"Coordination of Generator Protection with Generator Excitation Control and Generator Capability"

Major Project Report

Submitted in Partial Fulfillment of the Requirements for semester IV of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Electrical Power System)

By

Bhavinkumar H. Patel

(14**MEEE**13)

NIRMA UNIVERSITY
INSTITUTE OF TECHNOLOGY
NAAC ACCREDITED 'A' GRADE

Department of Electrical Engineering

INSTITUTE OF TECHNOLOGY

NIRMA UNIVERSITY

Ahmedabad-382481

March 2016

Undertaking for Originality of the Work

I, **Bhavinkumar H. Patel** (**Roll.No.14MEEE13**), give undertaking that the Major Project entitled **"Coordination of Generator Protection with Generator Excitation Control and Generator Capability"** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in Electrical Power Systems of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

____

Patel Bhavinkumar

Date :-

Place :- Ahmedabad

Endorsed by:

____

Institute Guide
Prof. Shanker Godwal
Assistant Professor
Department of Electrical Engineering
Institute of Technology
Nirma University
Ahmedabad

Institute Co-Guide
Prof. Guarang Buch
Assistant Professor
Institute of Technology
Nirma University
Ahmedabad

Certificate

This is to certify that the Major Project Report (Part-I) entitled "Coordination of Generator Protection with Generator Excitation Control and Generator Capability" submitted by **Mr. Bhavinkumar H. Patel (RollNo: 14MEEE13)** towards the partial fulfillment of the requirements for Semester-III of Master of Technology (Electrical Engineering) in the field of Electrical Power System of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

Date:

Institute Guide
Prof. Shanker Godwal
Assistant Professor
Department of Electrical Engineering
Institute of Technology
Nirma University
Ahmedabad

Institute Co-Guide
Prof. Guarang Buch
Assistant Professor
Institute of Technology
Nirma University
Ahmedabad

Head of Department
Department of Electrical Engineering
Institute of Technology
Nirma University
Ahmedabad

Director
Institute of Technology
Nirma University
Ahmedabad

Acknowledgements

With immense pleasure, I would like to present this report on the dissertation work related to "Coordination of Generator Protection with Generator Excitation Control and Generator Capability". I offer my sincere gratitude to Prof. Shanker Godwal (Assistant Professor, Electrical Engineering Department, IT, NU), Prof. Gaurang Buch (Assistant Professor, Electrical Engineering Department, IT, NU) for his valuable guidance, motivation and encouragement. He has shown keen interest in this dissertation work right from beginning and has been a great motivating factor in outlining the flow of my work. I am also thankful to my classmates and all the member of Electrical Engineering Department who have directly or indirectly helped me during the project.

I would also like to thank Prof. Dr. P. N. Tekwani, Director, Institute of Technology, Nirma University for allowing me to carry out my project work in industry. I am thankful to Nirma University for providing all kind of required resources.

Bhavinkumar H. Patel

14MEEE13

Abstract

The project work basically includes specific calculation methods that ensure the coordination between generator protection and excitation system control. Better settings of relays with generator full load ability and machine steady state limits is the work included in project.

Recent mal-operations of generation protection while major system disturbances have emerged the require for effective coordination of generator protection with generator capability, generator excitation control and transmission system protection. So it is very much needed to improve the coordination between generator protection and control so that during major system disturbances such mal-operations can be prevented.

Abbreviations

AVR .... Automatic Voltage Regulator

V/Hz .... Volt sper Hertz

UEL .... Under Excitation Limiter

OEL .... Over Excitation Limiter

OV .... Over Voltage

K_{ramp} .... OEL proportional ramp rate gain

E_{fd} .... Exciter output voltage

I_{fd} .... Synchronous machine field current

I_{TFPU} .... OEL timer pickup level

I_{max} .... OEL enabled threshold

I_{inst} .... OEL limit of instantaneous current

T_{FCL} .... OEL timer setpoint

T_{lim} .... OEL timing signal

T_{min} .... minimum limit of over excitation limiter timer

V_f .... output of the excitation system stabilizer

VH_{ZHI} .... V/Hz limiter disabled setpoint

V_t .... Synchronous machine terminal voltage

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Generator insurance designers are well known with the requirement for planning generator security with generator control and load ability. There are different strategies and procedures to give this coordination are settled yet scatter in different sources. In each force framework there are transient aggravations happening time to time since issues and/or exchanging of significant burden. With the assistance of generator excitation other control frameworks, the framework embraces new unfaltering state condition. Likewise some extra power framework control plan might be utilized to receive new unfaltering state condition.

The control functions ensure control of voltage, reactive power flow, and the improvement of system stability. The role of the protective functions is to check the capability limits of the synchronous machine, excitation system and other equipment does not exceed. From generator thought perspective, excitation framework supply and will conform field current of the synchronous generator for keeping up the terminal voltage as the yield changes inside the persistent ability of the generator. From force framework perspective, the excitation framework ought to add to legal control of voltage and upgrade of framework security.

Because of late mis-operation of generator assurance in the season of real system unsettling influences, the precondition of coordination between generator insurance and control has came into light. When some fault or disturbance occurs, the relay energizes after its set time and gives signal to circuit breaker to disconnect system from generator. Because of small perturbations coming every time the circuit breaker disconnects main system from generator. By doing proper coordination between excitation system, relay and generator capability, tripping of relay for each disturbances has to be prevented and continuous supply is maintained. This project work incudes following coordination:

- Generator Capability Curve Coordination
- Under excited setting coordination with generator loss-of-field protection
- Overexcited setting coordination with generator impedance backup protection
- AVR Coordination Under excited Operation
- AVR Coordination Over excitation Operation
- Coordination of AVR V/Hz limiter with over excitation(V/Hz) assurance
- Coordination of the Under Excitation Limiter (UEL) with loss-of-field assurance and Steady State Stability Limits

1.1 Excitation Control Basics

The generators excitation system supplies the energy for the magnetic field to keep the generator in synchronism. Aside from proceeding with the synchronism of the generator, the excitation system likewise impact the measure of reactive power that is taken or given by generator. It is seen that Reactive power output is expanded with the increase in the excitation current and the other way around. The most ordinarily utilized voltage control mode for generators is the AVR mode. During disturbances where short circuits depress the system voltage, electrical power is fully not delivered into the system.

Fast response of the excitation system help to increase the synchronizing torque to keep the generator in synchronism with the system.Excitation controls are used to prevent the AVR from imposing undesirable conditions upon the generator. These controls are maximum and minimum excitation limiters. The overexcitation limiter prevents the AVR from supplying more excitation current than the excitation system can supply. The underexcitation limiter prevents the AVR from losing synchronism by reducing excitation to very low level.

1.2 Generator Steady State Stability Basics

When there are too few transmission lines to transfer power from generating side, Steady state instability occurs. which means loss of transmission line will result in steady state instability. The capacity to transfer real(MW) power is described by below power equation and shown graphically in Fig.1.1.

$$P_e = \frac{E_g E_s}{X} sin(\theta_g - \theta_s) \tag{1.1}$$

Where:

Eg = Generation Voltage

Es = System Voltage

Pe = Real Power Transfer

X = Steady State Reactance Between Generator and System

θ_g = Voltage Angle at Generation

We can see from the power transfer equation above that maximum power(Pmax) is transmitted when θ_g-θ_s=90^o i.e sin90^o=1

When the magnitude of phase angle between two electrical quantities - load and remote generation, exceeds more than 90, the electrical power which can be transmitted is reduced and the whole system becomes unstable one. Because of tripping of few lines between load centre and remote generation, the reactance will increase to a point where extreme power cannot be transmitted. This is shown in the Power angle curve

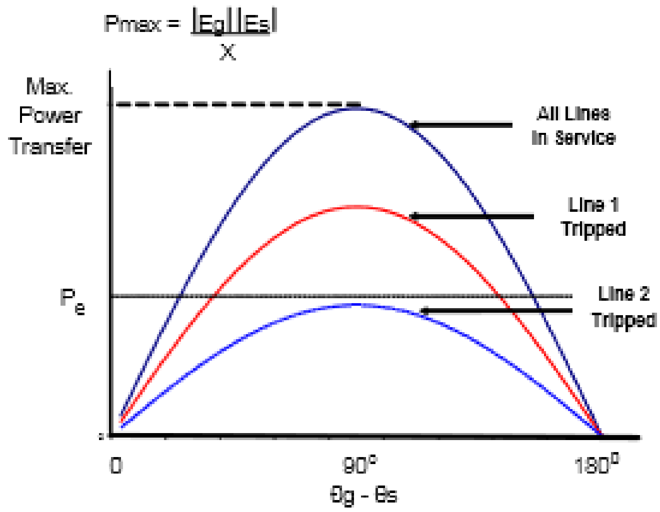

Figure 1.1: Power Angle Analysis-Steady State Instability[1]

Fig.1.1 that when line 1 We can see that When the reactance increases the maximum power transmitted and height of the power angle curve is reduced. Voltage collapse and steady state instability occurs as the tripping of the lines increases. Tripping of lines should be reduced for continuous power transfer between generating station and far load.

1.3 AVR Coordination - Underexcited Operation

Excitation system once in a while works to the greatest or least of their abilities till the system voltage tries to increment or reduction more than its typical working range. At the point when voltage transient happen, excitation controls comes in the operation more than the evaluated enduring state limits. Coordination between relays and excitation controls should be done properly also considering two quantities pickup magnitudes and time delays. The consideration of generator capability curve and the setting of loss of field is required for the under excitation limiter settings. For the calculation of existing operating conditions, the AVR uses terminal voltage of generator and phase current. The protection of generator from operating too far in under excited region is the function of Under excitation Limiter. The settings of the limits can be changed with the voltage. Some of the limiters will change with the square of the voltage while some are proportional with the voltage.

1.4 Loss of Field Coordination

The synchronous generator will keep on operating like induction generator because of the loss of field and will bring about induced heating in the field and different parts, reactive current over-burden of stator winding and voltage stability issues. System voltage can be limited by making the generators to be operated in underexcited and absorb Vars from the system. As indicated by the generator ability curve, it is essential that Generator ought to do this inside its capacities. The impedance type of LOF protection can be affected by the following abnormal operating conditions:

- Power swing disruptions;
- Decreased frequency;
- Increased level of leading reactive load.

It is incredibly hazardous to the generator and the force framework where it is related when there is fragmentary or hard and fast loss of field on a synchronous generator. To keep up a vital separation from generator harm it is key to perceive the above condition fastly moreover it ought to be isolated from the system. Source like loss of reactive power support and reactive power loss happen if loss of field condition is not distinguished and can have destructing influence on the system. Distance relay is mostly used method for detecting generator loss of field condition which sense the changes of impedance as seen from the generator terminals.

1.5 AVR Coordination - Overexcited Operation

Proper coordination between excitation system defence and in addition outside protection of excitation framework is required so that the generator overexcitation ability is not restricted. The generator should be operated upto its short time capabilities allowed by the excitation control or protection during major disturbances. The protection or control elements inside the excitation system which affects overexcitation operation of generator include:

- Overexcitation Limiter(OEL) - The Over Excitation Limiter is utilized for counteracting inordinate current versus time in the field circuit of the generator. Field current or field voltage is the variable which is checked. The field current can be surpass to the full load levels by numerous ways. There are two most common reasons, one of them is when there is close in fault on the machine and other is during overload. When OEL is not in control, its output is fixed at full level, which makes sure the AVR signal will always be in control. The settings of the new excitation systems over excitation limiter control can be modifies based on also hydrogen pressure.

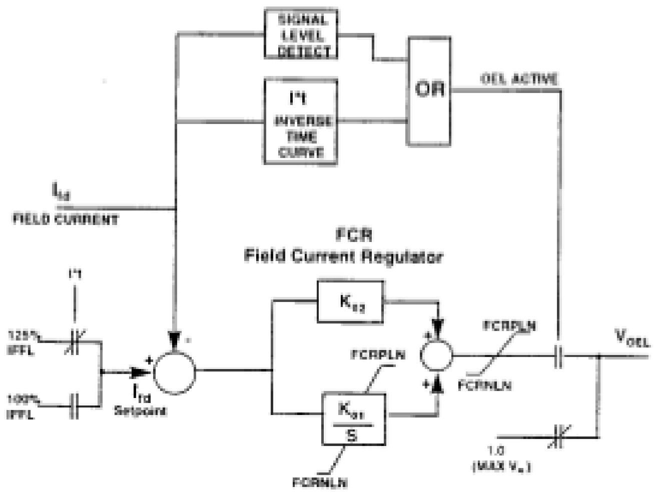

Figure 1.2: Over Excitation Limiter Block Diagram[2]

- Volt perHertz Limiter - The V/Hz fraction of the generator can be restricted by constraining the generator voltage with the assistance of V/Hz limiter depending on program. Serving as a reinforcement when there is collapse of V/Hz limiter in to the excitation control is one of the significant capacity of V/Hz security. Immersion of the iron core of generators and the transformers will happen due to the expansion in V/Hz proportions which will bring about breakdown of core between overlay protection due to exorbitant voltage and eddy current heating. The unfaltering state limit for evaluated generator stator terminal voltage is +/ - 5% at estimated frequency.

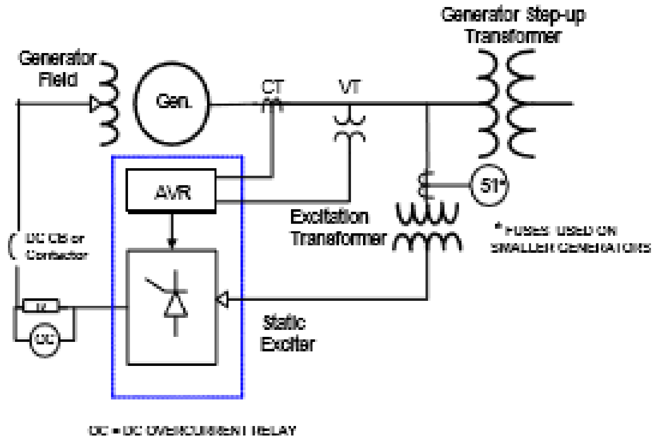

Figure 1.3: Typical Transformer Supplied Excitation System[1]

- Field Overcurrent Protection - Fig.1.3 shows the DC overcurrent which is provided in the exciters. In a portion of the exciters there is a defensive inverse time module which figures the current into time to give a inverse time bend. The coordination between Over excitation setting and brief time ability of the field is required. In the event that inoperative conditions happens it additionally permit the field forcing to be occur. In some cases if the over excitation limiter begin runback is not successful then this protection may trip exciter.

1.6 Test Methodology

Todays excitation limiter controls are digital based, so understanding of the basic design of limiter is required for the process of testing the excitation limiter. It might be hard to organize tests at this configuration limits in light of the fact that the limiters are planned in such an approach to secure the generator and excitation system which work outside the cutoff points of its ability. This tests are performed at lower great focuses and it likewise comprise of check of the working of the ordinary parts of the limiter. In the process of testing it is required that some of the settings are to be changed, and proper documentation is to be done and the parameters are resettled to insure correct normal operation.

Chapter 2

Literature survey

[1] Charles J. Mozina, Michael Reichard "COORDINATION OF GENERATOR PROTECTION WITH GENERATOR EXCITATION CONTROL AND GENERATOR CAPABILITY " IJESIT Volume 2, Issue 2, March 2013.

This paper was created by a working social event of the IEEE Power System Relay Committee for providing guidance to the business to better organize generator security with generator control. There are particular figuring techniques examined in the paper that can be utilized for better coordination of generator security and excitation framework. It moreover shows coordination of exchanges with generator full load capacity and steady state limits. The necessity for arranging generator security with generator control and load capacity has been comprehended to generator protection engineers.

There are different systems and techniques to give this coordination however scattered in various books, papers and so forth. The inspiration driving this paper is to give single record that can be used for coordination of generator security with generator control. Due to misoperation of generator affirmation and critical system unsettling impacts, the necessity for improving coordination between generator security and control came into light. Two noteworthy unsettling influences are the 1996 western region aggravations and 2003 east drift power outage. In this paper first some broad discourse of generator capacity and excitation control is completed. Further the discussion is done about the steady state stability limits in the paper. There are limiters utilized as a part of excitation control. Their settings has to be done accordingly with relays. Over excitation limiter is used to prevent generator excitation from going beyond its maximum limits and Under excitation limiter is used to prevent generator excitation to go below minimum capability.

Therefore late misoperations of period certification encompassed by genuine system aggravations have highlighted the prerequisite for coordination of generator security with generator limit. This paper give single report that can be utilized by relay engineers. Keeping generators on-line among noteworthy system unsettling impacts is a key target that requires coordination of generator control with generator protection.

[2] Alexander Murdoch, Robert W. Delmerico, Sundar Venkataraman, Rodney A. Lawson "Excitation System Protective Limiters and Their Effect on Volt/Var ControlDesign, Computer Modeling, and Field Testing, Vol. 11, No. 1, January 1996.

The activity of excitation framework defensive limiters and var control are regularly not considered in arranging thinks about and genuine units might be entirely not quite the same as reproductions. This may prompt mistaken expectations of genuine stability restrictions or even voltage breakdown event. In this paper the outline of excitation framework defensive limiters, for example, Over Excitation Limiters(OEL), Under Excitation Limiter(UEL), and Volt/Hertz(V/Hz) is clarified.A crucial part of the new automated based excitation controls is that they contemplate more wise limiter limits and protective components not invaluable with more settled equipment.

The fundamental limit of the excitation system is to oversee voltage besides control var flow in the structure. There are number of cautious limiters in the excitation structure which are associated with security of the generator and excitation system. The excitation limiters are proposed to act to shield the generator and excitation structure from operation in area where there could be over-weights and following warming, or higher than tolerable flux levels. Flux level is measured by V/Hz within the machine. Admissible degrees for unending operation are some place around 95% and 105% V/Hz. The method of testing the excitation limiters begins with understanding the fundamental blueprint of the limiter circuits in today's fresher progressed based controls. The testing thusly may comprise of check of the usefulness of the fundamental parts of the limiters utilizing tests done at less compelling working points.

This paper has given the strategy for thinking and a complete course of action of limiter models for the EX2000 excitation structure addressing static excitation systems IEEE model sort ST4B. This paper likewise gives the technique to testing the excitation model limiters. Expanded steady quality and capacity with more up to date smart limiters may actually permitthe update of more seasoned excitation hardware in today's energy model.

[3] Working Group J6 of the Rotating Machinery Protection Subcommittee "Performance of Generator Protection During Major System Disturbances" 2004 IEEE.

Unsettling influence is innate part of any force framework among the move starting with one resolved state working condition then onto the next. Defensive relays may encounter anomalous working conditions between this transient period. In this paper different control activities that that have impact among the move is appeared, and specialized direction to the business is given on application and setting of generator defensive transfers that can work among real framework disturbances.

Each system framework is subjected to unsettling influences now and again because of deficiencies and/or exchanging of significant burden. The system gets another consistent state condition with help of generator excitation and turbine typical control. There are different distinctive force framework control plans which can be utilized to restore an adequate new consistent state condition. It is imperative for the relay to surrender protection while building their coordination to avoid unpleasant operation among system unsettling impacts and thusly spare the genuineness of the power system.

In this paper brief depictions of past power system unsettling influences and also generator excitation, power system controls are incorporated. Power system unsettling influences are the occasions that deliver irregular conditions in system and change the condition of system from ordinary to crisis. These aggravations are characterized into two gatherings - Small and Large. Extensive interference influences are the testing issue to the utilities as a result of size and multifaceted nature of the power system. Better assurance and the controlled system are the need to anticipate further harms in framework after an unsettling influence is happened. A portion of the real unsettling influences which happened in past are as per the following:

a. On August 10, 1996, a noteworthy aggravation seperated the Western System Coordination Council (WSCC) framework into four islands, interfering with administration to 7.5 million clients for the time period extending from a few minutes to around 9h.

b. On Feb 21, 1995, at 3:05 A.M., a 230-kV lightning arrester on the 220-16 line from Whitpain Substation to North Wales Substation fizzled. The shortcoming was solved in five cycles by exercises of relays and breakers however on account of this insufficiency other six transmission lines were mistakenly faltered.

c. On Aug 22, 1987, in the midst of a glow storm, a 115-kV change that had a spot with Memphis Ligth, Gas and Water Division flashed stage to organize while their chairman was trying to restrict a hurt air impact breaker. This was cleared following few moments. Because of this substantial measure of responsive power was drawn by engines.

[4] P. Kundur, 1994 "Power System Stability and Control" McGraw-Hill, New York.

The fundamental capacity of an excitation framework is to give direct current to the synchronous generator field winding. More than that excitation framework additionally performs control and defensive capacities in the force framework by controlling voltage and field current. The control capacities incorporate the control of voltage receptive force stream, and keeping up system dependability. This defensive capacities must ensure that ability points of confinement of the synchronous machine, excitation framework, and different types of gear are not surpassed. Description of characteristics and modelling of different types of synchronous generator excitation system is given in the book. Also it discusses dynamic performance criteria and provides definition of related terms. The performance requirements of the excitation systems are given by consideration of Synchronous Generator and Power System. Elements of an Excitation System are as shown in fig.2.1.Sorts of excitation system are as per the following:

- DC Excitation systems
- AC Excitation systems
- Static excitation systems

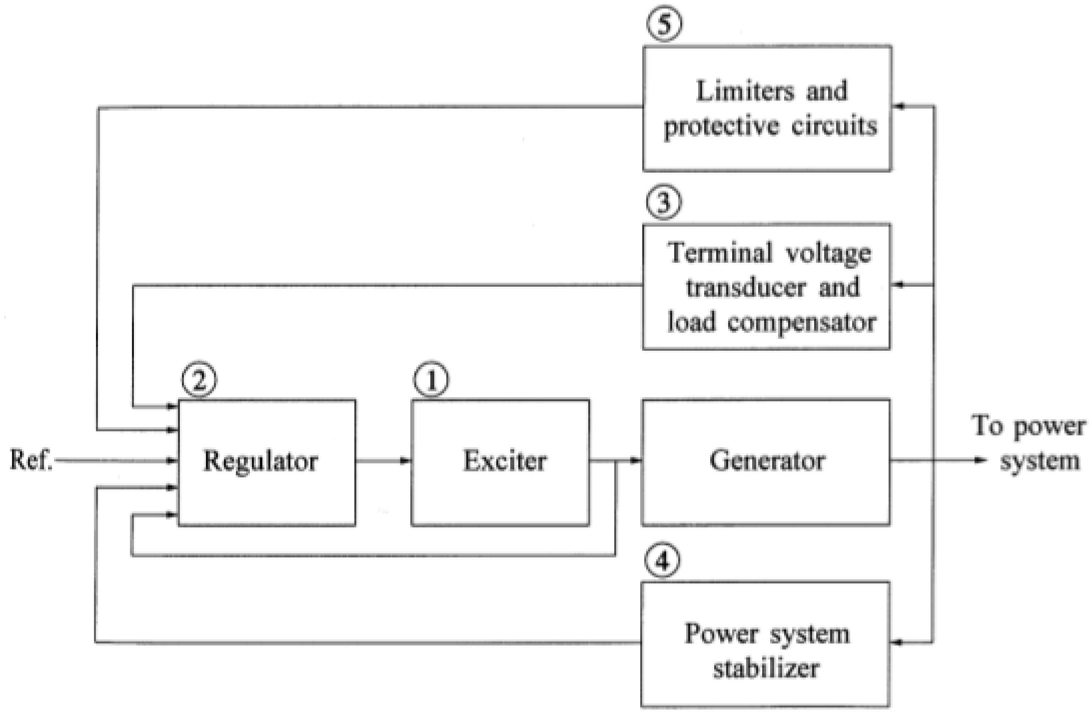

Figure 2.1: Block diagram of excitation control system[4]

Since the system is nonlinear, the dynamic performances of excitation control system are classified as:

- Large-signal performance
- Small-signal performance

Amodern excitation control system is different than a simple voltage regulator. It includes many controls, limiting, protective functions which fulfill the performance requirements as identified above. Following are some of the control and protective functions:

- AC and DC Regulators
- Power System Stabilizer(PSS)
- Under Excitation Limiter(UEL)
- Over Excitation Limiter(OEL)
- Volts-per-Hertz Limiter

[5] "Recommended models for overexcitation limiting devices" Energy Conversion, IEEE Transactions on Year: 1995, Volume: 10, Issue: 4.
In these paper Overexcitation, overvoltage, and overfluxing limiter models which are sensible for use in deep scale structure trustworthiness research are shown. The models given here are perfect with present day IEEE endorsed excitation system models. The limiters introduced to give this assurance incorporate OV (overvoltage) limiters to farthest point machine terminal voltage, V/Hz (volts/hertz) limiters to forestall overfluxing, and OE (overexcitation) limiters to avoid field winding overheating.

Chapter 3

Simulation and Work

3.1 Over Voltage Protection

Over voltage happens in view of the expansion in the velocity of the prime mover because of sudden misfortune in the heap on the generator. Generator over voltage does not happen in the turbo generator in light of the fact that the control governors of the turbo generators are exceptionally touchy to the speed variety. In any case, the over voltage security is required for the hydro generator or gas turbine generators. The over voltage assurance is given by two over voltage transfers have two units one is the instantaneous relay which is set to get up at 130 to 150% of the appraised voltage and another unit is IDMT which is set to get up at 110% of evaluated voltage. Over voltage may happen because of the flawed voltage controller furthermore because of manual control mistakes. Overvoltage insurance is Class An assurance. Set qualities for the same is 120%.

Table 3.1: Generator overvoltage relay (59G)[6]

	Dust inside Relay	Condition of Contacts	Condition of Pivots	Sticking of moving parts
Observation	Yes	carbanised	NA	NA
Action Taken	Clean	clean using rubber		

Table 3.2: Generator overvoltage relay (59G)[6]

	Magnetic Particles in air gap	What Maintenance Or repairs?	Breaker Trip Test through Relay cont.
Observation	NA	contact carbanised	Yes
Action Taken		Contact clean using rubber	Breaker Tripped

Following fig3.1 shows the simulation of overvoltage protection of generator. Synchronous generator of 50Hz 400V 16kVA 1500RPM is used. Excitation system and steam turbine is connected with generator. Output of generator is measured through VI measurement and is connected with three phase circuit breaker. Three phase series RLC load of 14500W is connected at the end of line. The output of V-I measurement is input for relay subsystem, where generator voltage is compared with its 120% set value and output of subsystem is given to the circuit breaker.

Following fig3.2 is the waveform of voltage. The waveform is three phase sinusoidal till the amplitude crosses 480V. When output is more than 480V, the subsystem sends signal to circuit breaker to disconnect generator from main system. When relay output goes to zero from one the circuit breaker gets open. The current waveform in fig3.3 shows 28-30 Amp current is generated at terminals.

3.2 Over Excitation Limiter

Most excitation system introduced on producing units have enough capacity to supply the typical excitation condition of the unit in every working conditions, which include a 5 to 10 percent edge above ordinary evaluated conditions. For framework steadiness (or other) reasons, exciters typically have a compelling capacity which far surpasses these unfaltering state necessities. The presence of this driving ability must run as an inseparable unit with the limiters to guarantee both the generator and exciter are appropriately secured against overvoltages, overfluxing, overheating, and so on.

Regular limiters introduced to give this protection incorporate OV (overvoltage) limiters to bound machine terminal voltage, V/Hz (volts per hertz) limiters to anticipate overfluxing, and overexcitation (OE) limiters to anticipatet field winding overheating. Over Voltage limiters monitor synchronous machine terminal voltage and come into action when this voltage surpasses a planed level. These limiters also work through the segment of the voltage controller circuits or specifically on the terminating circuits of SCR power amplifiers. Despite the fact that these limiters are vital to secure hardware if there should be an occurrence of breakdowns in controller segments, these limiters can be merge with Volt per Hertz limiters as a solitary segment for system strength designing reason.

3.2.1 Simulation of OEL

Simulation model of OEL is shown in figure 3.5

The input data to these model are the constrained amount (field current I_{fd}, field voltage E_{fd}, or a sign relative to exciter field current V_{fe}, in some brushless excitation applications) and the excitation system stabilizer output, V_f. A switch is given at the yield to damage the limiter for a short timeframe to permit big transient constraining. By taking switch 1 in position "A," the limiter model capacities as an opposite time gadget. On the off chance that the constrained amount (I_{fd}, E_{fd} or V_{fe}) are more noteworthy than the limiter pickup setpoint, I_{TFPU}, the planning integrator starts ramping up. Typically $1/T_{fb}$ will likewise be zero after that the timing integrator will give an ramp rate that is relative to the magnitude given in input. By keeping switch 1 in position "B" the timing integrator capacities as a settled tin gadget. At the point when the output from the timing integrator, T_{lim} , achieves the clock setpoint value, T_{FCL}, the variable limiter reference, I_{ref}, will start to ramp down from as far as possible, set by I_{inst}, to the coordinated limiter value, selected by I_{lim}. The descending ramp rate of this variable is set by K_{rd} or by the pickup mistake signal through gain K_{ramp} as controlled by the setting of switch 3.

Limiters that ramp down at the rate corresponding to the overexcitation are displayed by changing switch 3 in position "A" and utilizing K_{ramp} for setting the ramp rate pick up. Limiters that ramp down at a steady rate are demonstrated with switch 3 in position "B" and K_{rd} setting the ramp rate. In the event that the constrained amount turns out to be not exactly I_{TFPU}, the timing integrator will ramp down. At the point when T_{lim} falls underneath T_{FCL}, the changing limiter reference will start to ramp go below I_{inst}. The upward ramp rate is set by K_{ru} or by

pickup mistake signal through addition K_{ramp} as chose by switch 2. The limiter model yield can be disable for a brief timeframe to permit high driving by setting T_{en} to a positive worth and I_{max} to the proper quality. To guarantee operation of the planned limiter, the output should be empowered when T_{err} is more noteworthy than zero. This element can be handicapped by setting T_{en} to zero or I_{max} to a little esteem.

3.2.2 Application of OEL

The Overexcitation limiters are ordinarily connected on every vast synchronous generators, engines, and condensers. Regularly, they are utilized as a part of conjunction with some sort of field winding protective device. This gadget may sense field current, field voltage, or even temperature. The assurance plan ordinarily includes exchanging control to manual voltage controller and tripping the unit. Hence, the setting of the gadgets is typically planned such that the limiter works initially and brings down excitation so that the defensive gadget just works if the limiter breakdowns.

3.3 Volt per Hertz Limiter

Volt per Hertz limiters detect both synchronous machine terminal voltage and terminal recurrence and secure synchronous machines and every single associated transformer from harming overfluxing conditions. These conditions can be created by high voltage and/or low frequency operation that may come about because of extreme power system occasions. V/Hz limiters as a rule work through a part of the voltage controller hardware and utilize either rate input or transient addition lessening for control loop dependability.

3.3.1 Simulation of V/Hz

Figure 3.6 show the simulation of V/Hz model. The input data to the model are: terminal voltage V_t, terminal recurrence, Freq, and excitation framework stabilizer output, V_f Low-pass channels might be utilized on the voltage and recurrence inputs.With switches 1 and 2 in position "A," the limiter controls the proportion of terminal voltage to terminal frequency. Putting switch I in position "B" and switch 2 in position "A," the limiter controls voltage as it were. By making both switches 1 and 2 in position "B," the limiter set point is lessened directly with reducing frequency. Set point VH_{zhi}, and the related comparator are given to impair the Volt per Hertz limiter if the recurrence is over this set point.

3.3.2 Application of V/Hz

Volt per Hertz limiters are normally connected on every substantial synchronous generators. Normally, the limiters are conformed to grasp the proportion of voltage to the frequency at 1.1 for each unit; be that as it may, settings as low as 1.05 for each unit have been reported. Volt per Hertz limiters are normally connected on substantial synchronous generators. Normally, these limiters are conformed to keep the proportion of voltage to frequency at 1.1 for each unit; be that as it may, settings as low as 1.05 for each unit have been reported. The relays don't work unless the limiters come up short and harm to the generator is inescapable.

3.4 Under Excitation Limiter

The capacity of the under excitation limiter is to secure the generator in opposition to working excessively far in the under excited (driving power factor) area. Increments in the vars consumed by the machine result in small flux levels in the machine which be liable to diminish both transient and element security margin. Likewise, the flux distribution guide of the stator and results in whirlpool streams and heating in the center end region. Increments in the vars value consumed by the machine result in small flux levels in the machine which try to diminish both the transient and dynamic

stability margin. Likewise, the flux circulation prompts fixation at last winding region of the stator and results in eddy currents and warming in the center end region.
As in the over excitation limiter impacts are warm in nature and it can be go through transient entrance of the cutoff points. The endless condition cutoff points are regularly put marginally inside the generator capacity curve.The transient or element steadiness may require expanding the settings over the capacity curves now and again. As far as possible is re-adjusted taking into account square of terminal voltage into the control succeeding to the machine capacity is diverse as the voltage vary. The under excitation limiter control functional block chart is appeared in Figure 3.7. The sort of the UEL controller is a PI control.
The set point for under excitation limiter controller is a data transfer capacity restricted signal from the client inserted under excitation curve, a component of watts level and re-aligned by the square of terminal voltage. The period steady T_u in the set point figuring to minimize association of the under excitation limiter with nearby mode motions through the watts signal. The set point is then contrasted and VAR yield of generator. Over as far as possible line, the controller will be driven and held at the lower furthest reaches of zero output. After the breaking point has been come to, there can be a output of the under excitation limiter controller in a heading to expand the voltage and rise the VAR output over the cutoff line. Variables that ought to be considered in deciding the under excitation limiter settings are the established unfaltering state strength limit, and coordination of the under excitation limiter and loss of excitation security.

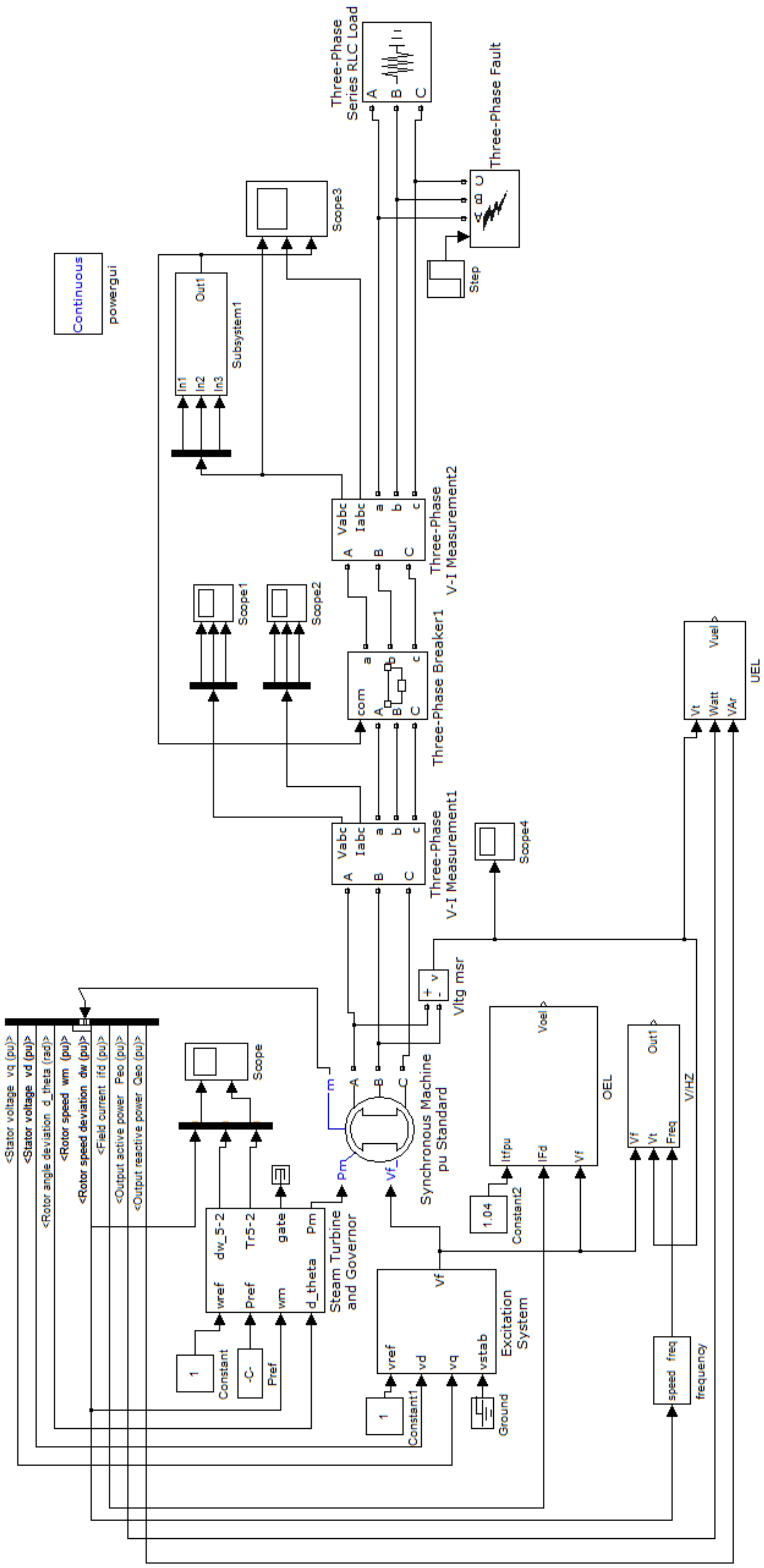

Figure 3.1: over voltage protection

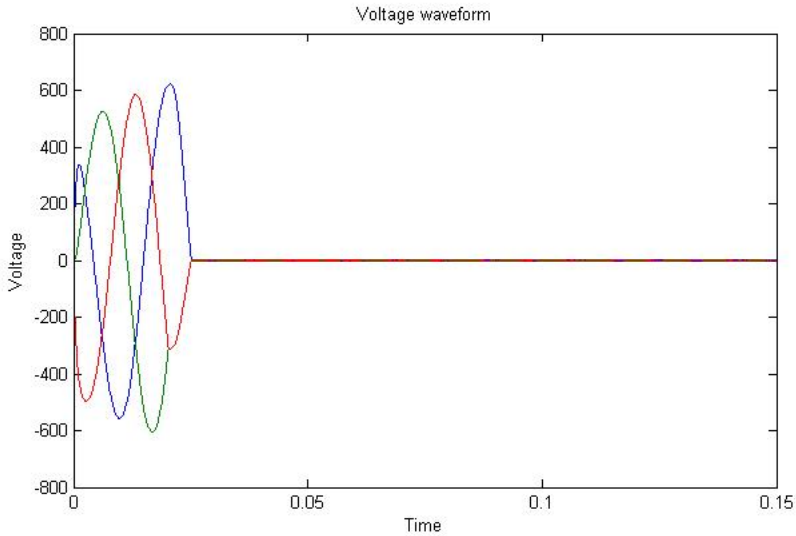

Figure 3.2: Voltage waveform

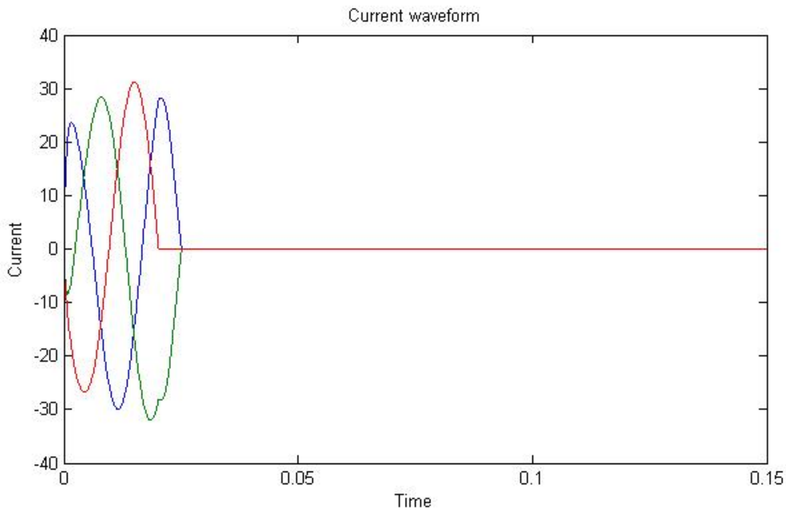

Figure 3.3: Current waveform

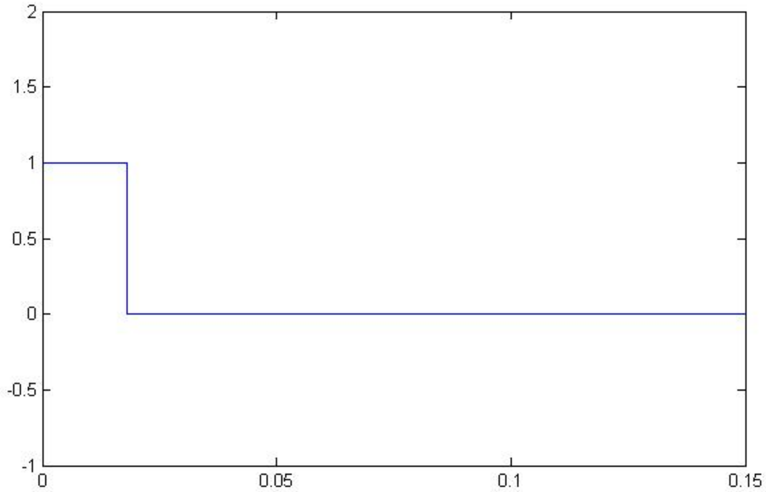

Figure 3.4: Relay status

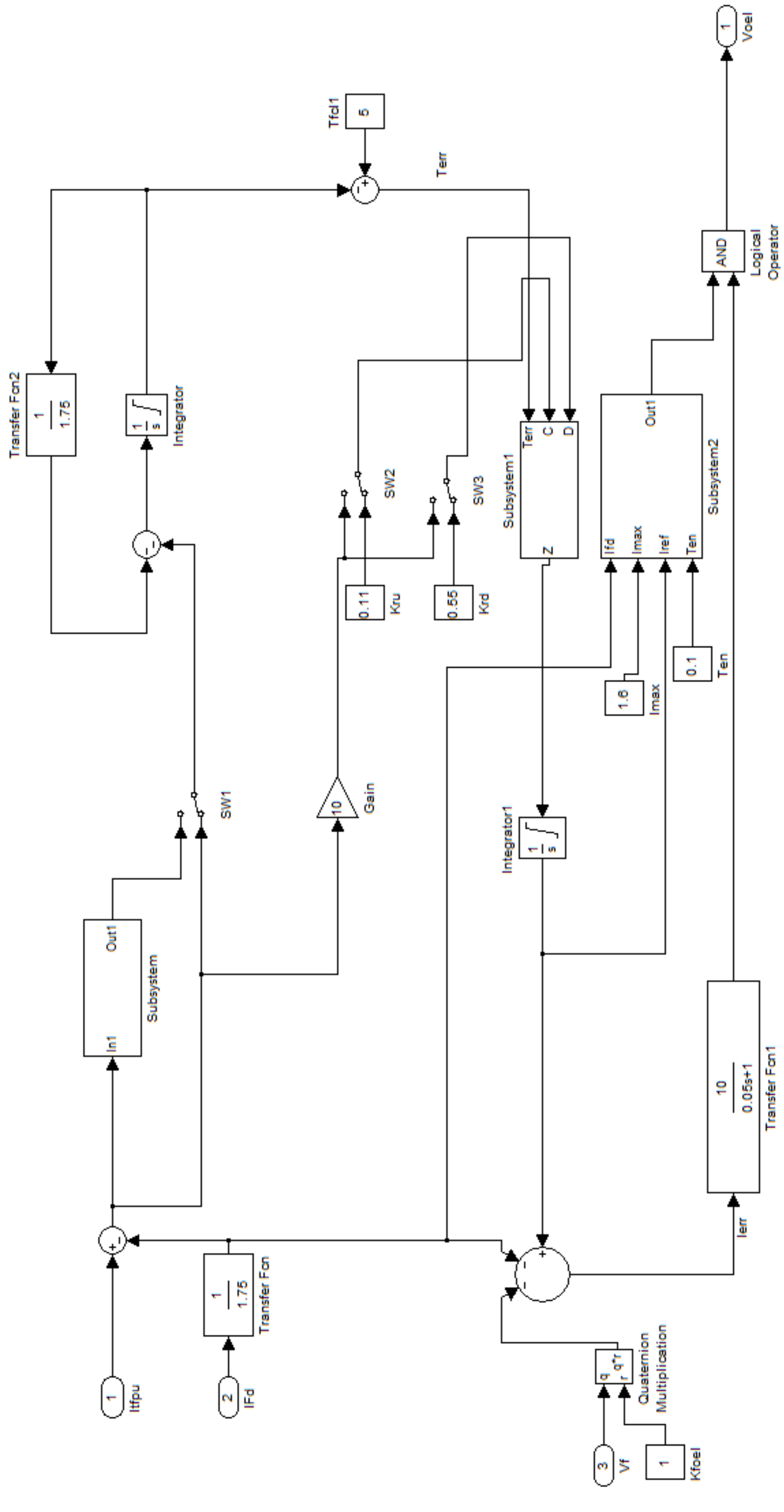

Figure 3.5: OEL

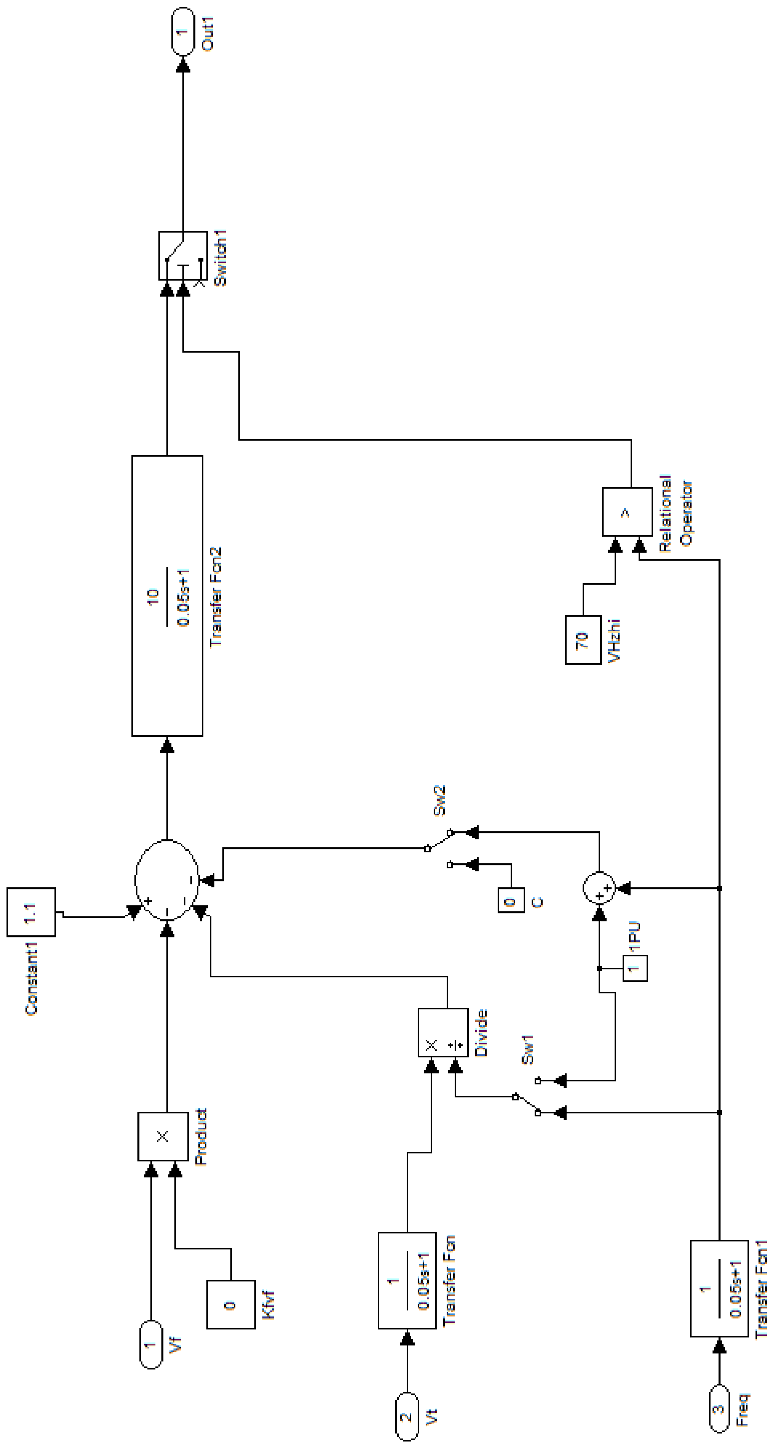

Figure 3.6: V/Hz

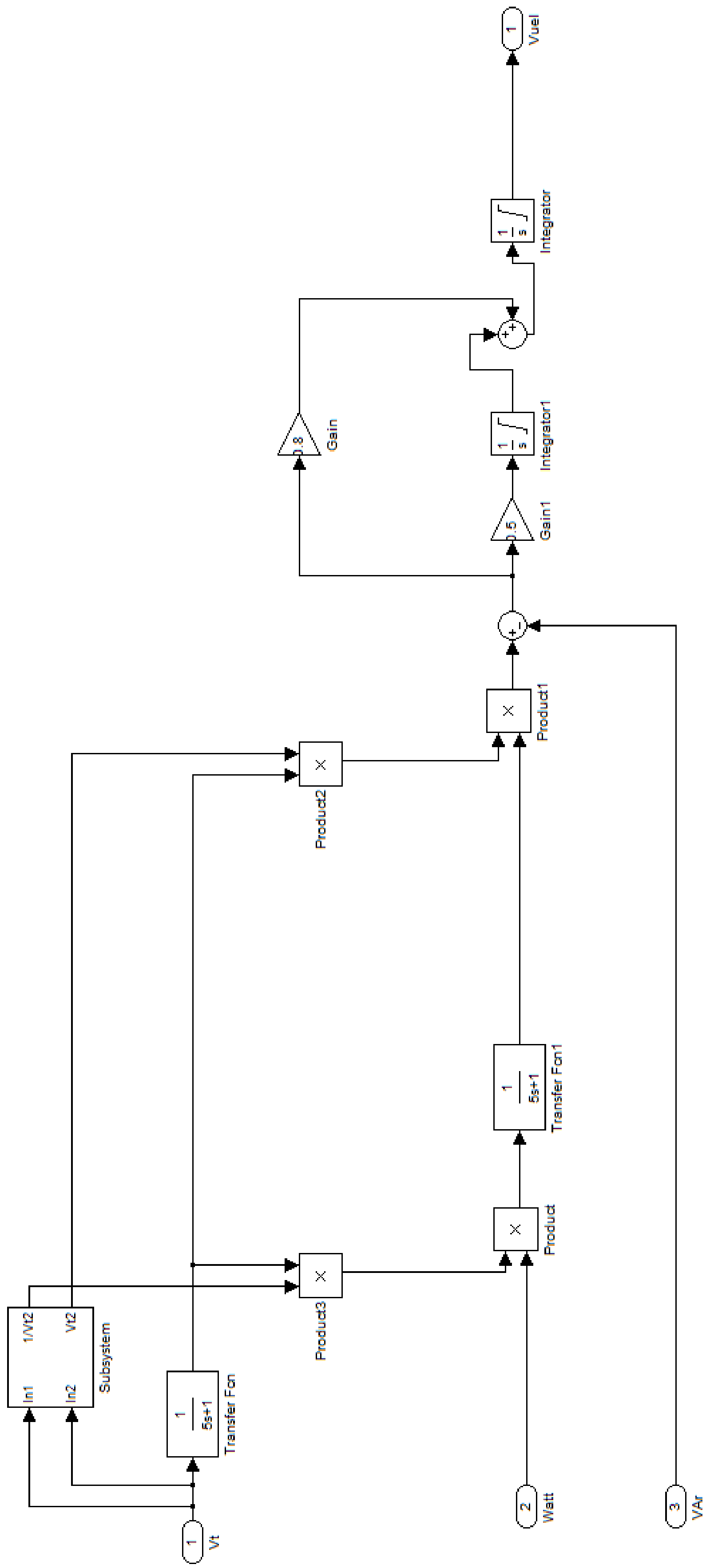

Figure 3.7: UEL

Chapter 4

Conclusion and Future Work

4.1 Conclusion

In every power system there are disturbances occurring time to time. Because of these transients the system stability changes. Sometime generator may go out of synchronism. Sometimes due to mis-operation of relays, circuit breaker gets open and generator is separated from the system discontinuing the power supply. There were some major disturbances occurred in past, due to which coordination of relays and excitation control and generator capability came into light. There are distinctive sorts of limiters and insurance accommodated better coordination of generator control and assurance and generator capacity. Some of them are OEL, UEL, V/Hz, Over voltage protection, Loss of field protection etc. Proper coordination of this protective measures should be done to avoid false tripping of relay's and prevent generator from losing synchronism.

4.2 Future Work

Coordination of different protections with generator capability and excitation controls and settings of relay's.

References

[1] **Mozina, Charles J.; Reichard, Michael; Bukhala, Z.; Conrad, S.; Crawley, T.** "Coordination of Generator Protection with Generator Excitation Control and Generator Capability; Working Group J-5 of the Rotating Machinery Subcommittee, Power System Relay Committee" Power Engineering Society General Meeting, 2007. IEEE Year: 2007.

[2] **Murdoch, A.; Delmerico, R.W.; Venkataraman, S.; Lawson, R.A.; Curran, J.E.; Pearson, W.R.** "Excitation system protective limiters and their effect on volt/VAr control-design, computer modeling, and field testing " Energy Conversion, IEEE Transactions on Year: 2000, Volume: 15, Issue: 4.

[3] **Patel, S.; Stephan, K.; Bajpai, M.; Das, R.; Domin, T.J.; Fennell, E.** "Performance of Generator protection during major system disturbances" Power Delivery, IEEE Transactions on Year: 2004, Volume: 19, Issue: 4.

[4] **P. Kundur, 1994** "Power System Stability and Control" McGraw-Hill, New York.

[5] "Recommended models for overexcitation limiting devices" Energy Conversion, IEEE Transactions on Year: 1995, Volume: 10, Issue: 4.

[6] "Generator Protection Relay Setting and Testing Results" Unit 5, Ukai Thermal Power Station, GSECL.