frameworks, iceboxes, or charging of module and electric cars electric water warmers) to form a smart load. To investigate the effect of arranging Electric Spring on loads, Matlab/Simulink was utilized to validate the current methodology, as observed in a prototype Electric Spring.

[6] Shu Yuen (Ron) Hui, Fellow, among others indicated in the 1660s, British physicist Robert Hooke depicted the rational rule of "mechanical springs." From the moment on. ES has been shown to be effective in controlling mains voltage through variations caused by the discontinuous concept of wind power. It is anticipated that ES, when disseminated over the power matrix, would give a different form of power structure equilibrium agreement that is free of data and correspondence creativity.

[7] Binita Sen and colleague's another great lattice invention that can handle voltage fluctuations generated by the joining of discontinuous renewable power sources is the electric spring. For the most part, ES have been considered of resistive burdens that are still ON. The circuit was tweaked to the point that a part of heaps is turned off for a single piece of reenactment. The effect of a slight deviation from the exhibition of an electric spring did not vary depending on the type of burden. However, the weight change on an electric spring with a burden variation is dependent on the kind of burden applied to it. The paper contains a point-by-point investigation.

[8] Xile Wei and colleagues inquired into the consistent state of ES for the purpose of balancing out a potential genius system of intermittent renewable power sources. The aim of this work is to discover the working norm of ES for providing voltage support to the power matrix, as well as to provide a hypothetical premise for the Electric Spring scheme. Finally, three studies are conducted to validate voltage boosting and decrease elements of ES in balancing out fluctuant voltage, as well as the feasible operating spectrum of ES. The investigation provides guidelines for the distribution of ESs in the expressed frameworks.

[9] E. F. Areed, et al. indicated that the Electric Spring (ES) is another invention that has recently risen to prominence in the intelligent network zone. This breakthrough has tremendous potential for tuning out the future keen lattice by regulating the primary voltage independent of changes in the yield capacity of intermittent renewable power sources. In sudden transition and various unsettling effects on working environments, the feasibility and execution of the controllers are investigated. The reproductions show that the regulators can be used to upgrade the electric spring for voltage guidelines.

[10] Benzeeta Ann D'Souza and colleagues stated that voltage and recurrence vacillations are connected to the power matrix associated with an intermittent sustainable power supply. This paper intends to use an Electric Spring (ES) in a genius way to improve the heap voltage guideline and increase the framework's stability. The simple burden is linked in shunt with this keen burden, whose voltage must be monitored on a regular basis. Depending on the type of Critical Load, the stage point between Non-Critical Load current and ES voltage is regulated to maintain constant transport voltage. The reenactment shows that ES can be used to improve the heap voltage guideline.

[11] Ye-lin Hu et al., mentioned “Replication on the use of ES for reactive force remuneration at the burden line," ES has a lot of advantages, for example, simple control and not having a lot of energy stockpiling, and it is linked to the heap side by methods for stifling voltage vacillation caused by reactive power variation.

[12] Rana Abou Hashem et al., stated that the ES (Electric Spring) concept arose as a result of the mechanical spring concept. Since renewable energy sources (RESs) are erratic in nature, Electric Spring is presented in a DC lattice for balancing out voltage variations caused by RESs power shifts, such as PV frameworks. To analyse the effect

of arrangement ES on non-basic burden, MATLAB/Simulink simulations for both open and closed circle tasks are used to validate the proposed solution. Furthermore, exploratory is added for a prototyped ES.

[13] According to Neethu S. Nair et al., Electric spring is a recent concept to increase the stability of future keen frameworks for renewable energy sources. Electric springs, in conjunction with noncritical loads, can shape savvy loads that can be used to guide voltage at the function of the dispersion system to which it is linked. Simulink is used to implement an electric spring in this paper. The adequacy of the electric spring in regulating mains voltage is determined by observing voltage waveforms with and without the electric spring.

14] Narala Guru Maheswar Reddy and others indicated the idea is to regulate voltage through Critical (C) load while allowing Non-critical (NC) impedance-type load to vary their power consumption and thus contribute to demand-side reaction. A simple contextual inquiry with a single topic. STATCOM and ES are presented first to show that, in order to achieve comparable voltage guidelines, ES and STATCOM need nearly equal reactive capacity.

[15] According to X. Luo and colleagues, the aim is to regulate voltage through 'simple burdens' while allowing 'non-basic' impedance-type loads (such as water radiators) to adjust their power consumption and thus contribute to the demand-side reaction. A simple contextual inquiry with a single, Correlation between an ES and STATCOM is also supported by comparative contextual investigations on an IEEE 13-transport test feeder system and a portion of a distribution network in Sha Lo Wan Bay, Hong Kong. Given the current state of affairs, a grouping of ESs achieves the preferred full voltage

guideline over STATCOM by using less commonly reactive energy ability. The reliance of ES capability on the level of basic and non-basic strain has also emerged.

[16] Among others who have contributed to this work are Qingsong Wang et al. An epic control technique of direct flow control and symphonic concealment work, such as control of a running energy channel (APF), is using another form of ES with flow source inverters (CSIs) to improve ES exhibitions. Absolute consonant twisting can be greatly reduced by converting potential difference source inverters to CSIs and, moreover, by replacing potential difference control with direct current control. The definition of ESs may also be translated more clearly through direct current regulation. Working criteria for ES and control are well defined all over the place.

[17] Chetna Jangade et al., mentioned, "Electric Spring" in view of Single Phase three-level Cascaded H-Bridge Inverter to achieve efficient DSM for balancing out keen network bolstered by generous intermittent renewable power sources (RES). Among the most appealing features of a staggered inverter (MLI), a good arrangement of ES is for stifling voltage vacillation in power dispersion mechanism arising from RES and maintaining the simple burden voltage. An elite efficient system using ES has been attempted and demonstrated by itemized MATLAB reenactment.

[18] P. Nitish Raj and colleagues indicated the main goal is to develop fuzzy control procedures for the FACTS-based damping controller setup in order to increase power framework stability. In these, we are using ES 'Electric Spring,' which is referred to as a sharp brace gadget that is used to dispatch active and reactive power in the system that is connected between the Gird and Load or demand and supply. Legitimate commitment of streamlining procedures plays an important role in the reliability upgrade of the power

network and increases power efficiency. Fuzzy enhancement approaches were compared to other popular advancements and got. The damping controller is built using a fuzzy logic controller. Significant conclusions have been made about the reasonableness of the enhancement plan.

CHAPTER-3
EXPLANATION OF ELECTRIC SPRING AND CIRCUITS

3.1 BRIEF OVERVIEW

Voltage control is of great importance in a power system network. Voltage Control optimizes the operation of electrical devices. Proper voltage control ensures system stability in the system. Here, we have introduced the concept of electric spring and used the same for voltage control and power factor correction in an overvoltage system and as well in a undervoltage system.

In the under-voltage Case, with the use of electric spring there is injection of real power and capacitive power in the system which leads to the voltage stability. The other parameters like power factor, active power flow and reactive power flow is observed in the system.

For the over-voltage case, with the use of electric spring there is injection of real power and inductive power in the system which leads to the voltage stability. The other parameters like power factor, active power flow and reactive power flow is observed in the system.

3.2 MODELLING OF THE COMPONENTS

3.2.1 Modeling of the electric spring

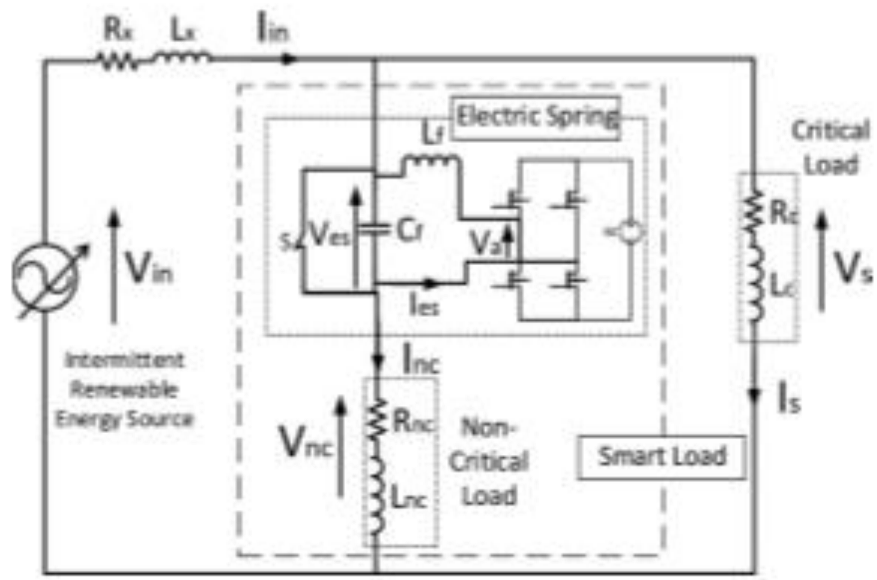


Figure 3.1: Electric spring model.

The modeling of the electric spring is shown in the circuit. The modeling shows the critical load across which the regulation is performed in case of overvoltage or under voltage situations. Also, the performance is enhanced in case of different scenarios

3.2.2 Modeling of the electric spring in MATLAB 2016A

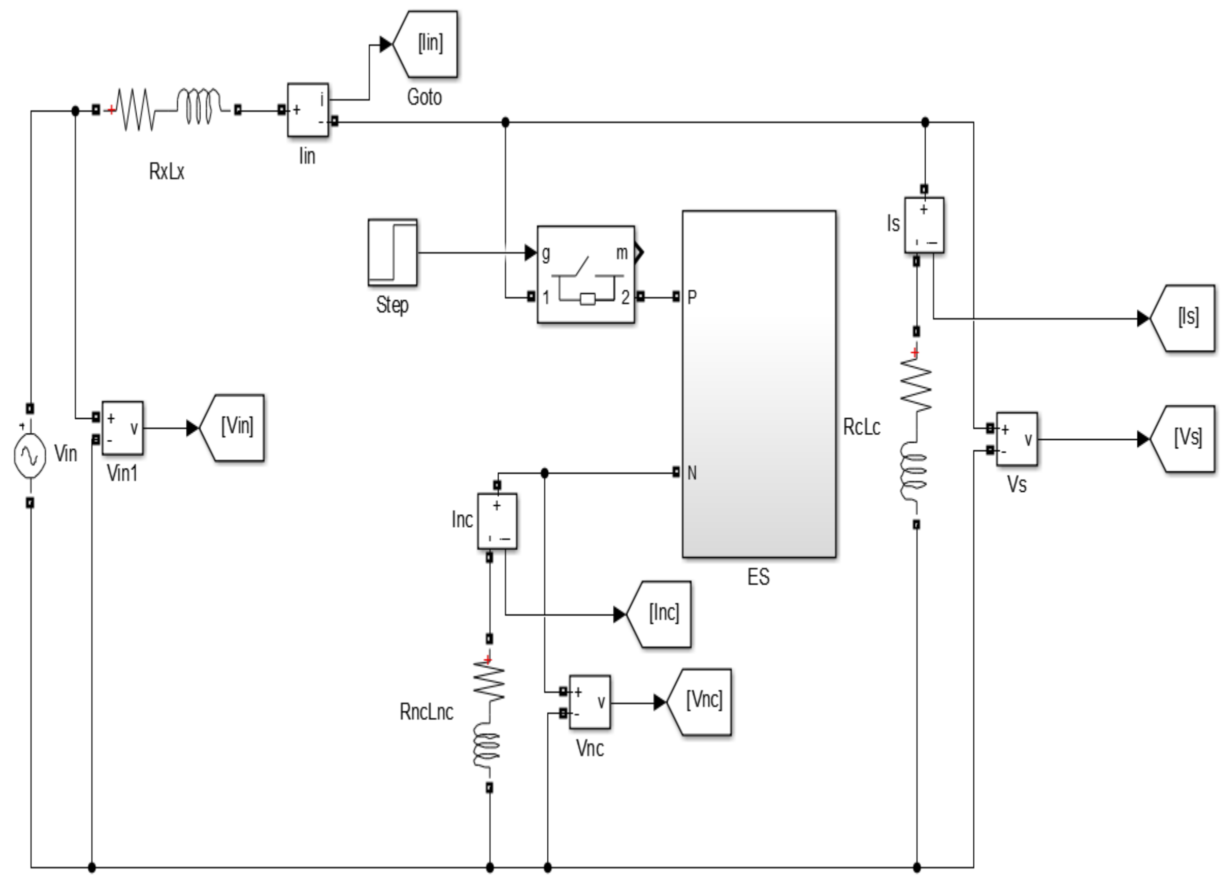


Figure 3.2: Electric spring model in MATLAB 2016A

3.2.3 ELECTRIC SPRING WITH SWITCHES

The electric spring circuit consists of 4 power electronic switches S1, S2, S3 and S4 which is connected to the spring and powered with the help of a D.C voltage source connected across the spring. The switches get the control signal from the control circuit that is in the spring.

The electric spring circuit with the switches is given below.

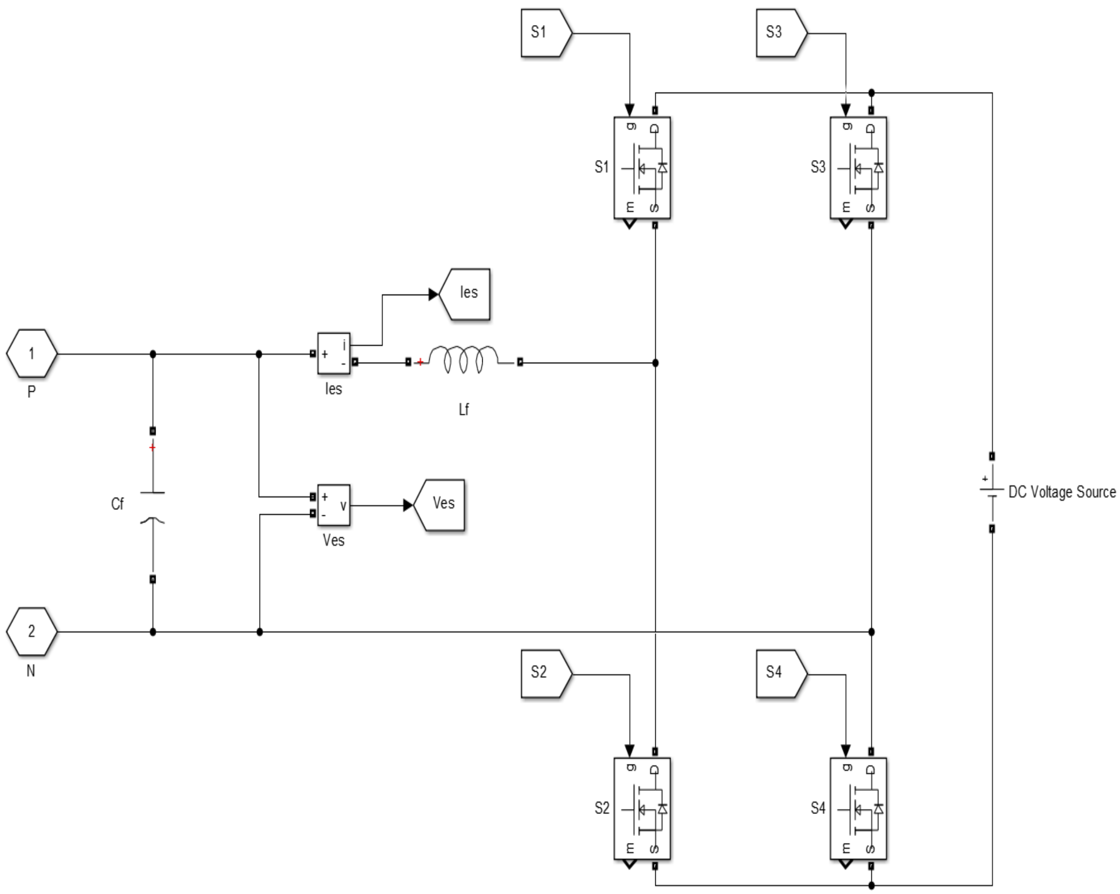


Figure 3.3: Electric Spring circuit with switches.

The effective resistance in the spring is of the filter inductor L_f and the capacitor C_f are neglected and assumed that the devices are lossless. . The voltage across the filter inductor is indicated by V_{Lf} and the current through it is indicated by I_{es}, the voltage at the terminal is indicated by V_a, and the critical load impedance is Z_c

The equations are given below:

$Va - Ves = V_{LF} = L_f \, dI_{es}/dt$ ……………………….....(1)
$Vs = ZcIs = Zc\,(I_{in} - I_{nc})$ ……………………………(2)
$C_f \, dV_{es}/dt = I_{es} + I_{nc} = I_{es} + I_{in} - Vs/Zc$ ……………....(3)

For the mathematical simplification, it is assumed that only only $V_{a,1}$ is available as the terminal output voltage. m is the modulation index and V_{dc} is the DC link voltage.
The state space equations can be written as:

$$\frac{d}{dt}\begin{bmatrix} I_{es} \\ V_{es} \end{bmatrix} = \begin{bmatrix} 0 & \frac{-1}{L_f} \\ \frac{1}{C_f} & 0 \end{bmatrix}\begin{bmatrix} I_{es} \\ V_{es} \end{bmatrix} + \begin{bmatrix} \frac{1}{L_f} \\ \frac{1}{Z_c C_f} \end{bmatrix}\begin{bmatrix} mV_{dc} & V_s \end{bmatrix} \quad \text{…………(4)}$$

3.2.4 CONTROL CIRCUIT

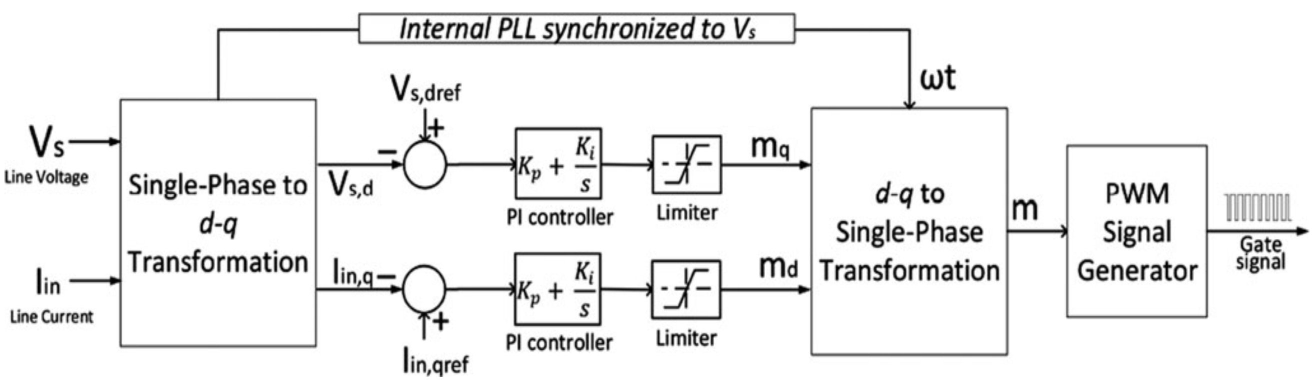


Figure 3.4: Control circuit

The control circuit of the developed electric spring is given as follows. The line voltage and line current are applied as inputs to the control system which is used to generate the gate inputs for the designed electric spring.

The use of d-q system requires the generation of two orthogonal signals which are generated using the SOGI (Second Order Generalized Integrator). Two variables i.e. Real and the imaginary variable are created using this SOGI that are used in d-q transformation.

The imaginary variable is identical in characteristics to real variable but has a 90° electrical phase shift with respect to real variable. If the real sinusoidal signal, X_r, then the imaginary sinusoidal signal, X_i, would be as indicated as having 90° phase shift compared to the previous one. The SOGI Circuit is given below:

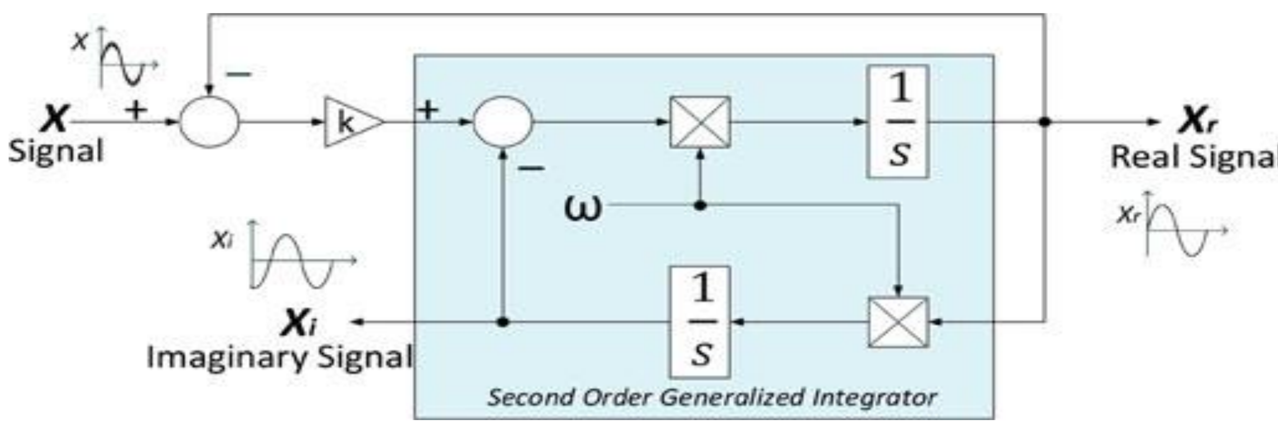


Figure 3.5: SOGI (Second Order Generalized Integrator) circuit

The orthogonal signals could be generated using transport delay block, the inverse peak transformation and the Hilbert transformation but due to complexities like frequency dependency, high complexity. A system based on SOGI as discussed previously is used.

An internal phase locked loop PLL could be generated and used. The reason of using this is that the d-q transformation is independent of frequency variations.

Thus, the reason of using single phase d-q transformation is a time varying AC signal can be converted into DC values and an appropriate controller can be designed for the application.

CONTROL CIRCUIT IN MATLAB

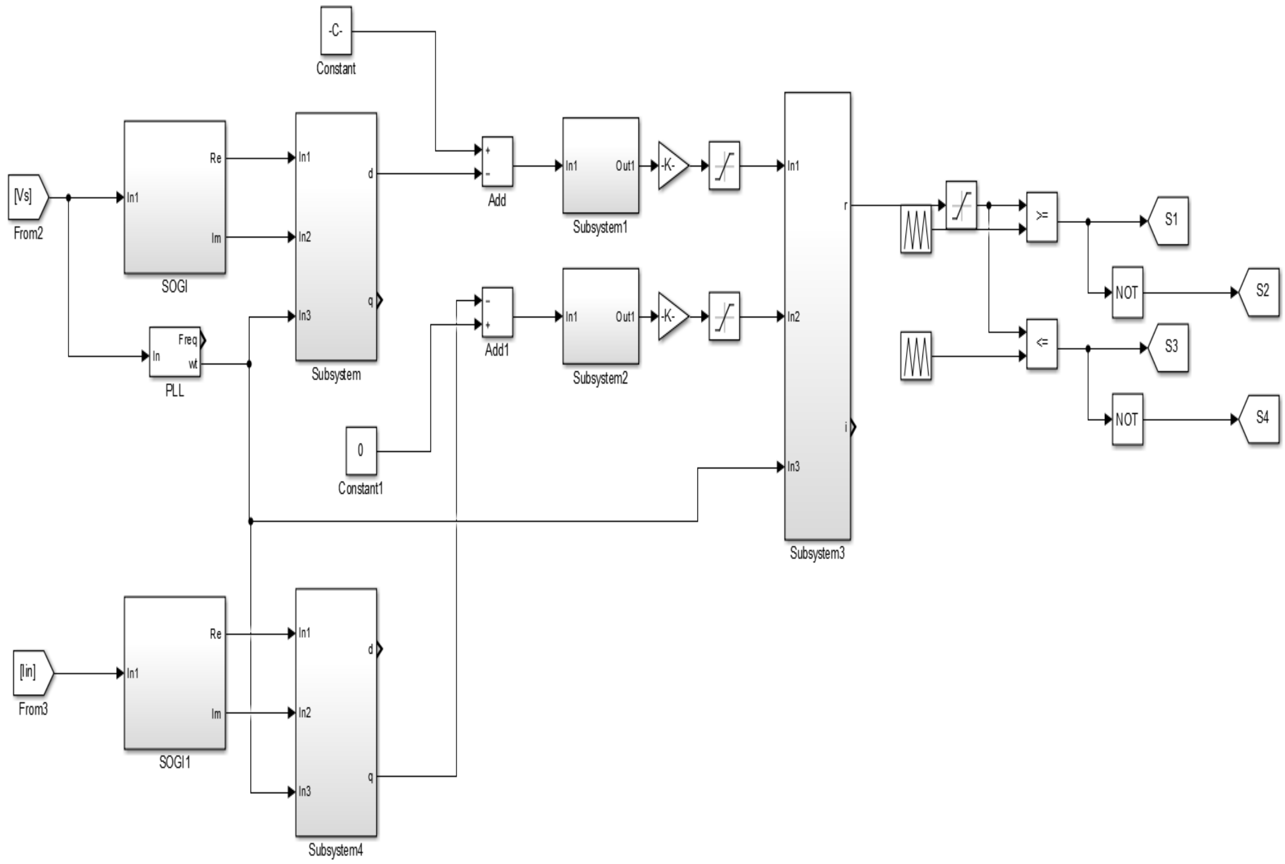


Figure 3.6: Control circuit in matlab

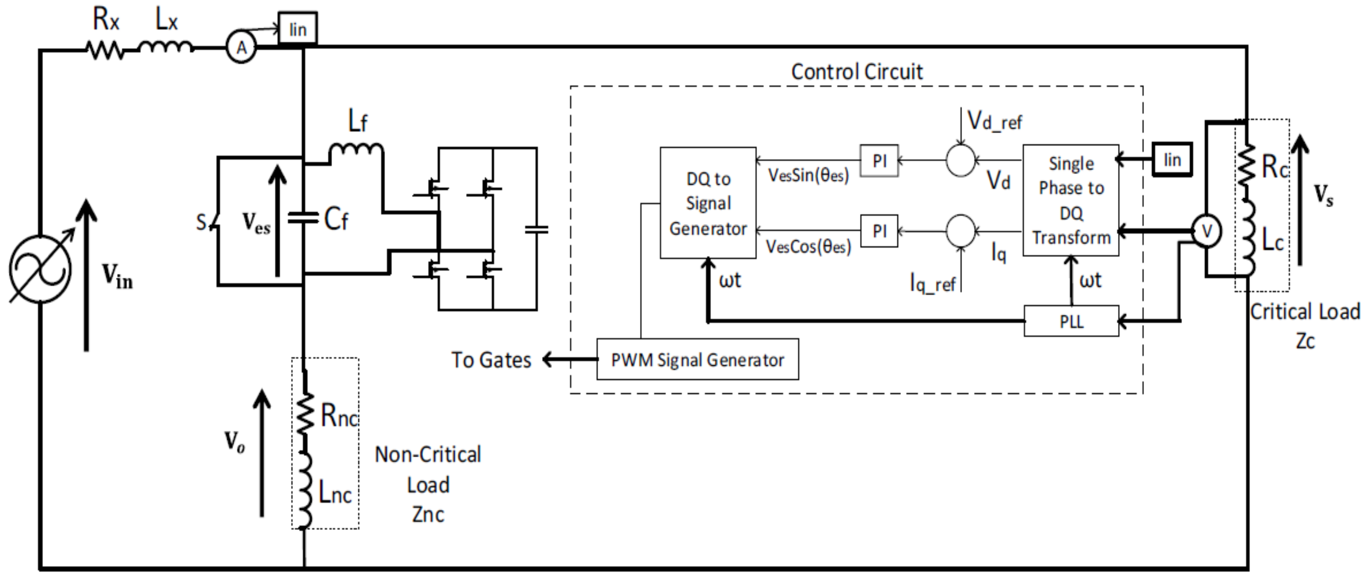


Figure 3.7: Application of the control circuit in the electric spring

The figure shows the application of the control circuit in the electric spring. The effect of which is the regulated voltage with an improved performance of the system.

3.2.5 OUTPUT CIRCUIT

The output circuit is given below. The output circuit with show the RMS value of the line voltage, electric spring voltage. The power factor of the system is also in the output circuit. Moreover, the flow of active and reactive power in the entire system will be shown.

The output of the circuit is internally connected to the spring circuit and the control system with the help of GO TO and FROM functionalities which will be described in the next section.

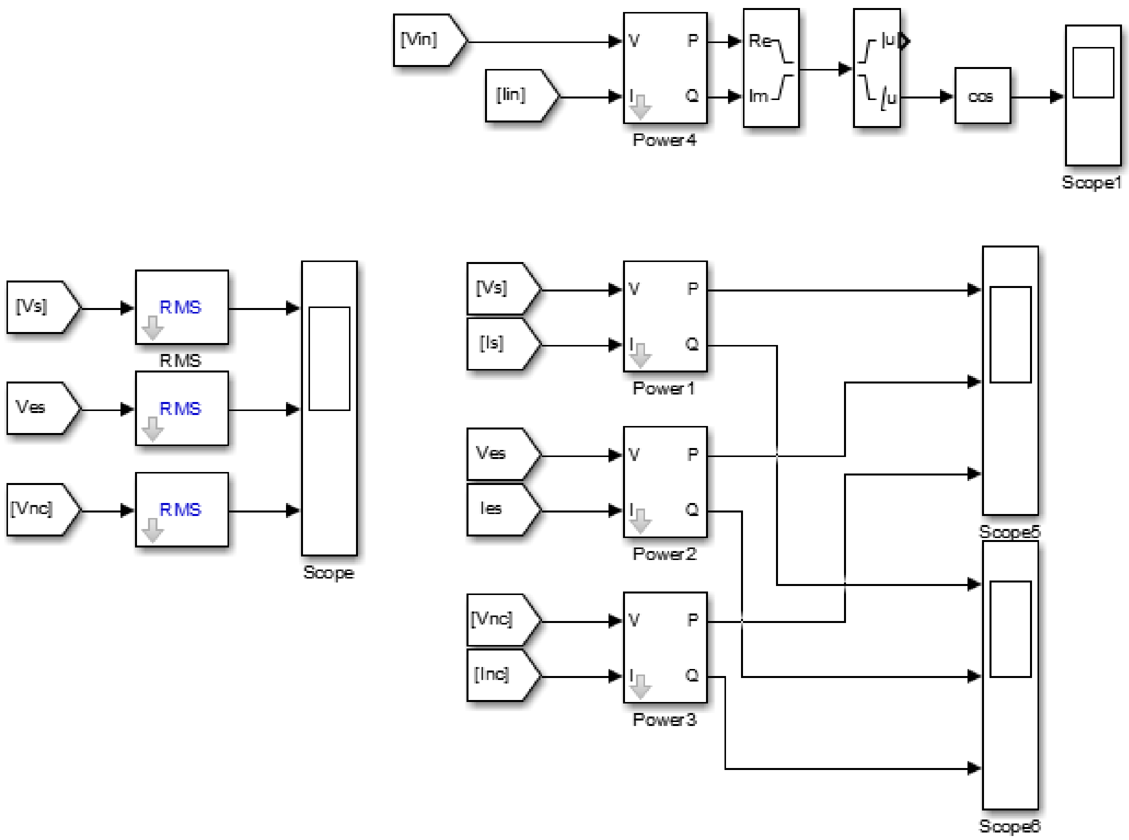


Figure 3.8: Output circuit of the electric spring.

3.3 <u>SOFTWARE USED AND BLOCK FUNCTIONALITIES</u>

The software used for the project is MATLAB 2016a and SIMULINK to run the program.

The 3 parts used in the circuitry are as follows:

1. **The spring circuit.**
2. **The control circuit.**
3. **The output circuit.**

The control circuit is used to generate the gate pulses that are to be used in the spring circuit. The output circuit is the circuit that generates the output. The output circuit with show the RMS value of the line voltage, electric spring voltage. The power factor of the system is also in the output circuit. Moreover, the flow of active and reactive power in the entire system will be shown.

<u>GOTO AND FROM BLOCKS</u>

The above mentioned 3 circuits, in the total circuitry will be internally connected with the help of GOTO and FROM blocks. The internal connection is made so as to minimize the complexity of the circuitry and making it a simpler one.

3.4 <u>CASES CONSIDERED</u>

Below are the two cases considered for the operation of the electrical spring. The cases are described below:

a. CASE OF OVERVOLTAGE.
b. CASE OF UNDERVOLTAGE.

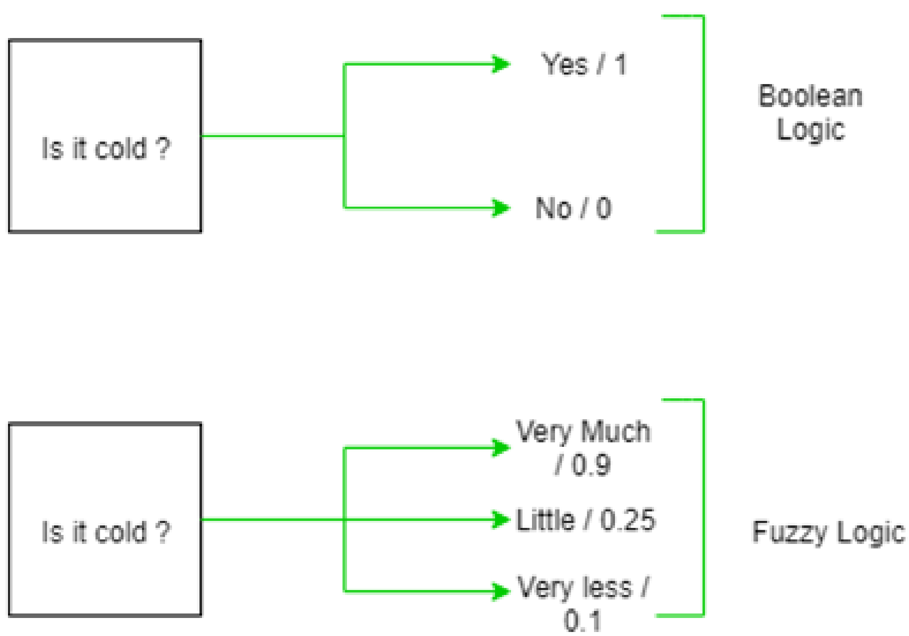
The simulation study is done for the above two cases and accordingly, the system parameters are studied in both the cases.

CHAPTER 4
IMPROVED MODELLING USING FUZZY LOGIC

4.1 INTRODUCTION TO FUZZY LOGIC

The term fuzzy refers to things that are not clear or are vague. In the real world many times we encounter a situation when we can’t determine whether the state is true or false, their fuzzy logic provides very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation.

In the boolean system truth value, 1.0 represents the absolute truth value and 0.0 represents the absolute false value. But in the fuzzy system, there is no logic for the absolute truth and absolute false value. But in fuzzy logic, there is an intermediate value too present which is partially true and partially false.



The term fuzzy logic was introduced with the 1965 proposal of fuzzy set theory by scientist Lotfi Zadeh. Fuzzy logic had, however, been studied since the 1920s, as infinite-valued logic

4.2 BASIC BLOCK DIAGRAM OF A FUZZY LOGIC CONTROLLER

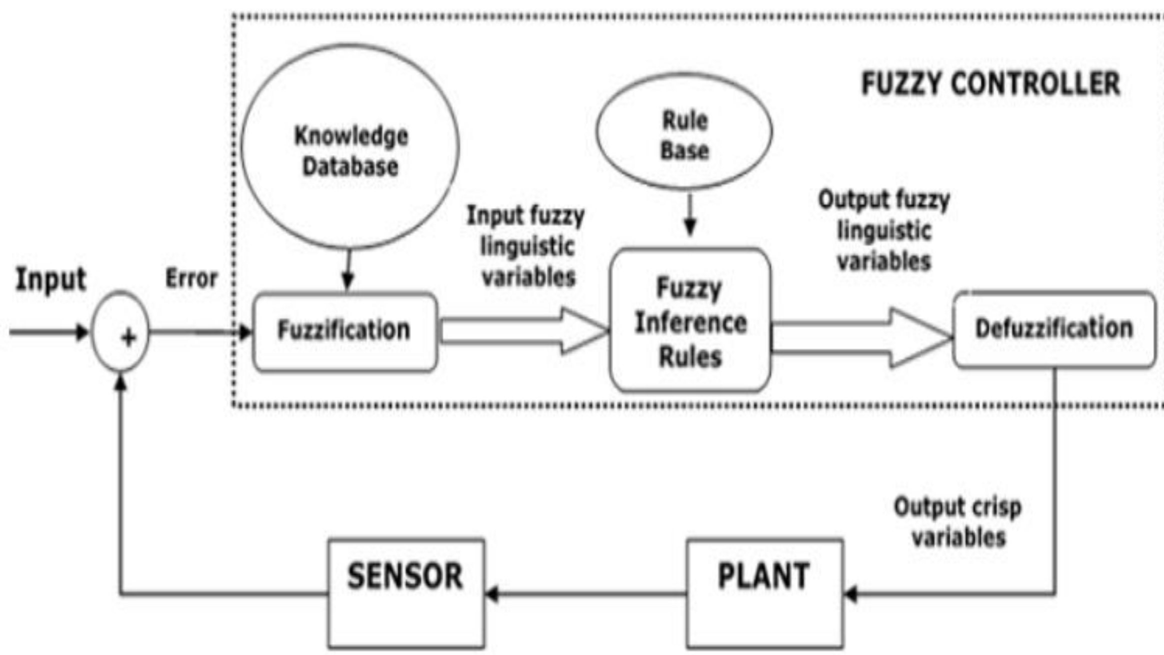


Figure 4.1: Block diagram of FLC

Followings are the significant segments of the FLC as appeared in the above figure:

1. **Fuzzifier** − The role of fuzzifier is to convert the crisp input values into fuzzy values.
2. **Fuzzy Knowledge Base** − It stores the knowledge about all the input-output fuzzy relationships. It also has the membership function which defines the input variables to the fuzzy rule base and the output variables to the plant under control.
3. **Fuzzy Rule Base** − It stores the knowledge about the operation of the process of domain.
4. **Inference Engine** − It acts as a kernel of any FLC. Basically, it simulates human decisions by performing approximate reasoning.

5. **Defuzzifier** – The role of defuzzifier is to convert the fuzzy values into crisp values getting from fuzzy inference engine.

4.3 FUZZY LOGIC DESIGNER IN MATLAB

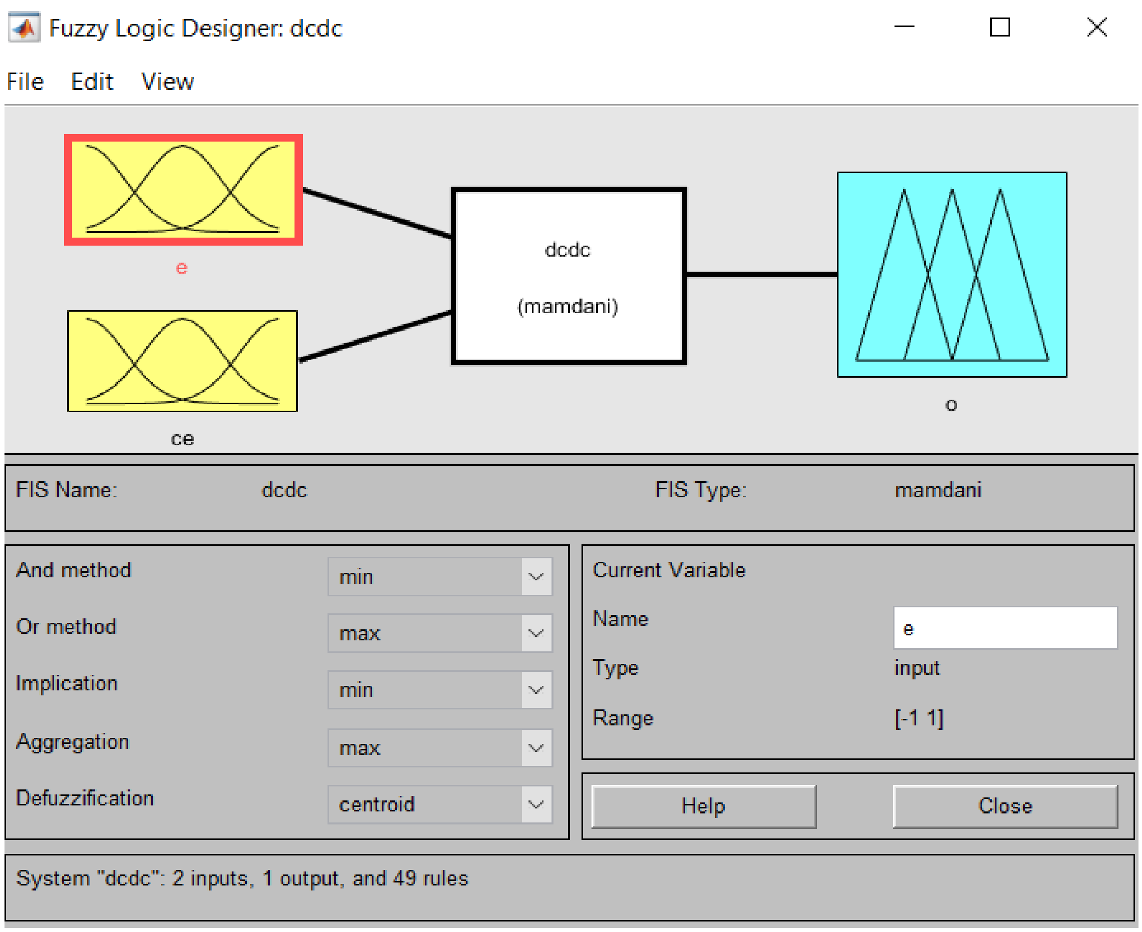


Figure 4.2: Fuzzy Controller toolbox, error and change in error inputs

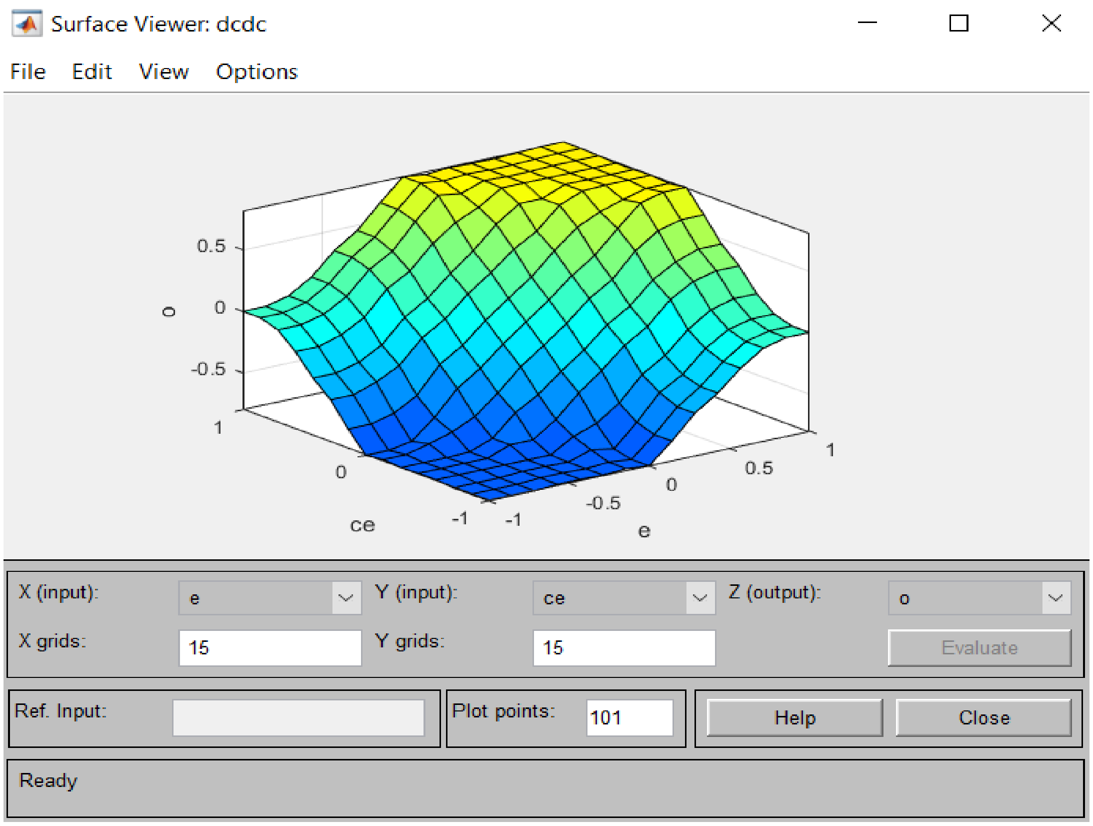


Figure 4.3: Fuzzy Controller rule surface view

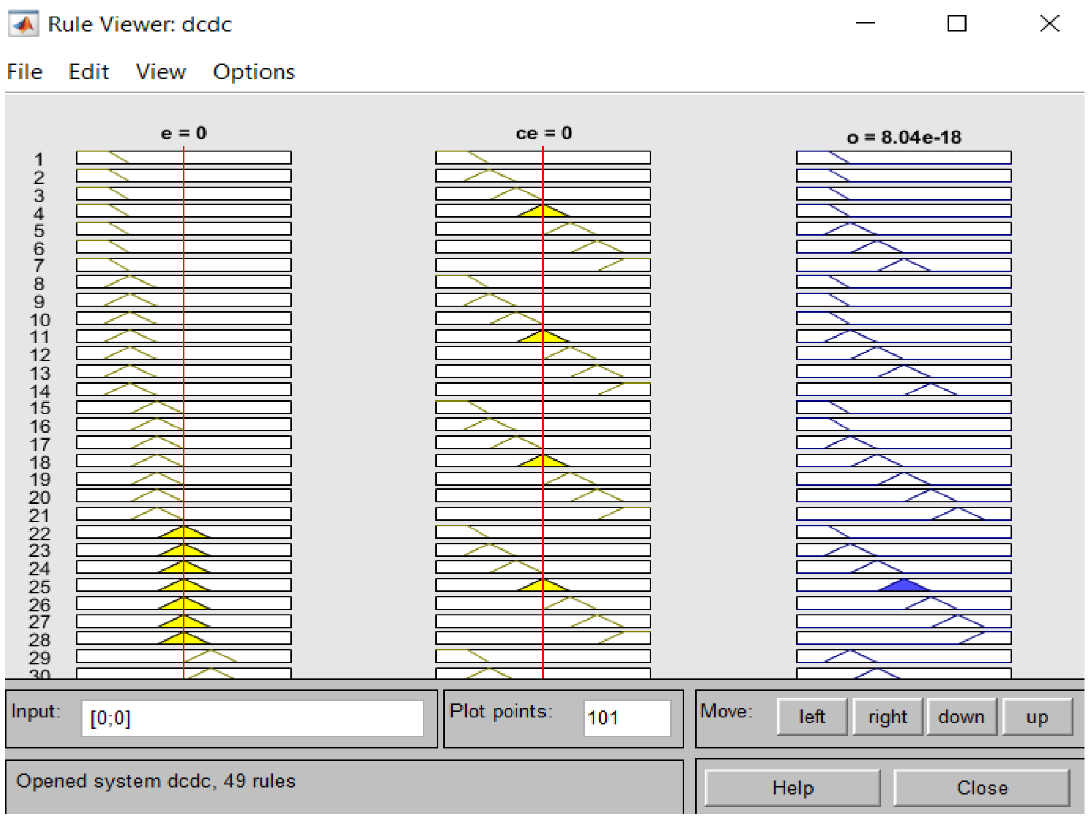


Figure 4.4: Fuzzy controller rule views

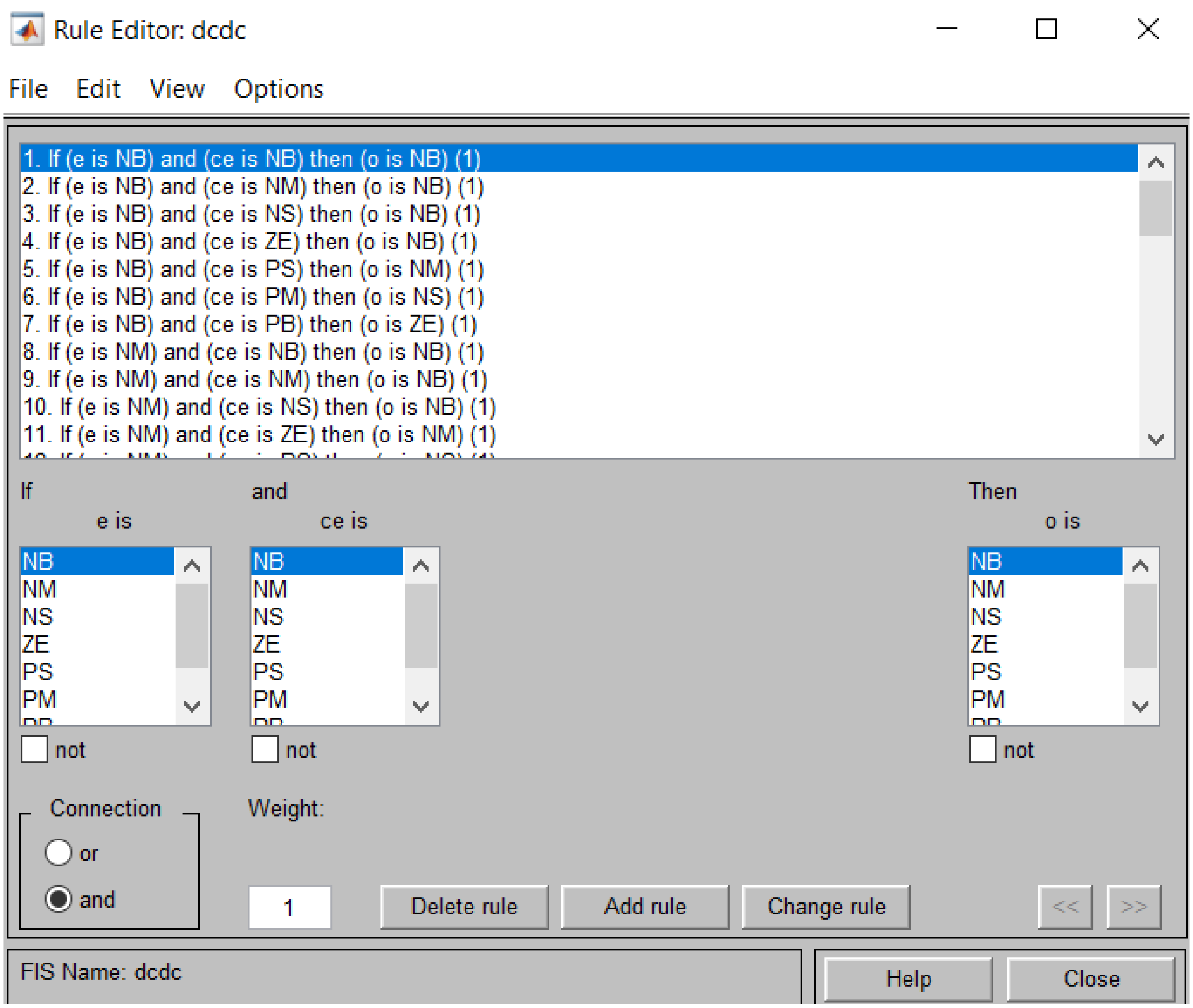


Figure 4.5: Fuzzy controller Rules

CHAPTER 5
EXPERIMENTAL RESULTS

5.1 OVERVOLTAGE AND UNDERVOLTAGE CASES

Below are the two cases considered for the operation of the electrical spring. The cases are described below:

a. CASE OF OVERVOLTAGE.
b. CASE OF UNDERVOLTAGE.

The simulation study is done for the above two cases and accordingly, the system parameters are studied in both the cases.

5.2 SIMULATION STUDY OF CONVENTIONAL ELECTRIC SPRING

The Electric Spring developed will be able to inject both active and reactive power in the system. The spring is activated with the help of a step signal (we have chosen the time as 0.5 seconds for the activation of the spring).

1. <u>OVERVOLTAGE SYSTEM</u>

The RMS Line voltage is kept at 238 Volts for the system and the electric spring is turned on at 0.5 seconds. The line voltage is brought to the reference of 230 Volts by the electric spring at the designed time 0.5 seconds.

There is both the injection of real power and inductive power in the already existing inductive system. The voltage profile graph developed is given below (Figure 5.1)

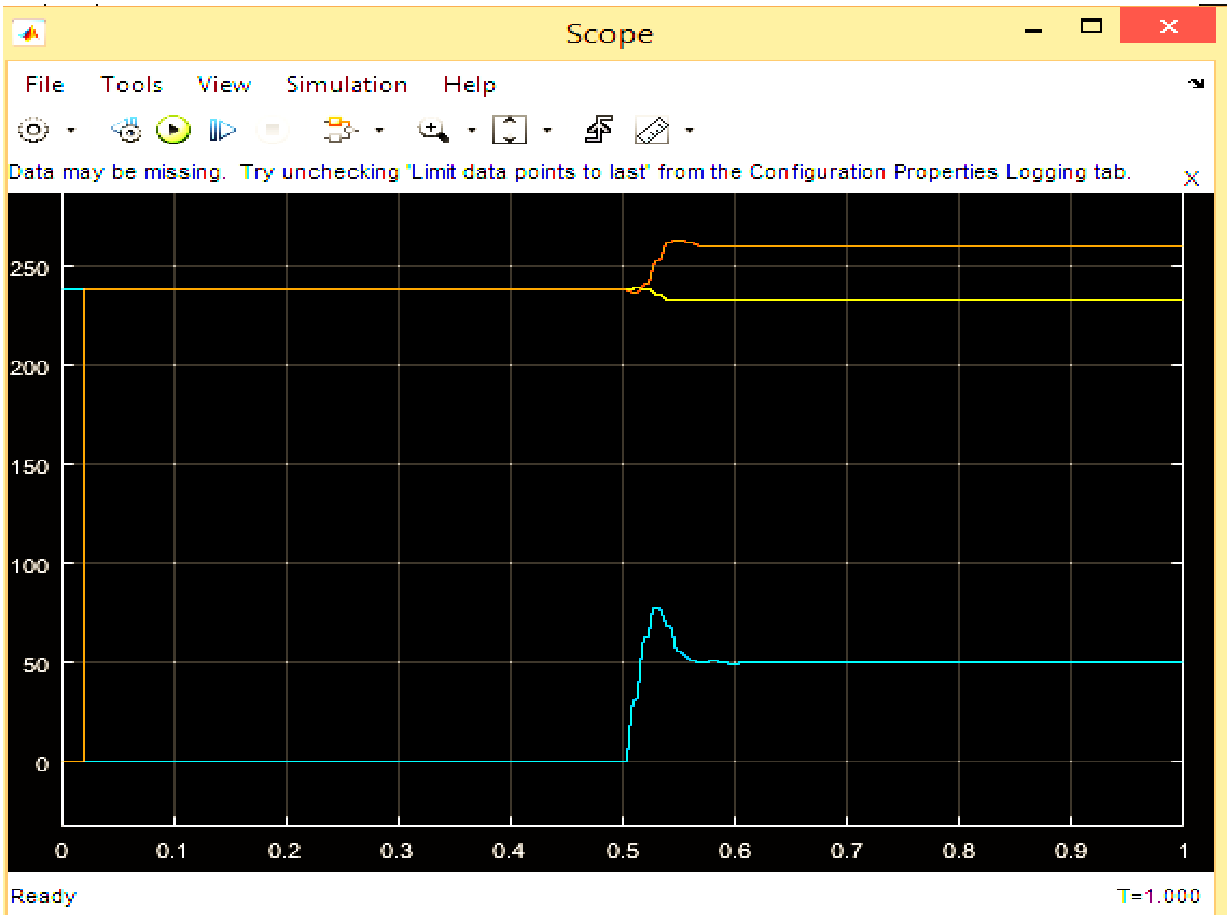


Figure 5.1: Voltage profile graph for overvoltage system
Unit of X-axis: time (sec)
Unit of Y-axis: Rms voltage (volts)

Yellow graph: RMS Line Voltage (change taking place at 0.5 seconds)
Blue Graph: Electric spring voltage

OBSERVATIONS

The change is due to the fact, that to maintain the RMS line voltage to the value of 230 V the spring will inject real and inductive power, in the already existing inductive system. At 0.5 seconds the RMS line voltage of 230 is attained as indicated in the graph.

The power factor profile is shown in the next page:

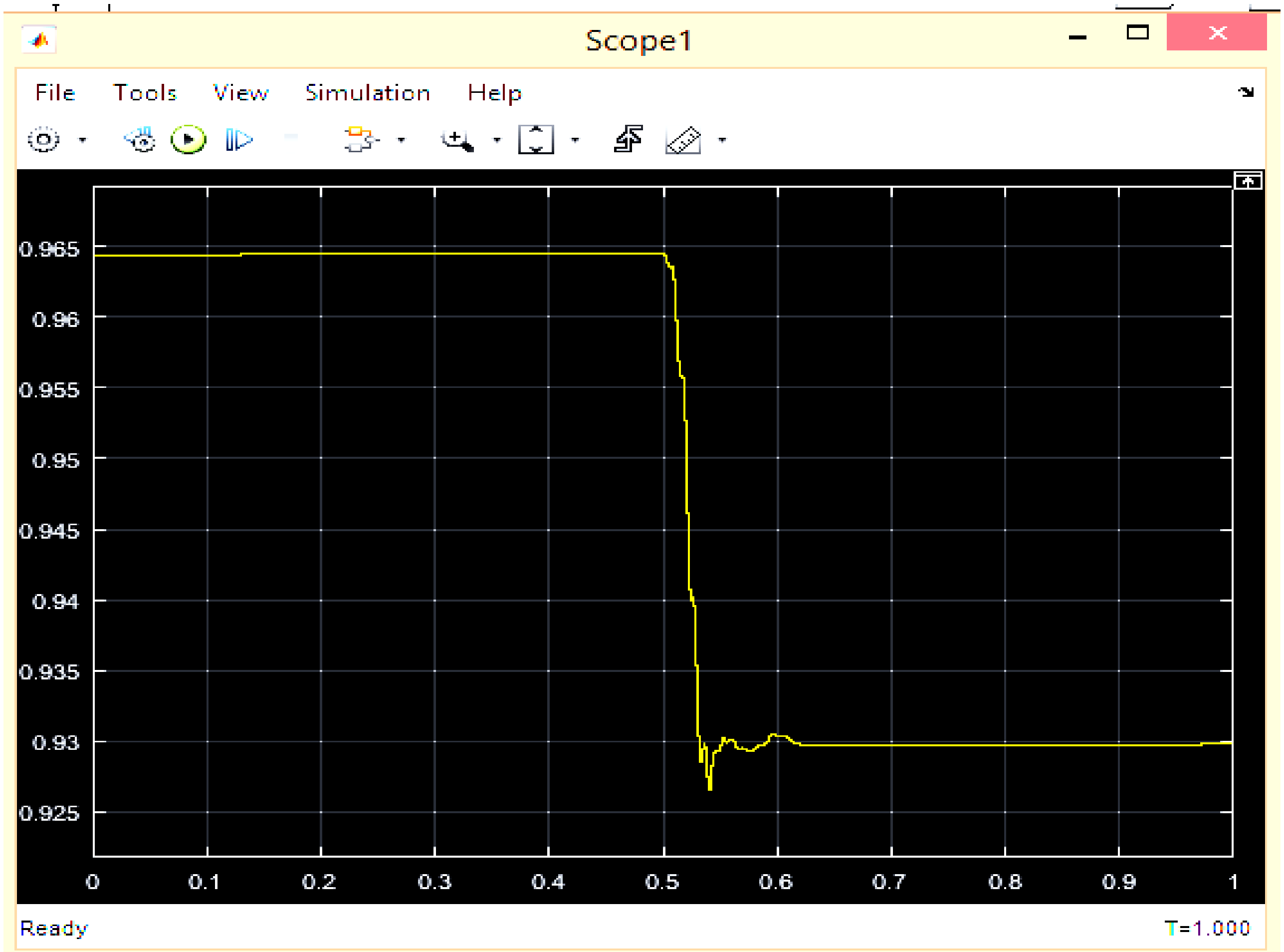


Figure 5.2: Power factor profile graph for overvoltage system

Unit of X axis: time (sec)
Unit of Y axis: power factor

OBSERVATIONS:

The power factor of the system is reduced to 0.93 (lagging) from 0.965 (lagging) in the overvoltage scenario.

The Active and reactive power flow across the circuit is given below.

GRAPH:1 (Active power flow in the circuit for overvoltage system)

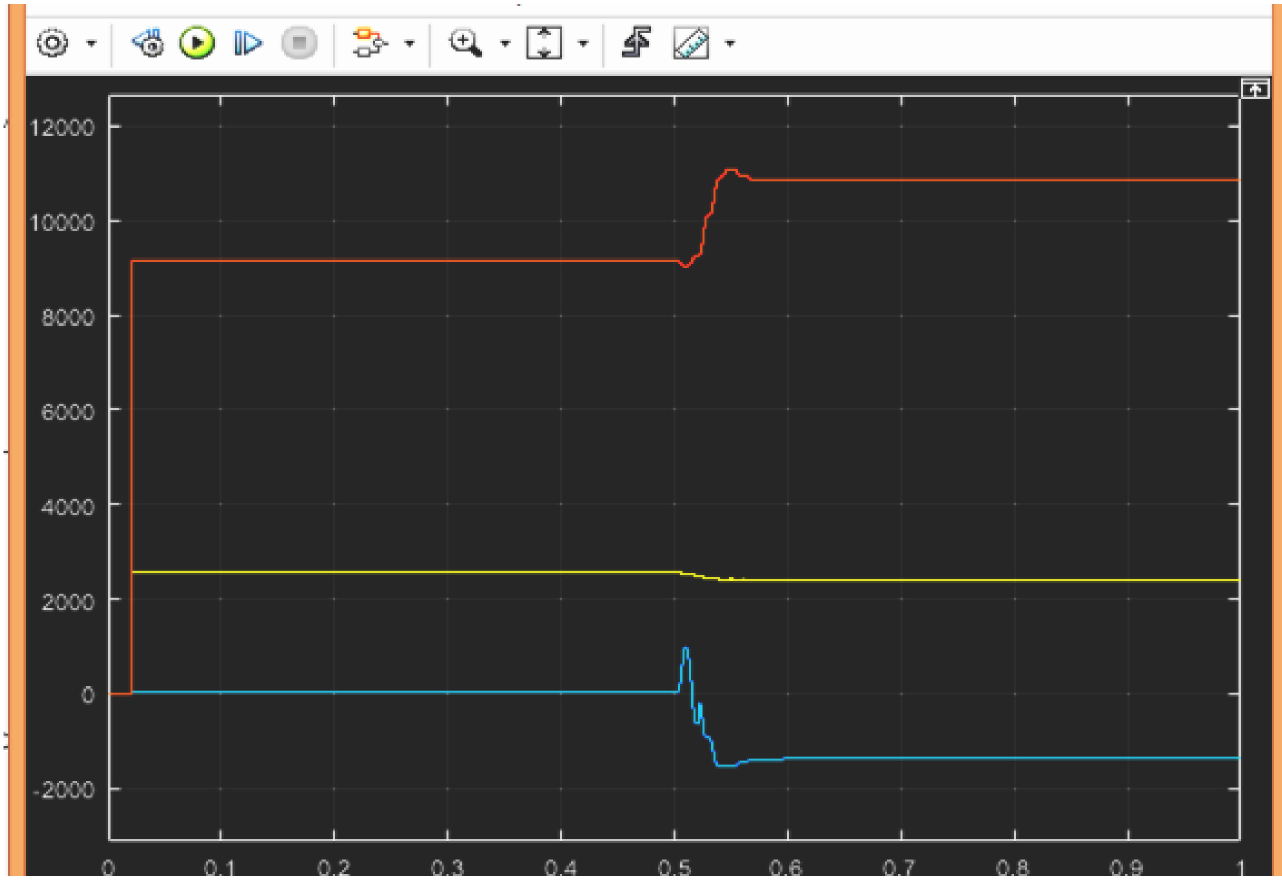


Figure 5.3: Active power flow in the circuit graph for overvoltage system

Unit of X Axis: time (sec)
Unit of Y Axis: Power (watts)

Yellow graph: Power flow across the main load
Blue Graph: Power flow across the electric spring

GRAPH:2 (Reactive power flow in the circuit for overvoltage system)

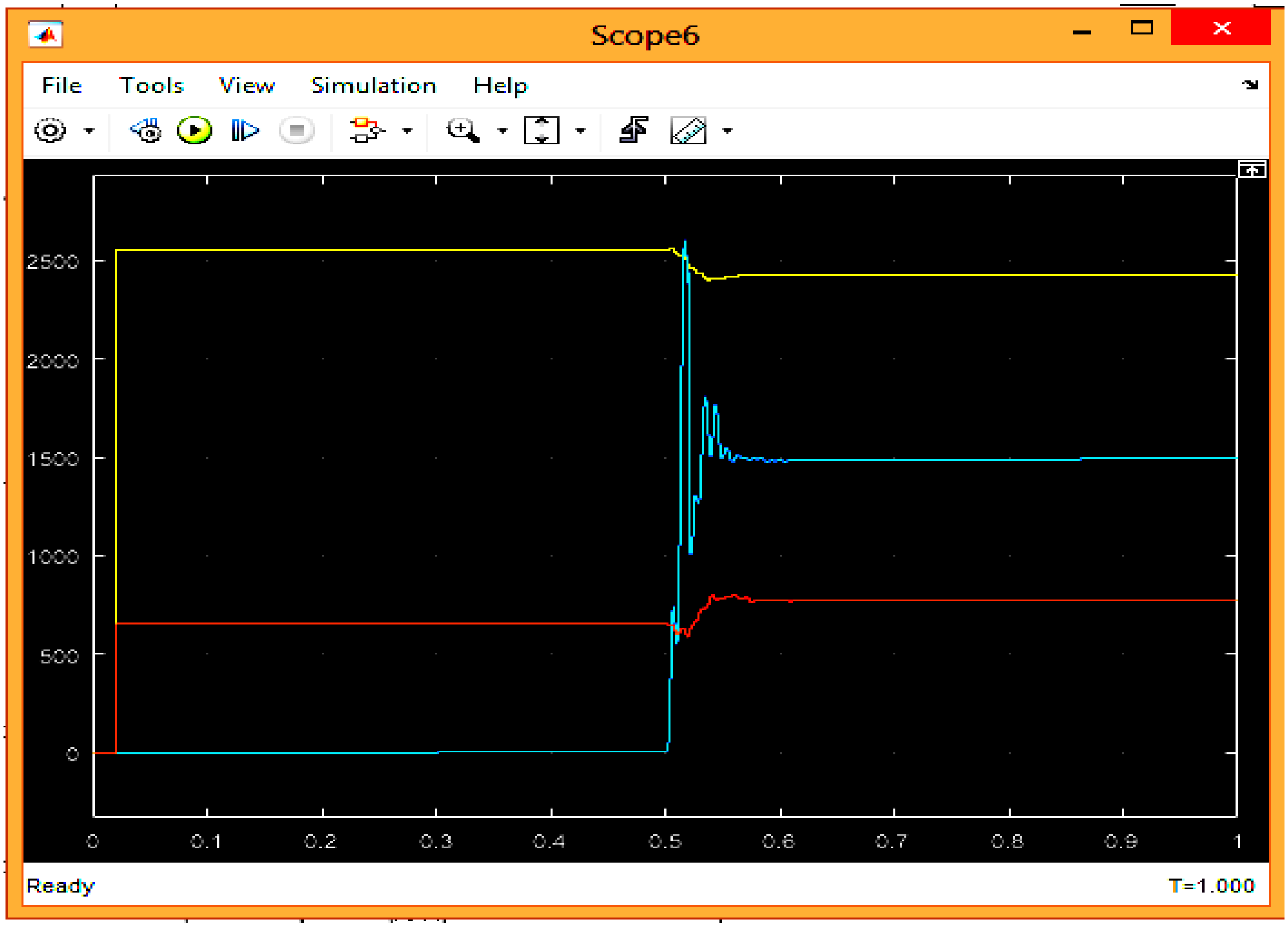


Figure 5.4: Reactive power flow in the circuit graph for overvoltage system

Unit of X Axis: time (sec)
Unit of Y axis: Power (KVAR)

Yellow graph: Power flow across the main load
Blue Graph: Power flow across the electric spring

2. UNDERVOLTAGE SYSTEM

The RMS Line voltage is kept at 218 Volts for the system and the electric spring is turned on at 0.5 seconds. The line voltage is boosted to the reference of 230 Volts by the electric spring at the designed time 0.5 seconds. There is both the injection of real power and capacitive power in the already existing inductive system.

The voltage profile graph developed is given below (Figure 5.5)

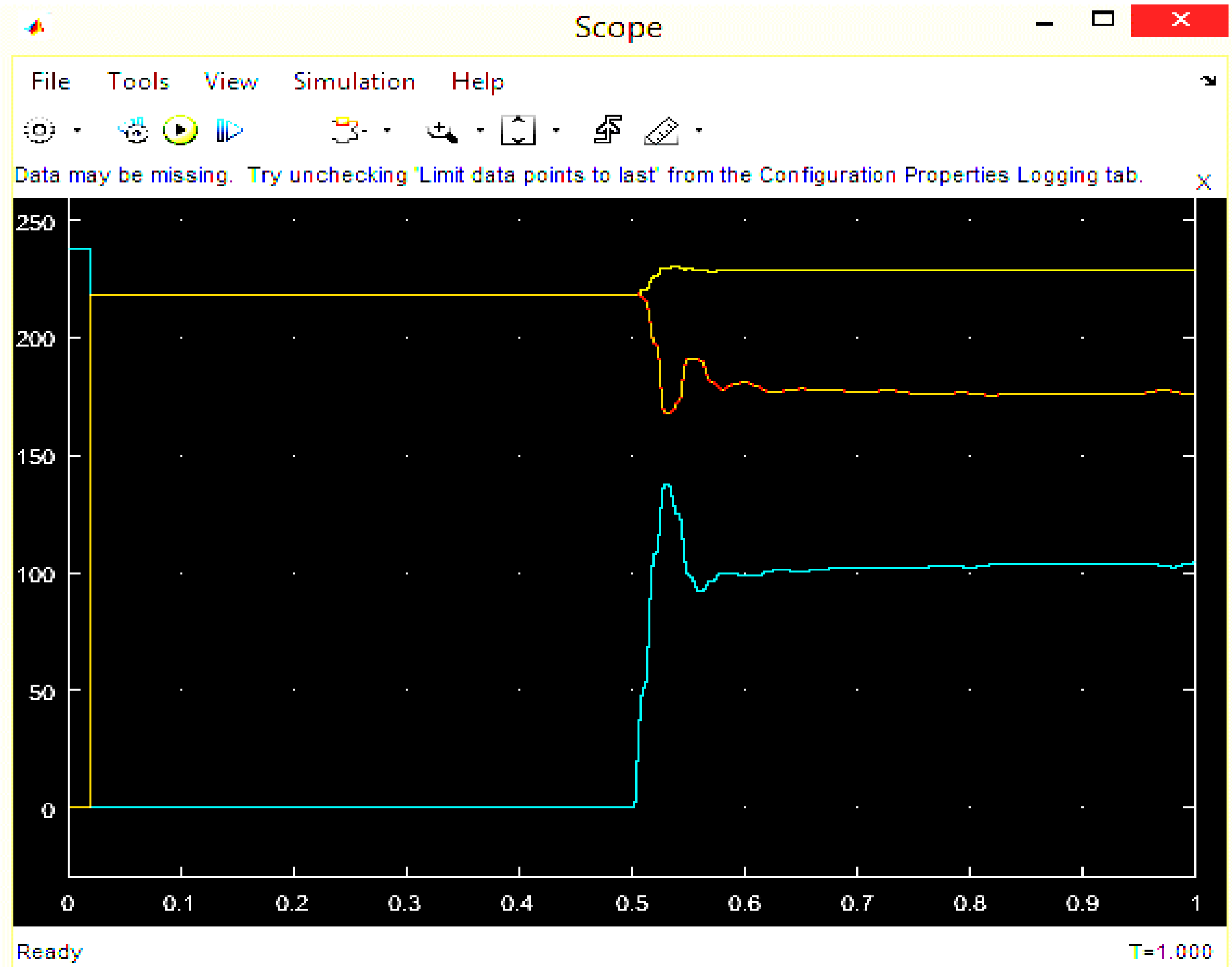


Figure 5.5: Voltage profile graph for undervoltage system
Unit of X-axis: time (sec)
Unit of Y-axis: Rms voltage (volts)

Yellow graph: RMS Line Voltage (change taking place at 0.5 seconds)
Blue Graph: Electric spring voltage

OBSERVATIONS

The change is due to the fact, that to maintain the RMS line voltage to the value of 230 V the spring will absorb real power and inject capacitive VAR, in the already existing inductive system.

The power factor profile is shown below (Figure 5.6)

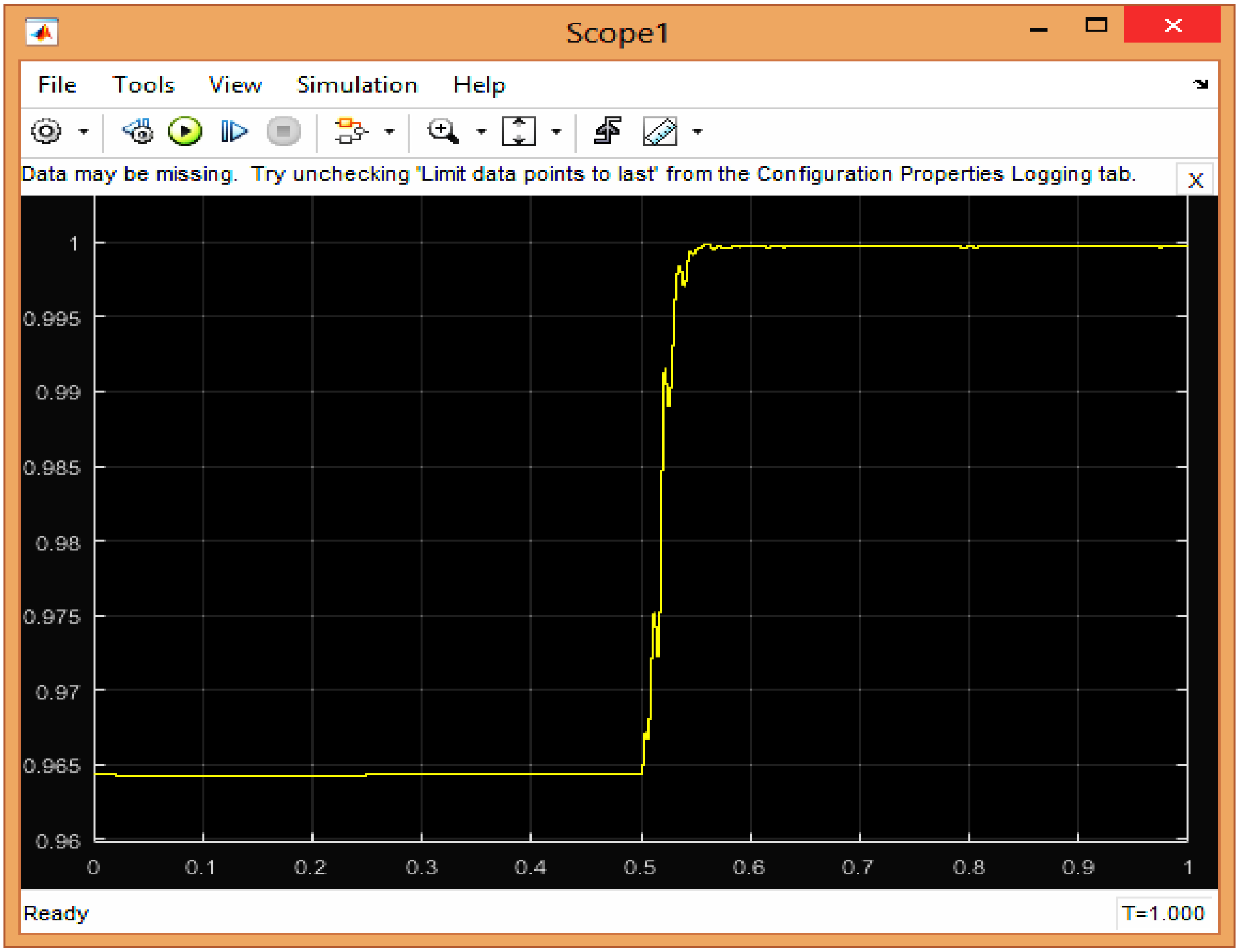


Figure 5.6: Power factor profile graph for undervoltage system

Unit of X axis: time (sec)
Unit of Y axis: power factor

OBSERVATIONS

The power factor of the system is improved to almost unity from 0.965 (lagging) in the undervoltage scenario.

The Active and reactive power flow across the circuit is given below.

GRAPH: 1 (Active power flow in the circuit for undervoltage system)

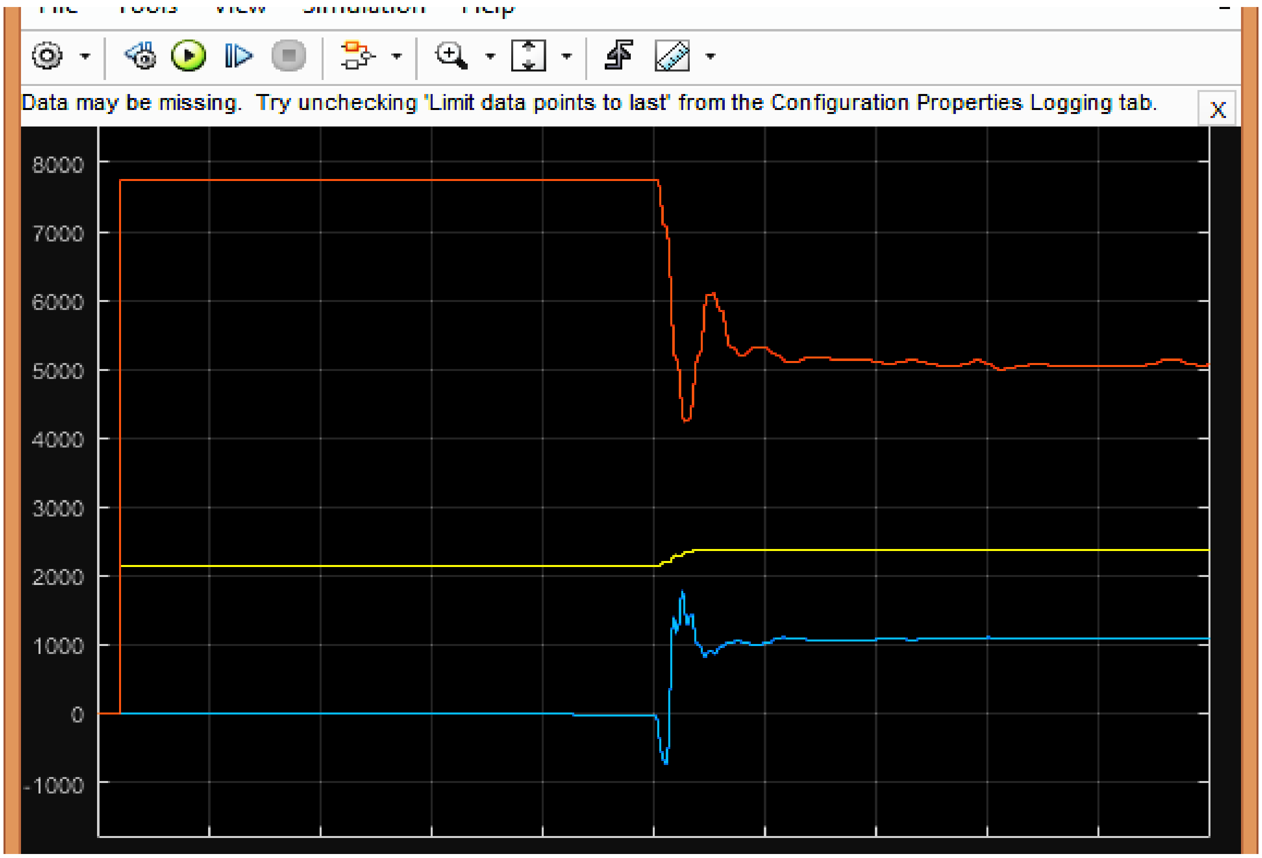


Figure 5.7: Active power flow in the circuit for undervoltage system

Unit of X axis: Time(sec)
Unit of Y axis: Power (watts)

Yellow graph: Power flow across the main load
Blue Graph: Power flow across the electric spring

GRAPH: 2 (Reactive power flow in the circuit for undervoltage system)

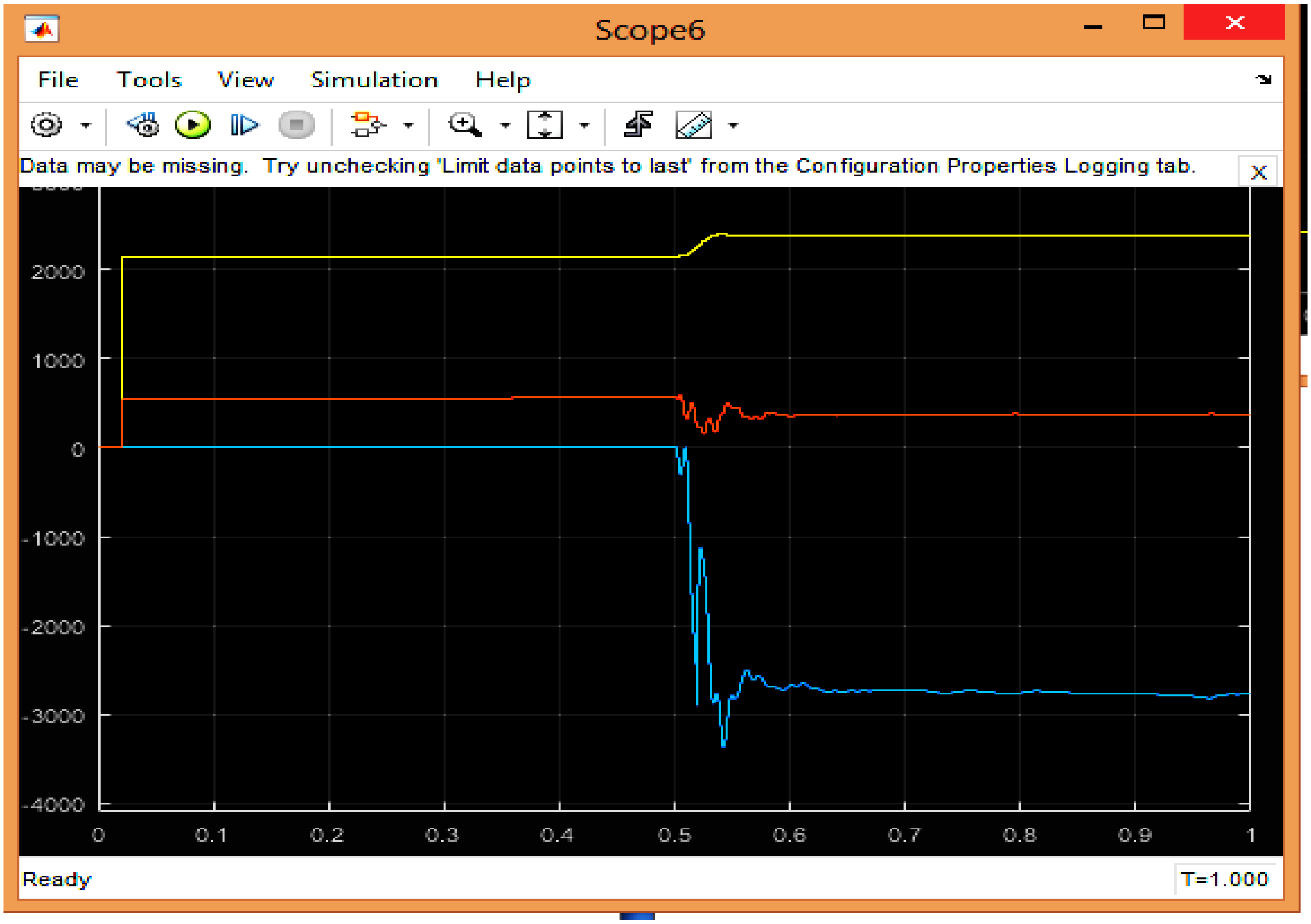


Figure 5.8: Reactive power flow in the circuit for undervoltage system

Unit of X axis: time (sec)
Unit of Y axis: Power (KVAR)

Yellow graph: Power flow across the main load
Blue Graph: Power flow across the electric spring

5.3 SIMULATION STUDY OF ELECTRIC SPRING USING FUZZY LOGIC CONTROL

The Electric Spring developed will be able to inject both active and reactive power in the system. The spring is activated with the help of a step signal (we have chosen the time as 0.5 seconds for the activation of the spring).

1. OVERVOLTAGE SYSTEM

The RMS Line voltage is kept at 238 Volts for the system and the electric spring is turned on at 0.5 seconds. The line voltage is brought to the reference of 230 Volts by the electric spring at the designed time 0.5 seconds. However, there is improved stability of the system and reduced noise as the final value is reached then the conventional spring.

There is both the injection of real power and inductive power in the already existing inductive system. The voltage profile graph developed is given below (Figure 5.9)

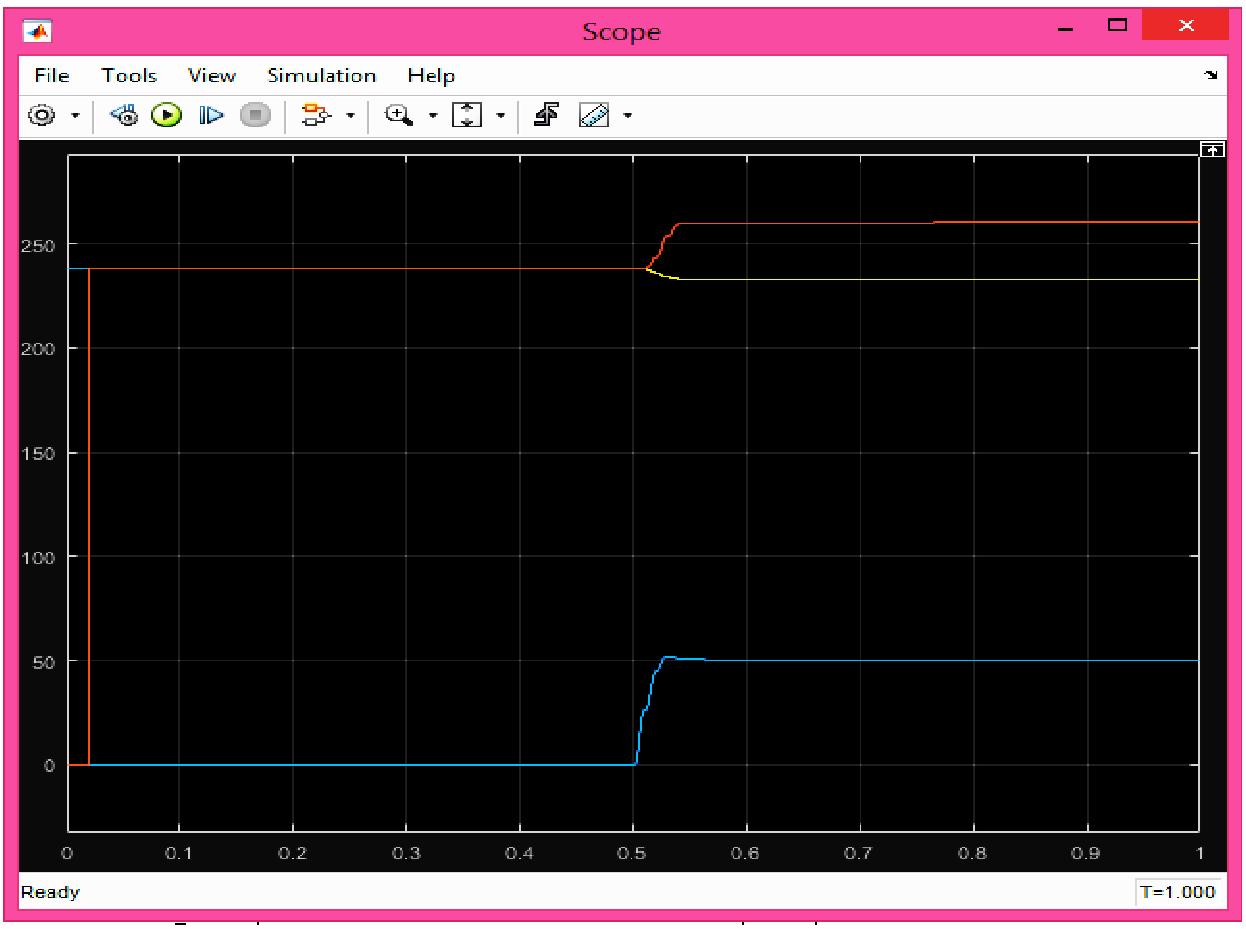


Figure 5.9: Voltage profile graph for overvoltage system
X axis: time (sec);
Y axis: voltage (volts)

OBSERVATIONS:

The change is due to the fact, that to maintain the RMS line voltage to the value of 230 V the spring will inject real and inductive power, in the already existing inductive system.

There has been improvement in the power factor then the conventional case. (Figure 5.10)

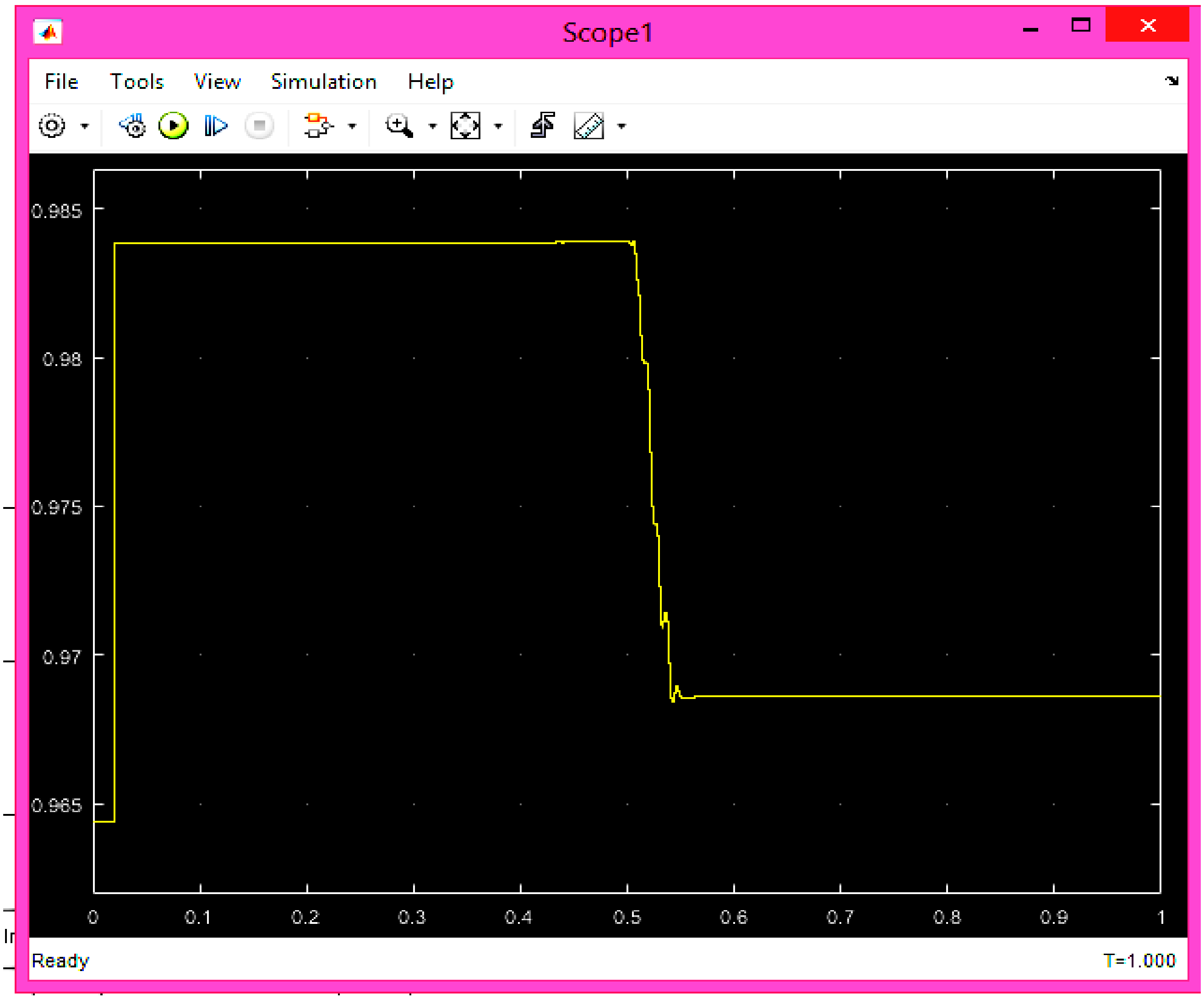


Figure 5.10: Power factor profile for overvoltage system

X axis: time (sec);
Y axis: power factor

OBSERVATIONS:

The power factor of the system is reduced to slightly less than 0.97(lagging) from 0.983 (lagging) in the overvoltage scenario.

2. UNDERVOLTAGE SYSTEM

The RMS Line voltage is kept at 218 Volts for the system and the electric spring is turned on at 0.5 seconds. The line voltage is boosted to the reference of 230 Volts by the electric spring at the designed time 0.5 seconds. There is both the injection of real power and capacitive power in the already existing inductive system.

There has been reduction in the noise and improvement of stability then the conventional system as the final value is reached.

The voltage profile graph (Figure 5.11) developed is given below:

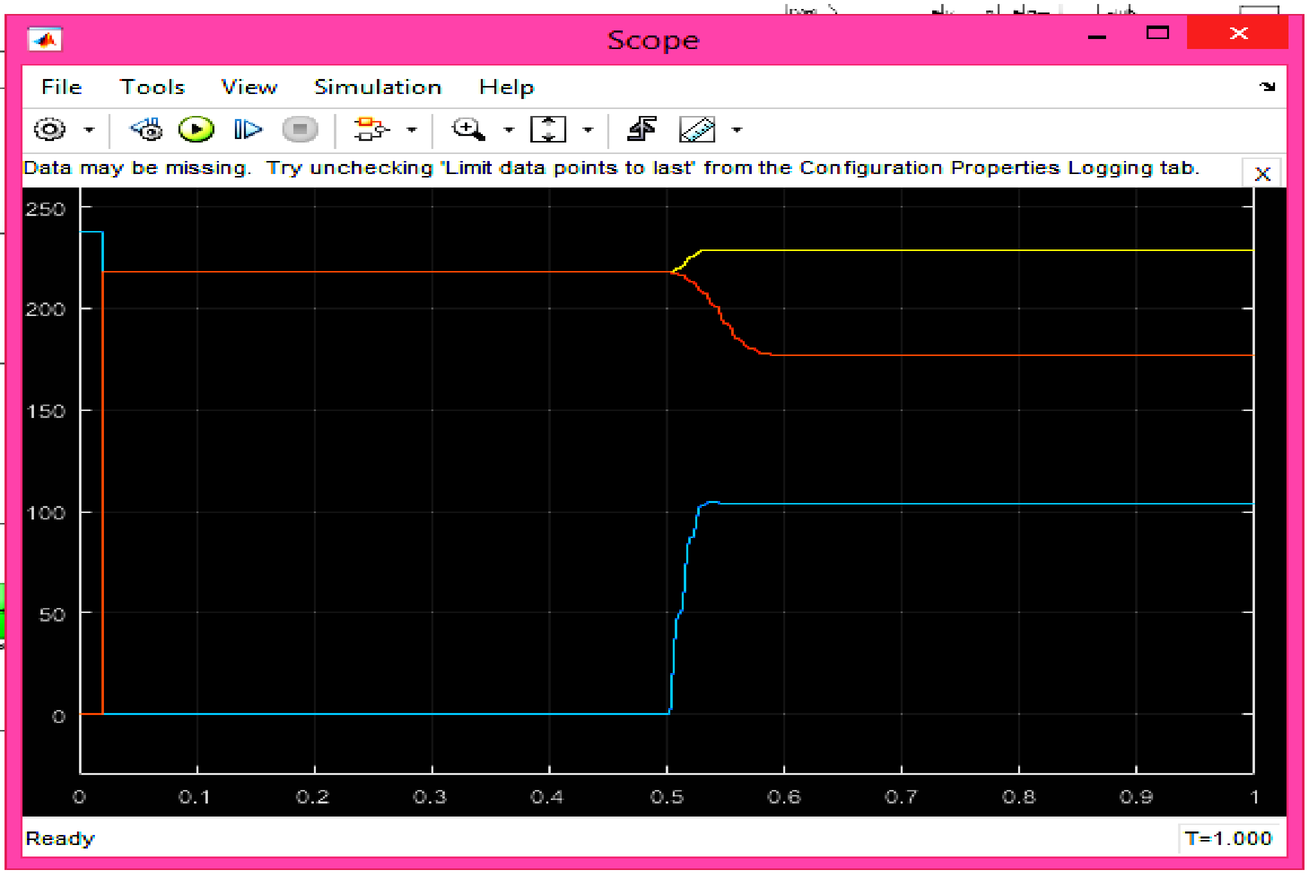


Figure 5.11: Voltage profile graph for undervoltage system

X axis: time (sec);
Y axis: voltage (volts)

OBSERVATIONS:

The power factor of the system is improved to almost unity from 0.977 (lagging) in the undervoltage scenario. The change is due to the fact, that to maintain the RMS line voltage to the value of 230 V the spring will absorb real power and inject capacitive VAR , in the already existing inductive system. The power factor profile is shown below

However, there has been an improvement in the power factor and reduced noise in this case as in comparison to the conventional case (Fig 5.12)

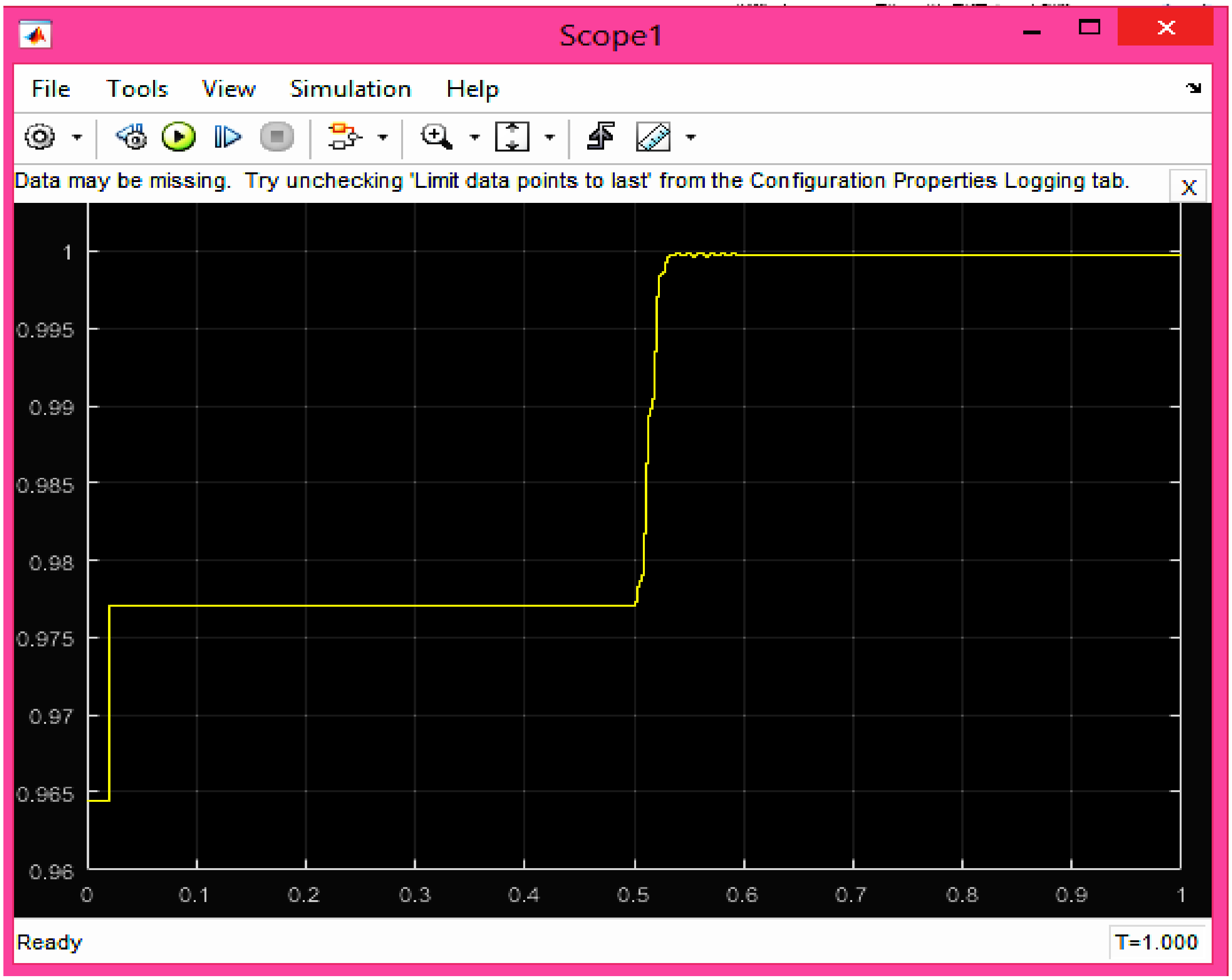


Figure 5.12: Power factor profile for undervoltage system

X axis: time (sec);
Y axis: power factor

5.4 COMPARISION BETWEEN THE CONVENTIONAL AND IMPROVISED ELECTRIC SPRING RESULTS (OVER VOLTAGE SYSTEM)-VOLTAGE PROFILE

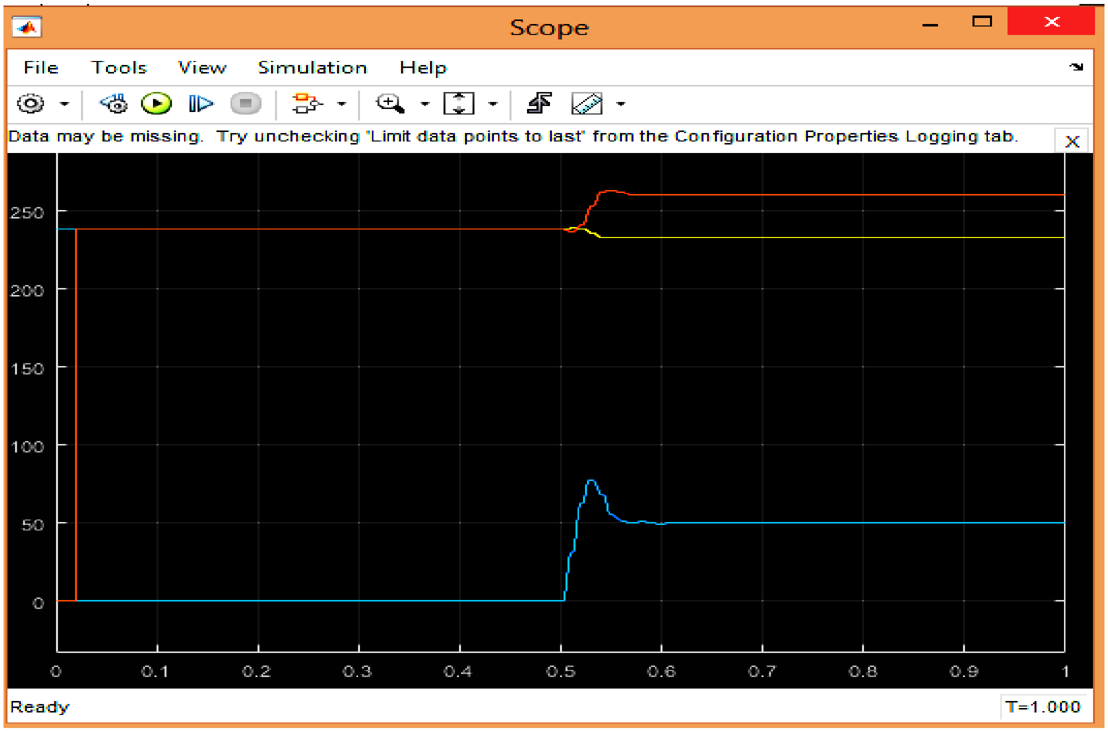


Figure 5.13: Conventional Electric Spring usage results (over voltage system)-voltage profile [X axis: time (sec); Y axis: voltage (volts)]

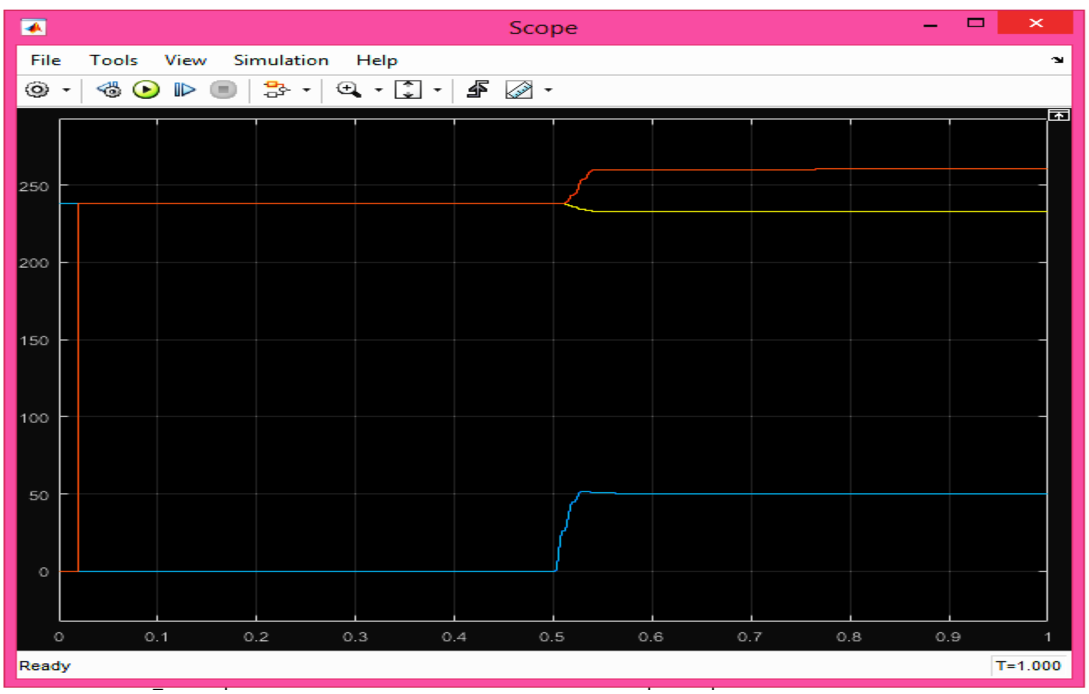


Figure 5.14: Improvement using Fuzzy Logic results (over voltage system)-voltage profile [X axis: time (sec); Y axis: voltage (volts)]

5.5 COMPARISION BETWEEN THE CONVENTIONAL AND IMPROVISED ELECTRIC SPRING RESULTS (OVER VOLTAGE SYSTEM)-POWER FACTOR

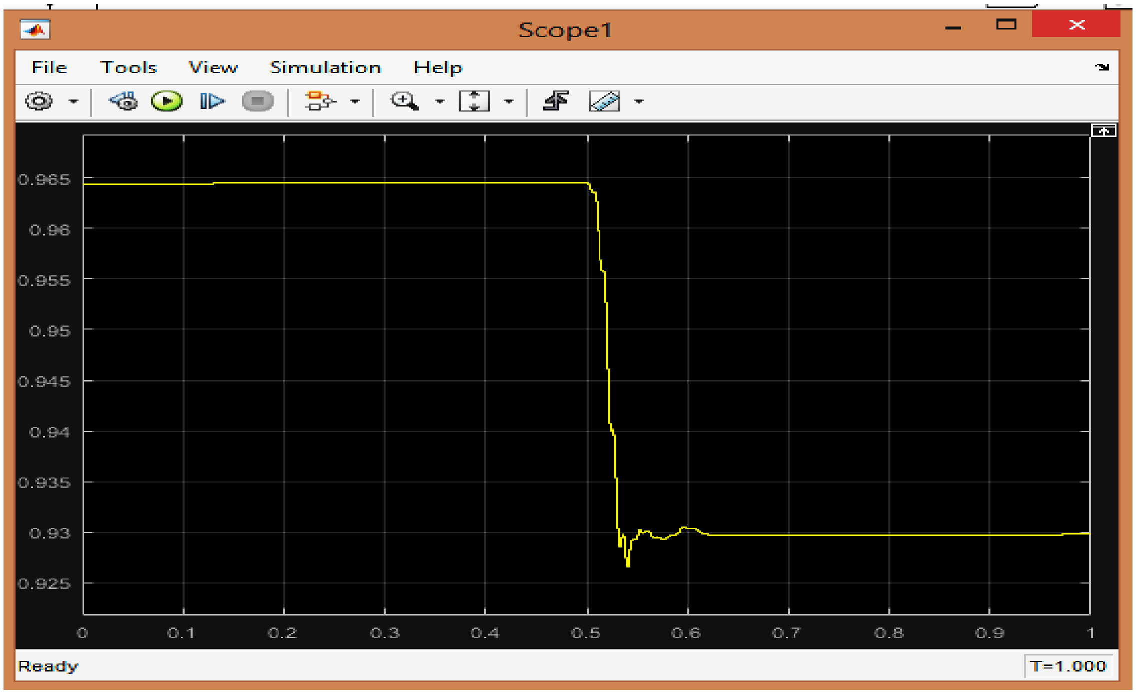


Figure 5.15: Conventional Electric Spring usage results (over voltage system)-power factor profile [X axis: time (sec); Y axis: power factor]

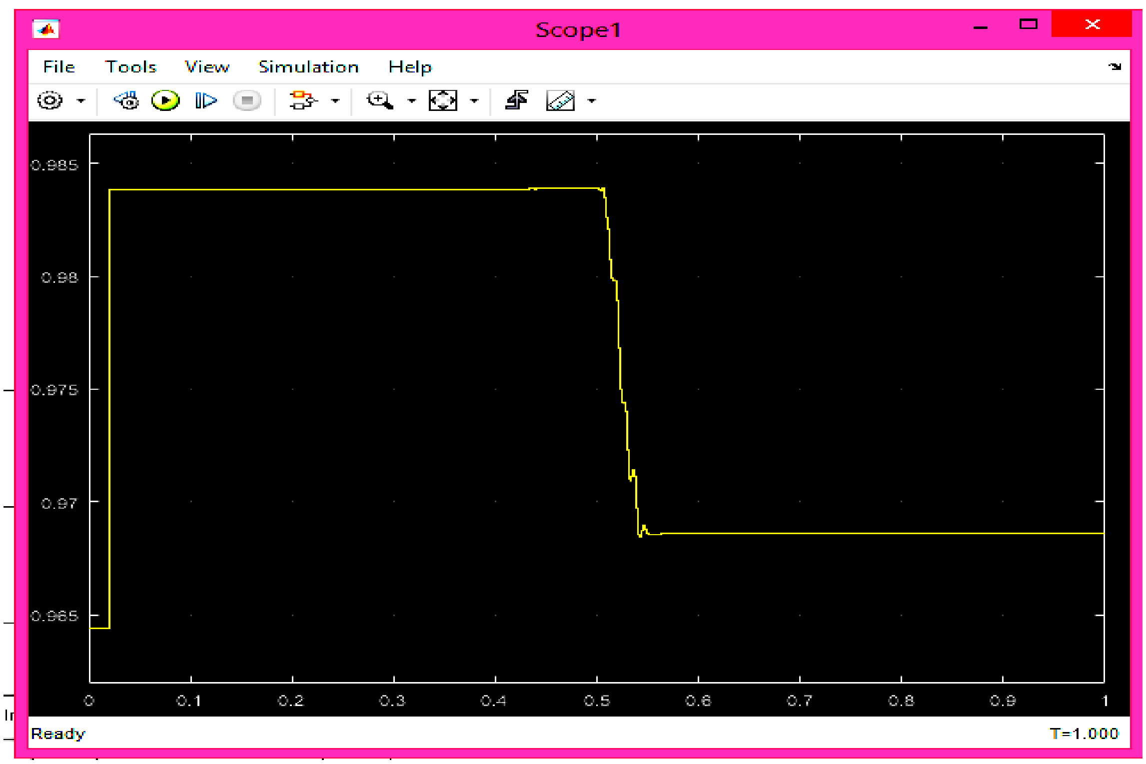


Figure 5.16: Improvement using Fuzzy Logic results (over voltage system)-power factor profile [X axis: time (sec); Y axis: power factor]

5.6 COMPARISION BETWEEN THE CONVENTIONAL AND IMPROVISED ELECTRIC SPRING RESULTS (UNDER VOLTAGE SYSTEM)-VOLTAGE PROFILE

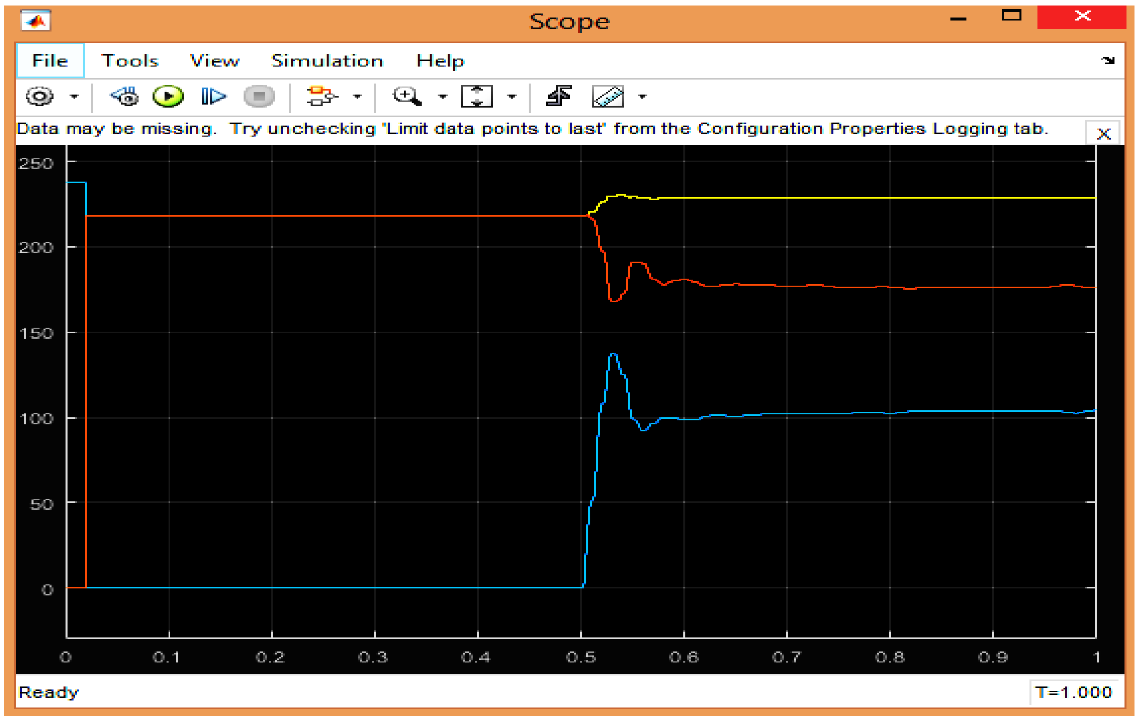


Figure 5.17: Conventional Electric Spring usage results (under voltage system)-voltage profile [X axis: time (sec); Y axis: voltage (volts)]

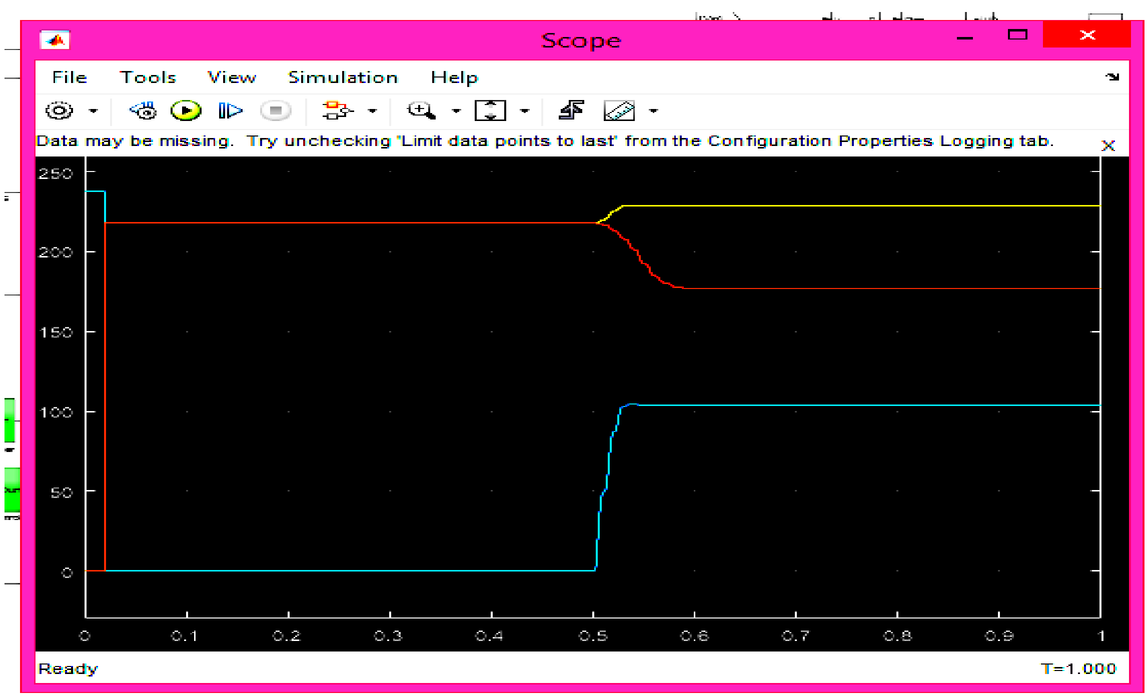


Figure 5.18: Improvement using Fuzzy Logic results (under voltage system)-voltage profile [X axis: time (sec); Y axis: voltage (volts)]

5.7 COMPARISION BETWEEN THE CONVENTIONAL AND IMPROVISED ELECTRIC SPRING RESULTS (UNDER VOLTAGE SYSTEM)-POWER FACTOR

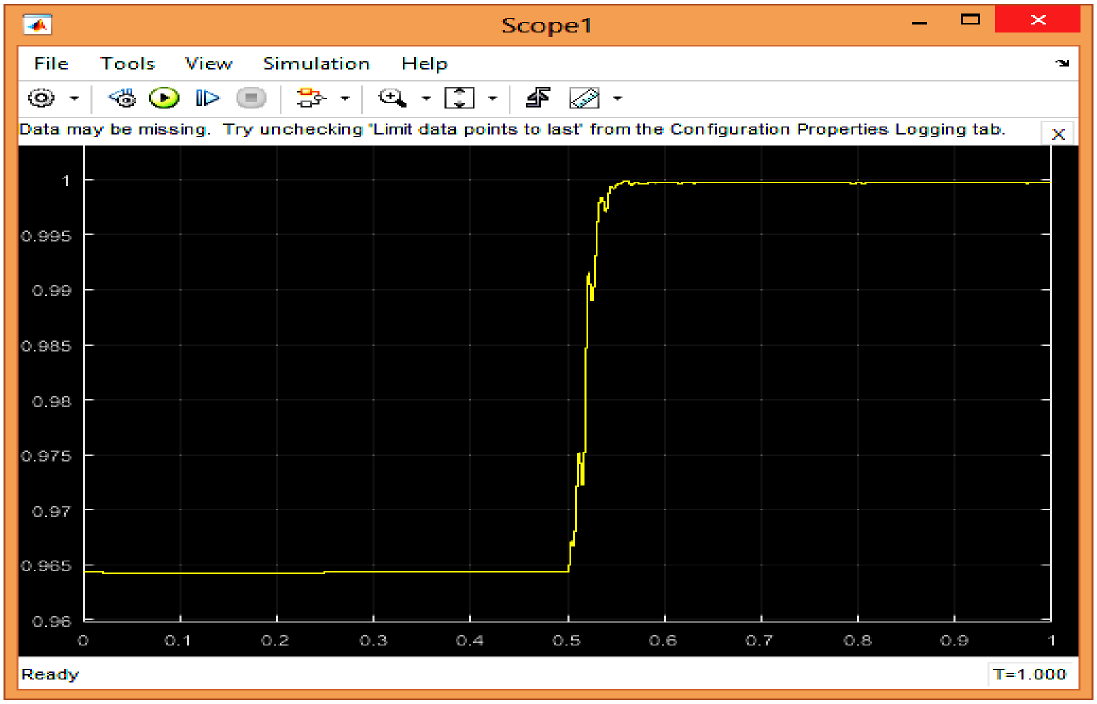


Figure 5.19: Conventional Electric Spring usage results (under voltage system)-power factor profile [X axis: time (sec); Y axis: power factor]

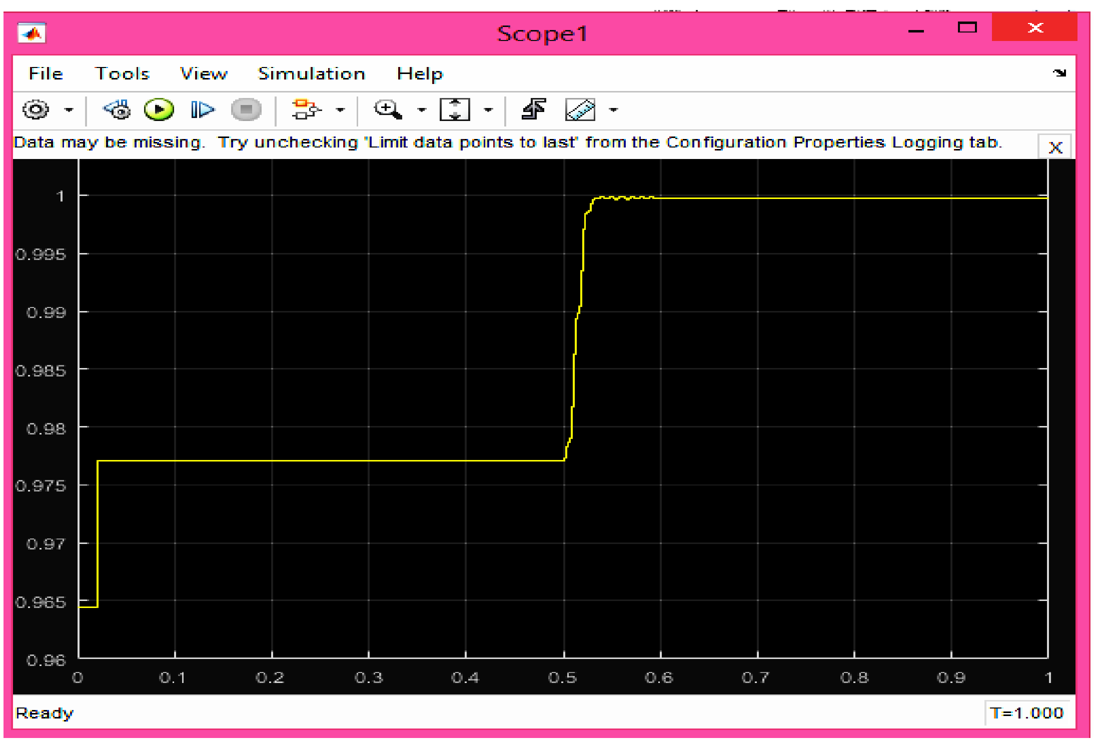


Figure 5.20: Improvement using Fuzzy Logic results (under voltage system)-power factor profile [X axis: time (sec); Y axis: power factor]

`5.8 ANALYSIS OF THE RESULTS

The analysis of the project can be summarized in the following manner. We have considered two cases in which the application of electric spring has been used to obtain voltage stability, power and power factor correction.

Overvoltage case

The RMS Line voltage is kept at 238 Volts for the system and the electric spring is turned on at 0.5 seconds. The line voltage is brought to the reference of 230 Volts by the electric spring at the designed time 0.5 seconds.

There is both the injection of inductive power in the already existing inductive system

The power factor of the system is reduced to 0.93 (lagging) from 0.965 (lagging) in the overvoltage scenario.

Undervoltage Case

The change is due to the fact, that to maintain the RMS line voltage to the value of 230 V there is both injection of capacitive power in the already existing inductive system.

The power factor of the system is improved to almost unity from 0.965 (lagging) in the undervoltage scenario.

However, by the use of advanced controlled we have seen improvement in power factor and reduced noise in this case as in comparison to the conventional case.

The power factor of the system is reduced to slightly less than 0.97(lagging) from 0.983 (lagging) in the overvoltage scenario. The power factor of the system is improved to almost unity from 0.977 (lagging) in the undervoltage scenario.

LIST OF INCLUDED RESEARCH PAPERS

1. **PAPER PUBLISHED**

   Paper Title: Advanced Controller for Power Factor Correction and Comparison with Conventional ES- ELECTRIC SPRING

   Journal and Volume: IJREET, Issue 1, August 2023

   Authors:

   1. Amlan Jyoti Kashyap (M.Tech Scholar, Assam Engineering College)
   2. Dr. Purobi Patowary (Professor, Electrical Engineering Department, Assam Engineering College)

   Published: Online

   ISSN: 2545-4523

2. PAPER COMMUNICATED

Paper Title: Voltage Control using ES and modification of properties using modified ES

CHAPTER-6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION:

As per the analysis in section 5.8 we have come to know that by the use of electric spring the voltage stability and power factor correction is achieved in both undervoltage and undervoltage scenarios. Also, by the use of advanced controllers we have seen improvement in power factor and reduced noise in this case as in comparison to the conventional case

Voltage monitoring in MV and LV appropriation organizations, as well as demand-side management (DSM), have traditionally been dealt with and managed separately. Voltage regulation is typically achieved by the use of the control devices discussed in the preceding section. Demand-side the board, on the other hand, is used in a more widespread manner (frequently at the computer level) and is based on intuition or communication office in the machine. In this thesis, the effects of various controllers were successfully applied and compared to discover that the fuzzy pi-based hybrid controller provides improved power efficiency and power factor correction as the power factor approaches one.

6.2 FUTURE SCOPE:

If various noncritical loads are outfitted with such electric springs and spread over the power system, those ES would provide an extremely dependable and convincing response for confiscated energy stockpiling, voltage control, and damping capacities for future power frames. Such stabilization mechanisms are also independent of data and correspondence creativity (ICT). a one-of-a-kind DSM scheme that could be carried out without relying on data and correspondence advances.

Further, scope will include the application of electric spring in large power systems and combination with FACTS device such as STATCOM to provide stability and improve the performance in the power system. Such study will enable us to improve and work upon the demand side management and work efficiently towards the development.

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