RESEARCH:

The faculty, students and other researchers at the department are dedicated to various engineering research areas. Funding by various agencies like Department of Science and Technology, Govt. of India, AICTE, UGC has aided the research. The work is published in leading international journals and conferences. Individual faculty home pages contain more information about specific research areas. The research encompasses areas like:

1. **Power Systems and Power Electronics**
2. **Electric Drives**
3. **Energy Systems**
4. **Control Systems**
5. **Electric Machines**
6. **Smart Grid**

1. Power Systems and Power Electronics

Name **MIS No.** **Guide:**	**Anant P. Deshpande** **131105003** **Prof. V. N. Pande**
Title	**Analysis, Modeling and Control of Doubly Fed Induction Generator for Wind Turbines and Power Quality Issues**

Introduction:

Energy generated by means of wind turbine generators today is a must on the way to reduce carbon dioxide production considerably. Converter fed, variable speed generators are state of the art in wind turbine generators. The power is harvested by the wind rotor and fed to the electrical grid via gear, generator and converter. Installations worldwide grow rapidly; their performance still has to be optimized as there are control, the grid side performance, the losses and costs of wind turbines including their power electronic generator system.Anather high requirement is energy feed in to the grid by the wind turbine confirming the standards. The grid codes define steady state as well as dynamic performance and are continuously stronger because of their higher density of these decentralized power sources. Both fields require intensive research and development of wind turbines and their power electronic generator systems.

Problem definition:

Identifying literature gaps and potential areas for the research, the problem is formulated as: *"Analysis, Modeling and Control of Doubly Fed Induction Generator for Wind Turbines and Power Quality Issues"*. Research and predevelopment in the field is to be carried out by analysis, by implementation and measurements at test set ups in the laboratory. The research includes power electronic circuits, control methods for better performance and hardware to comply with grid codes in the way of delivering reactive power or sustaining during voltage sags or wells. Comprehensive research on converters, generator and grid integration of wind turbine is possible and is to be carried out in the laboratory.

Expected outcomes:

1. Detailed simulation results of the total system under unbalanced as well as under various power line disturbances using MATLAB simulink software.
2. Working model of DFIG in the laboratory comprising of back to back converter, Induction generator and dSPACE software.
3. Hardware results of total system for 3 phase line to line fault as well as power line disturbances.
4. Comparison of hardware and software results.

Name	**Mrs. Meera Murali**
MIS No.	**159**
Guide:	**Prof. V. N. Pande**
Title	**Design and Analysis of Unified Power Flow Controller (UPFC)**

Introduction:

Advances in high power solid-state switches, such as GTO and thyristors, have led to the development of many controllers that provide high controllability and flexibility for power transmission. These are known as Flexible AC Transmission Systems (FACTS) controllers. One such controller that has caught the attention of power system engineers is 'Unified Power Flow Controller' (UPFC) commissioned into service in USA. UPFC was devised for real time control of all parameters affecting the power flow of transmission line and thereby provide dynamic compensation of ac transmission systems. The UPFC -- controls the power flow along prescribed transmission corridors, secures power transfer to a level closer to thermal limit, reduces generation reserve margin because of having greater ability to transfer power between controlled areas and prevents cascading of voltages. This, minimises equipment failures under faults. In short the UPFC has an inherent ability to solve many of the problems faced by Power Industry today.

Problem definition

To investigate the characteristics of a UPFC under steady state, dynamic and transient conditions through digital simulation using MATLAB/PSCAD. Further to fabricate a model of UPFC with a designed control circuitry to observe the behaviour of UPFC under practical conditions in the laboratory.

Expected outcomes:

1. There are different control possibilities of UPFC. However few of them such as active and reactive power flow modes have been incorporated in Power System Analysis.

Some of the lesser-known control modes are investigated for incorporation in Power System Analysis.

2. A low power (5-10kW) UPFC model along with a model of transmission network is to be fabricated for experimental purposes in the laboratory. Simulation studies of this laboratory model under steady state and dynamic conditions will be compared with experimental results. This experience will greatly help the utilities to integrate UPFC in the network.
3. Power System Engineers can be trained in understanding the working and use of FACTS controllers.
4. UG and PG students can also learn from hands on experience on the model.

Name	**Mrs. Ujjwala M. Mate**
MIS No.	**157**
Guide	**Prof. V.N. Pande**
Title	**Wind Power Systems-Planning and Operation with Grid**

Introduction:

Wind energy is gaining increasing importance throughout the world due to continuously diminishing fossil fuels, their increasing costs and the drive to get pollution free energy. Out of the renewable energy sources, wind energy is the most promising technology. The only concerning fact about the wind energy is that the power output of the wind generator may fluctuate depending on the wind speed. The information about the probable power output of a wind farm is extremely essential for the transmission system operator (TSO) for power system planning. Thus forecasting the wind speed and power a priori from statistical data is an important research area.

There are certain issues regarding interfacing of the wind turbines to the grid. To cope up with the variable wind speed, doubly fed induction generator technology with back to back converter in the rotor circuit is developing rapidly in medium and high power applications. It has capability to operate in four quadrants and is less costly due to partial size of converter. The operational issues like providing the real as well as reactive power support to the grid as per the requirement are critical and needs extensive research.

Problem definition

Identifying literature gaps and potential areas for the research, the problem is formulated as: **"Wind Power Systems-Planning and Operation with Grid"**

Forecasting of wind speed a priori from statistical data is to be done and investigation of probable power output of a wind generator is to be carried out.

The Control of DFIG is traditionally based on the vector control using proportional-integral (PI) controllers. This scheme has limitations that its performance largely depends on the tuning of the PI parameters, the accuracy in machine parameters and the connected grid voltage conditions.

Based on direct torque control (DTC) of induction motors, direct power control (DPC) strategy is developed which reduces the complexity of vector control algorithms and also reduces the dependency on accurate machine parameters.

Further, the sliding mode control is an effective technology which features simple implementation, fast responses, disturbance rejection and strong robustness. The only disadvantage is chattering. The discrete sliding mode controls are free from chattering and are best suited in the modern digital world.

This project will generate a mathematical model of the DFIG for the direct real and reactive power regulation using discrete sliding mode control. The Detailed simulations will be carried out using Mat lab simulink platform to study the method. The grid side converter will be implemented and tested on hardware using the dSPACE platform in the laboratory for validation of proposed techniques.

Expected outcomes:

1. Development of the statistical model for the wind speed and development of the probabilistic model for wind power generation.
2. Development of a new mathematical model for the rotor side converter of DFIG with discrete sliding mode controller based on direct power control approach for real and reactive power regulation.
3. Development of a new mathematical model for the grid side controller of DFIG with discrete sliding mode controller based on direct power control approach.
4. Simulation results of the above in MATLAB simulink software.

Design and development of the hardware for the grid side converter using dSPACE platform and test the set up and compare the hardware and software results.

Name	**Mrs. S.P. Ghanegaonkar**
MIS No.	**157**
Guide	**Prof. V. N. Pande**
Title	**Analysis of Radial Distribution System with Dispersed Generation**

Introduction:

Electrical energy demand is continuously increasing and so the generation requirement. Due to the increasing concerns of the global warming and the exhaustion of fossil fuels, clean energy based distributed generation is recognized as one of the feasible approaches for sustainable development. It is expected that the penetration rate of distributed generations in power system keep rising and the conventional power system will evolve from a centralized generating system to a more decentralized one. In the developing countries the utilities are already facing the problem of high power losses and poor voltage profiles because of high loads. Obviously the utilities need the distributed generation to be integrated properly, so it takes advantage of improving the loadability, reducing the losses and improving the reliability of the supply. In this scenario, analysis of radial distribution system has tremendous research potential.

Electrical power systems have been originally designed based on the unidirectional power flow, but the concept of distributed generation has led to new considerations concerning the distribution networks. The penetration of DG may impact the operation of distribution network in both beneficial and detrimental ways. Integration of renewable energy sources creates significant technical and economical challenges for distribution network operators (DNOs) and developers. Despite potential benefits, planning issues, regulatory framework and the availability of the resources, have limited the DNOs and developers in their ability to accommodate distributed generation.

Major issues in the analysis, operation and control of radial distribution systems are Power flow solutions, Optimal sizing and location of distributed generation in RDS, Voltage control, Voltage stability, Active network management and Inclusion of voltage dependent load models in the analysis.

Research Objectives

The prime aim of this proposed research is to tackle some of the challenges associated with the integration of renewable distributed generation units into existing distribution system. The research will be carried out with following objectives.

- To carry out efficient and accurate power flow solution of radial distribution system with integrated DGs which will be capable of handling various generation techniques besides conventional distribution system components.
- To develop a new methodology for optimal placement and sizing of distributed generation units by formulating multi objective function.
- To investigate impact of intermittent nature of the renewable generation and uncertainties in load and system parameters by implementing modern techniques such as fuzzy theory, Genetic Algorithm, Evolutionary algorithm.
- To develop a formulation and new solution algorithm for coordinated voltage control of various available controls like OLTC control, capacitor switching control and DG reactive power control.

2. Electric Drives

Name	**Sadhana V. Jadhav**
MIS No.	**65**
Guide:	**Prof. B. N. Chaudhari**
Title	**Studies on Direct Torque Control of A.C. Motors (Submitted)**

1. Introduction

Adjustable Speed Drive (ASD) has become essential commodity in today's industrial world. Applications such as process industry, manufacturing processes, robotics, electric vehicles, HVAC systems, washing machines, etc. need variable speed drives. DC drives dominated the AC drives during 1950-1990. The scene changed significantly post 1980's. Thanks to the VLSI technology, a tremendous computational power is made available within the chip in the form of microprocessor or digital signal processor, for on line real time processing of complex algorithms. Similarly, the advances of power devices and material technology have brought in renaissance of AC drives. Technology changes made it possible to develop variable voltage variable frequency power converters using power devices operating at high switching frequency. Initially scalar controls such as constant flux control, slip control were developed for induction motor. While those could give comparable steady state performance, the dynamic performance of DC drives was not met by AC drives till 1970's.

Blaschke and Hasse put forth vector control theory in 1971 and pioneered the control of modern electric drives. This theory was employed in Vector Control and further, Field Oriented Control (FOC) of induction motors. Being singly excited machine, induction motor provides complex control structure and cannot offer good dynamic control like DC machine. Fast processers like digital signal processers (DSPs) also contributed to application of advance control methods with FOC. An alternative way of speed control of induction motor, was suggested in 1986 as a advanced scalar control method. The direct torque control (DTC) was invented in Japan by Takahashi and Naguchi, and also in Germany by Depenbrock. It provides simple control structure which does not require co-ordinate transformation, and current sensors. It is based on bang-bang control i.e. on-off operation of inverter power devices. DTC could offer

comparable dynamic performance with relatively simpler implementation when compared with FOC. As the name implies, DTC controls electromagnetic torque and flux independently and directly by the use of a stator voltage space vector selected from look-up table of the possible eight voltage vectors. DTC based drives offer fast and dynamic performance, elimination of the need for position or speed information, less sensitivity to parameter variations high efficiency, high controllability and wide operating speed range. Owing to all these advantages, lot of interest is shown by researchers and industry in maturing the DTC. First commercialization of DTC is done by Asian Brown Brovery (ABB) in 1996. The drive develops the required torque even at zero speed. This is supposed to be significant industrial contribution.

The switching-table-based DTC (ST-DTC) approach has issues like variable switching frequency of the power devices used in voltage source inverter, and high torque ripples. Various solutions proposed are: use of controlled duty cycle variable hysteresis bands, a predictive controller to generate the reference voltage, which consists of a feed-forward controller, a dead-beat controller and two integrators, fuzzy logic based control and many more. A Major breakthrough came with Space Vector Modulation (SVM) wherein a control voltage vector based on flux and torque error is synthesized using SVM. The features of the DTC-SVM method can be summarized are: Good dynamic control of flux and torque, Constant switching frequency, Unipolar voltage due to use of PWM block (SVM), Low flux and torque ripple, Sinusoidal stator currents.

The literature reveals that the topic is being researched out heavily, is still subject of several publications worldwide, and offers challenges to the researcher. Literature indicated the scope to carry out modifications in DTC algorithms proposed, suggest new algorithm, and suggest a DTC for single phase induction machine. Extensive literature survey related with each of the above mentioned issues is carried out. All key papers in respective domains are studied thoroughly and understood. Algorithms corresponding to each of the issues are simulated on MATLAB-SIMULINK. For this, models of IMs in different reference frames, transformations, control theories and algorithms ranging from simple PI control to modern control like Sliding Mode, Fuzzy control, Fuzzy-Sliding Mode Control etc., are studied as well as simulated. Further, other aspects like Sensorless Control strategies, Dynamic Load Emulation are also simulated and results are analyzed. Real time implementation of few algorithms and comparison of the results is carried out. All these have given deep insight in the topic and enabled to contribute in the

research area.

2. Research work carried out and sample results

2.1 Algorithms simulation and implementation:

Following algorithms are simulated and the results are validated experimentally in few cases.

- Conventional DTC for 3-Phase Induction Motor.
- A class of SVM-DTC schemes for 3-phase IM based on following algorithms:
    - Simple PI Control
    - Fuzzy Inference System (FIS) based Control
    - Sliding Mode Control (SMC) algorithms:
        - Linear Variable Structure Control (LVSC)
        - Linear Switched Gains Control (LFSG)
        - Relays with Constant Gains Control (RCG)
- Fuzzy-sliding Mode Control
- Comparison of modern control algorithms.
- SVM-DTC for Linear and Nonlinear Load Emulation
- MRAS based Observer for Flux estimation and Speed Sensorless Operation.
- DTC for Single Phase IM.

2.2 Specific research contributions:

- Comparison of performance of modern control algorithms like fuzzy control, SMC, Fuzzy-SMC.
- Linear and nonlinear load emulation using fuzzy control and sliding mode control.
- DTC for Single Phase IM
- A new sliding mode controller based which uses simple amplitude angle control of stator flux scheme.
- Real time implementation of proposed scheme and its comparison with PI control

2.3 Real time implementation of proposed control algorithms and experimental results.

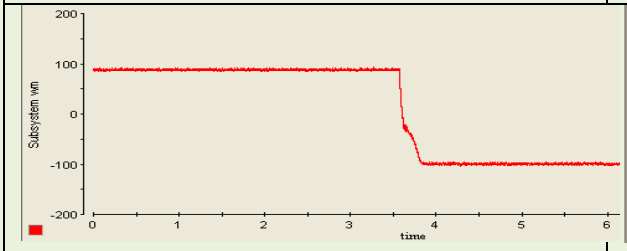
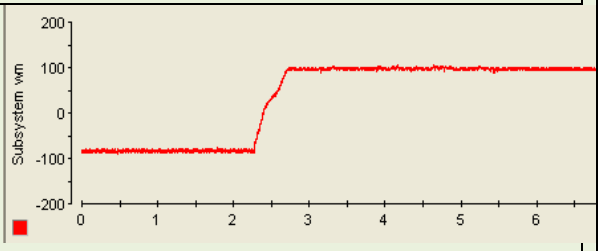
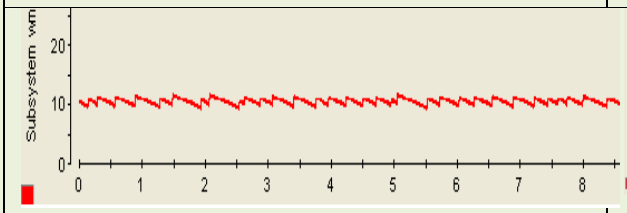
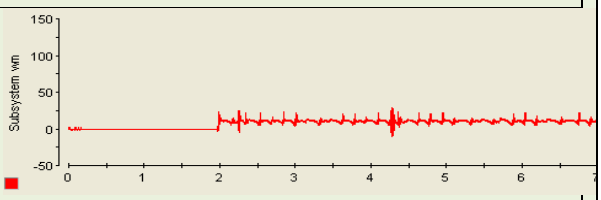
Out of several control strategies studied and indicated above, two methods namely SVM-DTC employing PI block, and SVM-DTC employing LVSC based SMC are experimentally validated on the experimental platform in the laboratory. The platform used for real time control is d-SPACE RTI 1104. The technique uses the relation between torque, angular slip frequency

and rotor angular frequency to control the stator flux angle. It is the decoupled control of the amplitude and angle of the stator flux (AAS Control). The AAS scheme with PI is simulated in MATLAB-SIMULINK. Then it is implemented to prove the ability of the algorithms to respond in real time. Experimental results for dynamic and steady state conditions with load variation, and low speed operation are presented. Further, Sliding Mode Control algorithm for AAS control is first time proposed and implemented**.** A stable switching surface is designed and reachability condition is ensured. It is proved that the resultant drive gives better dynamic and steady state performance with less chattering as compared to PI control. Zero steady state error is obtained. It also has the robustness and simplicity which are inherent in SMC.

The experimental setup of the control scheme is as shown. It has d-SPACE DS-1104 control board with TMS320F240 slave processor, ADC interface CP1104 and an induction motor fed by VSI Inverter. The DC bus voltage is 600v. The inverter devices have switching frequency of 10 kHz and dead time of 6µs. The control programs are developed in MATLAB-SIMULINK real time interface. Sampling time is 100µs. Parameters of motor used for experimental studies are: 3-phase, 0.37 kW, 50Hz, 4- poles, 415 V, 1.05A, Nr=1360 rpm, Stator Resistance Rs = 30Ω, Rotor Resistance Rr = 31.49 Ω, Stator and rotor Self Inductances Ls = Lr = 1.0942H, Mutual Inductance Lm=1H.

Experimental setup for validation of SVM-DTC control algorithms

Experimental results validate the performance of proposed SMC based AAS-SVM-DTC schemes. It is seen that proposed SMC algorithm is superior to the PI control as seen below in. Proposed SMC also offers ripple free behavior, good robustness, in all the conditions like start-up, speed reversal, low speed operation. Thus, it is superior than PI and at the same time less complex.

Proposed AAS controller with Sliding Mode Control	AAS Controller with PI controller
	
Speed reversal operation from 90 rad/sec to -100rad/sec	**Speed reversal operation from -90rad/sec to 100rad/sec**
	
Speed response when10rad/sec (low speed operation)	**Speed when the motor start-up for reference speed of 10 rad/sec**

DTC drives are replacing the current drives and modern intelligent control techniques are making them versatile to handle dynamically changing loads. Additional features like insensitivity to parameters, online identification, and sensor-less control are added advantages. High computational facilities are provided by DSP processors. The technology is extending with FPGA (Field Programmable Gate Array) which can provide better future to electric drives. This reveals that SVM-DTC based drives will be the future ASDs.

3. Energy Systems

Name **MIS No.** **Guide**	**Karandikar P.B.** **Dr. D.B.Talange**
Title	**Development, Characterization and Modeling of Aqueous Metal Oxide supercapacitor**

Introduction:

Electrical energy is primarily stored by conventional batteries and capacitors. In recent past, electrochemical double layer capacitor is also referred as Ultra-capacitor or Supercapacitor (SC) is emerging out as an option for electrical energy storage. Modeling of this device to make prototype from the commercialization point of view is very important. Further, the characterization for temperature and ageing decide its reliability. Combine pack of the lead acid battery and this kind of device can make a good power source. However, it is still new technology that has yet to experience wide spread use. Supercapacitor technology will be breakthrough in the electrical energy storage devices. Low price metal oxide based aqueous supercapacitor with sulfuric acid as a electrolyte is of particular interest due to its compatibility with Lead Acid Battery (LAB). Development of Metal Oxide Supercapacitor (MOSC) through modeling (for material selection) and prototype making is carried out in this research work.

MOSC is of particular interest as it is compatible with standard LAB. Development of this kind of capacitor will allow manufacturer to build a single unit consisting of battery and SC. MOSC can take care of most of the pulse power requirements in DC motor starting, where ever it is used. MOSC is associated with main problem of low voltage rating. Aqueous type of SC can operate up to 1.1V, whereas non aqueous SC can operate up to 2.7V. Non aqueous SC is very costly. It is at this point, where aqueous technology scores over the non aqueous technology and hence research in aqueous technology is undertaken.

Electrode of aqueous supercapacitor is made up of activated carbon, which has surface area more

than 1500 m^2/gram. Processed carbon materials like YP-20 or RP-50 are used in electrodes. Processed and filtered carbon with particle size 2 to 20 micron is most ideal material for electrodes. Activated carbon obtained from coconut shell is a low cost material, suitable for this. We have used low cost Vulcan XC-72 to reduce the cost of the device. Metal oxides are added in activated carbon to make electrodes. Metal oxide like ruthenium oxide is suitable for electrode construction to enhance its performance. However, it is very costly. Manganese oxide is used in place of the ruthenium oxide. It is considered to be unstable in the sulphuric acid environment. However, at low concentration of sulphuric acid its performance is acceptable for its use in aqueous supercapacitor electrodes. Adhesives like PBI or Nafiaon 117 are added in the electrode material to make electrodes. These binders, increase the value of internal resistance, which ultimately affects the pulse current deliverability of the device and hence the power output. Binder free technology is introduced in this research work, which is an innovation of this work and patents for this new concept are filed. Converting powder form activated carbon in to plate form is the main issue in electrode fabrication. In the present work, use of separator bags to hold the activated carbon along with metal oxides is successfully demonstrated. Electrolyte is sulfuric acid with 30% concentration.

RC modeling was considered for the research work at initial stages. However, it was found that, exiting RC models like ladder, 2/3/4 element or branch models are failing to correlate the circuit elements with physical parameters of the system. To do this, advanced machines like SEM, impedance spectrograph, cyclic voltammetry etc. are required. Such facilities were not available. It is also found that RC models are more suitable for circuit simulation of hybrid or electric vehicle using supercapacitor along with battery. Modeling, which can correlate the basic parameters such as atomic number, atomic mass or work function was consider, but efforts in that direction were not successful. Modeling suitable for deciding the manufacturing related parameters of supercapacitor were aimed in this work.

Material composition based modeling is proposed in the research work to decide the combination of the activated carbon and metal oxide. The modeling presented is not useful in selection of metal oxide or development of new material for supercapacitor electrodes. Proposed model allows change in value of the specific surface area of activated carbon, quantity of material loaded on the electrode material or percentage of metal oxide in activated carbon and then predict the capacitance value. Model is proposed for manganese oxide, ruthenium oxide,

vanadium pentoxide and stannic oxide as these are most suitable metal oxides.

Finally control system modeling approach was searched. System Identification (SI) is used in many control systems to model the complex system. SI considers the system as black box and then by establishing the relation between input and output, it gives the system equations or models. Various modeling approaches are available with the SI technique for multi input multi output systems. However considering the nature of the system in this research work, system is treated as stochastic process system, where statistical modeling methods are most suitable for finding probability distribution function or cumulative distribution function. Various statistical methods such as Taguchi method, design of experiment technique, response surface methodology, Placket Burman method, shining techniques or variable search method can be used. Among all these method, design of experiment was selected, as it gives maximum system information in minimum number of trials or experimentations.

Experiments are performed by investigator in virtually all fields of inquiry, usually to discover something about a particular process or system. Design of Experiment (DOE) is about planning and conducting experiment along with about analyzing the resulting data, so that valid objective conclusions are obtained. In short, when output parameter is a function of input parameters i) DOE means systematic and planned experimentation ii) DOE means to very input factors to achieve desired output results. In engineering, experiments play important role in new product design also known as Design for Six Sigma (DFSS), manufacturing process development, and process improvement. Design of experiment results in a) improved process output b) reduce development time, c) reduce overall cost d) reduce variability and closer conformance to nominal or targeted requirements and e) helps in deciding tolerances for different process/product variables f) helps in achieving six sigma level. Implementation of DOE is quite common in mechanical engineering problems, but its implementation for supercapacitor is done for the first time.

While implementing DOE on supercapacitor, 10-12 important parameters were identified and 3 most significant parameters i.e. sulphuric acid strength, electrode material loading on current collector and type of activated carbon based on specific surface area were selected for DOE trials. Main effects and interaction effects were obtained from the data generated during trials. Effect of these input factors on capacitance, equivalent series resistance and pulse current were studied. DOE model is used to decide the parameters of low cost manganese oxide based

aqueous supercapacitor. DOE output give some results, which standard RC models or SEM like techniques cannot give. Effect of three input factors on three output factors is presented in the thesis.

Prototype was developed and tested for repeatability. Temperature and ageing characterization of the prototype was carried out. Some of the applications such as toy motor, camera flash and regenerative braking of electric two wheeler were tried out. Thus all aspects i.e. development, characterization and modeling of manganese oxide based aqueous supercapacitor have been covered. Prototype development, testing and few applications have been presented.

Contribution of this research work

1) Development of aqueous metal oxide based supercapacitor prototype through modeling approach. Earlier work is with electrode membrane unit and in few cases with working module.
2) Application of statistical method and material composition approach for selection of parameters of supercapacitor for the first time.
3) Developing binder free electrodes for stacked type of supercapacitor
4) Bringing out the logical justifications for material/process/parameter effects on output parameters of supercapacitor (Such information cannot be obtained by R-C models or conventional metallurgical testing)
5) Introduction of concept of new hybrid, supercapacitor-battery power source for electric vehicle applications
6) Improvement of supercapacitor parameters with reduction in cost.
7) Demonstration of regenerative braking for electrically operated two wheeler along with some other applications.

4. Control Systems

Name	**Mrs. Amruta Mujumdar**
MIS No.	**131105003**
Guide	**Prof. S.R. Kurode**
Title	**Control of flexible link manipulator using Sliding Modes**

Introduction:

The ever-increasing utilization of robotic manipulators in various applications in recent years has been motivated by the requirements and demands of industrial automation. Among the rigid and flexible manipulator types, attention is focused more towards flexible manipulators. This is owing to various advantages such manipulators offer as compared to their rigid counterparts as: they require less material, are lighter in weight, consume less power, require smaller actuators, are more maneuverable and transportable, have less overall cost and higher payload to robot weight ratio. These types of robots are used in a wide spectrum of applications starting from simple pick and place operations of an industrial robot to micro-surgery, maintenance of nuclear plants and space robotics. But the main drawback of this manipulator is its flexibility, which makes it a complicated control problem for modeling as well as controlling the position of the end effectors. Flexibility also makes the manipulator an under actuated and non minimum phase system, imposing complexity in the controller. It is proposed to work on new developments in modeling, simulation and control of flexible manipulators, in light of the issues mentioned above using the latest techniques. Among the present robust control techniques, sliding mode control has proved to be more popular and effective technique, which will be used for the study purpose. Objectives of the proposed study can be summarized as: 1. Studying different modeling issues. 2. Studying and implementing different existing control algorithms for control of flexible manipulators. 3. Investigation of disturbance estimation using sliding mode philosophy. 4. Investigation of robust control using sliding mode, higher order sliding mode controller and fractional order controller for stabilization and tracking. 5. Validation in simulation and experiment.

Name	**Laware Ajit Rambhau**
MIS No.	**131105005**
Guide	**Dr. D.B.Talange**
Title	**Parametric Analysis and it's Optimization for Process Plant Based on Sliding Mode Control Strategies.**

Introduction:

The fundamental problem in control is to find a technically feasible way to act on a given process (system) so that the process (system) adheres, as closely as possible to some desired behavior.

Traditionally, for chemical processes, a way to accomplish this requirement is using model based control strategies. In order to apply one of these control strategies the model of the process has to be known (obtained). Many common process control problems exhibit nonlinear behavior, in that the relationship between the controlled variables and manipulated variables depends upon the operating conditions. For example, if the dynamic behavior of a nonlinear process is approximated by a linear model such as a first-order transfer function, the model parameters (e.g. steady-state gain, time constant, time delay) depend on nominal operating condition. If the process is only mildly nonlinear or remains in the vicinity of a nominal steady state, then the effects of the nonlinearities may not be severe. In these situations, conventional feedback control strategies can provide adequate performance.

But many important industrial processes including high purity distillation columns, highly exothermic chemical reactions, pH neutralizations and batch systems can exhibit highly nonlinear behavior. These processes may be required to operate over wide range of conditions due to large process upsets or set point changes. When conventional PID controllers are used to control highly nonlinear processes, the controller must be tuned very conservatively in order to provide stable behavior over the entire range of operating conditions. But conservative controller tuning can result in serious degradation of control system performance. There are other situations where conventional PID controller is inadequate, for example, when the process gain changes

sign (e.g. some reactor control problem).

The concept of sliding mode control is based on varying the structure of the controller based on the changing state of the system in order to obtain a desired response. A high speed switching control action has been traditionally used to switch between different structures and the system state trajectory is forced to move along a chosen manifold in the state space, called the switching manifold. The behavior of the closed loop system is thus determined by the sliding surface. The effectiveness of sliding mode control in the control of linear systems prompted the research of sliding mode control in other type of systems.

The sliding mode control technique results in controllers, which are insensitive to parameter variations and disturbances, and often decouples system variable dependencies. The controller is non-linear because the control input switches rapidly between two or more control limits. The control design problem is to choose a switching function, comprised of all the state variables, such that desirable dynamic behavior results from the system. The SMC method is ideally suited to electronic circuits where rapid switching is a normal mode of operation.

Variable structure systems (VSS) are an independent class of control systems, in which changes can occur in the structure of system during the transient process. The structure of VSS is changed intentionally, in accordance with some pre-assigned algorithm or law of structural change. The basic principle of the variable structure control (VSC) approach is to use a high speed switching control law to drive the system's state trajectory i.e. representative point in the state space on to a desirable user chosen surface in the same space and maintain it there for all subsequent time. The user chosen surface is called as sliding or switching surface and the motion of the representative point on this surface is called as the sliding mode motion. The systems dynamics restricted to this surface represent the controlled systems behavior.

During the control process, the structure of the controlled system varies from one structure to another and hence the name VSC. To emphasize the important role of the sliding mode, the control is also often called as sliding mode control. VSC system can be devised without a sliding mode, but such a system does not possess the associated merits. Systems employing VSC are referred to as variable structure systems.

Name **MIS No.** **Guide**	**Atul R. Dhamne** **Prof. V. S. Bandal**
Title	**Modeling and controller design of UPFC using Sliding Mode Control Techniques**

Introduction:

The power transfer capability of long transmission lines is usually limited by thermal capability, dielectric strength and a number of stability issues. Economic factors such as high cost of long lines and revenue from the delivery of additional power, give strong incentives to explore all economically and technically feasible means of raising the stability limits. The Unified Power Flow Controller (UPFC) is the most versatile and complex power electronic controller that has emerged for the control and optimization of power flow in electrical power transmission systems. UPFC can be used to control both real and reactive power flows of the transmission systems simultaneously and independently.

The proposed work aims at modeling UPFC and designing the controller with the application of sliding mode control strategies. The underlying idea of sliding mode control is variable structure control. In variable structure control, the structure of the control input is changed in accordance to the system states. This, in turn would result in dynamics that were not realizable with any constituent structure working alone.

Initially it is required to study UPFC in the context of contributions by earlier researchers. This study would help to focus on different aspects of control design approaches existing. As the literature review indicates sliding mode control techniques to be the robust control methods for dynamic system control, these can be implemented for UPFC operation. This controller designed for UPFC can be simulated in suitable environment like MATLAB under possible operating conditions.

Name **MIS No.** **Guide**	**Manojkumar Agarwal** **Prof. V. S. Bandal**
Title	**Modeling and Controller design for Multi Process Control Loops using Sliding Mode Control strategies.**

Introduction:

The Process Industries involves large no of complex control of the processes. Most of the processes are nonlinear in nature. Hence it offers difficulties in the design of the controller in the given environment. In order to design the controller in linear environment, processes are linearized for the range of input and output and classical controller such as PID is used and tuned by one of the techniques as Zigler-Nicols, Quarter amplitude or Process reaction curve. But they are useful in the environment for relatively small changes in set points, due to parametric uncertainties of the plant or disturbances present in the process, which cannot be taken care by the classical controller. The robust control of complex process is necessary for the accurate and precise performance.

Here it is proposed a new controller design based on "Sliding Mode Control Strategies", which has the inherent characteristic and guarantee for the disturbance rejection and robustness. The underlying idea of sliding mode control is variable structure control. In variable structure control, the structure of the control input is changed in accordance to the system states. This, in turn would result in dynamics that were not realizable with any constituent structure working alone. The controller designed with sliding mode control strategies can be commercialized for the Industrial application.

Initially it is required to study Process Control in the context of contributions by earlier researchers. This study would help to focus on different aspects of control design approaches existing. As the literature review indicates sliding mode control techniques are robust control methods for dynamic system, these can be implemented for Process Control operation. This controller designed for Process Control can be simulated in suitable environment like MATLAB under possible operating conditions.

Name **MIS No.** **Guide**	**Sneha Joshi** **Prof. D. B. Talange**
Title	**Mathematical Modeling & Robust/Fault Tolerant Controller Design for Autonomous Underwater Vehicles.(AUV)**

Abstract

The generation of ocean data platforms known as Autonomous under water vehicle (AUV).AUV is used extensively in many offshore and military applications.

AUVs are also used in oil and gas offshore industry, for survey & mineral source.

AUV is expected to operate in an ocean in the presence of poorly known disturbance forces and moments. The uncertainties make it difficult to apply open loop control scheme for the motion planning of vehicle. It is proposed to develop AUV due to the increased requirement on the high reliability and safety of control system. In proposed project new fault tolerant control strategy for AUV under adverse conditions is to be developed and also an attempt for exploring new and efficient algorithms for the robust control can be tried.

Robust fault tolerant control can be tried for AUV. Mechanical and structural parameters related to model and their influence on maneuverability can be studied. The proposed control strategy utilizes robust fault tolerant control as a first line of defense to failure and parameter variations. The proposed control strategy can be implemented in AUV in order to improve the operating characteristics of AUV, reduce false alarms and of course increase safety and reliability. The effectiveness of the system is verified by simulation experiments subject to parameter variations and failures. Then the effectiveness of proposed system is tested actually on prototype AUV.

Name	**Ashpana Shiralkar**
MIS No.	**131205004**
Guide	**Prof. S. R. Kurode**
Title	**Robust control of Electro hydraulic Actuator Position using Sliding Mode Approach**

Abstract:

Hydraulic systems are widely used in industries ranging from high power applications to minute tooling precision operations. Hydraulic control systems are popular in industry by virtue of their ruggedness, reliability, flexibility and quick response. Electrical excitation to systems brings about hydraulic actuation precisely. Electro-hydraulic servo valve plays key role in such processes. In practice, systems are subjected to parametric perturbations. These perturbations cause deterioration of performance. The traditional controllers like PID controllers fail to meet specified requirements under such conditions. The objective of the research work is to develop robust control for electro-hydraulic servo system. Typical electro-hydraulic system includes electro-hydraulic servo valve, actuating cylinder, mechanical load and controller. The system under consideration is electrical solenoid which drives the spool. Voltage applied to it produces the spool displacement which results in orifice openings in order to develop load pressures in piston which in turn drives load. Response of the system depends on parameters. Variations in the parameters like temperature, bulk modulus, density of the hydraulic fluid affect the output of the valve. The flow forces acting on spool valve (especially on single stage) are major disturbances acting in systems. The dynamics of hydraulic systems are highly nonlinear; the system may be subjected to non-smooth nonlinearities due to control input saturation, directional change of valve opening, friction, valve overlap, etc. Moreover parameters are uncertain hence Electro- hydraulic system demands robust control for getting desired performance.

Sliding Mode Control (SMC) being one of the best known robust control techniques, owever it suffers a drawback of chattering the research work focuses on development of chattering free control using higher order sliding mode (HOSM).

Name **MIS No.** **Guide**	**Ajit Laware** **Prof. D. B. Talange**
Title	**Parametric Analysis and it's Optimization for Process Plant Based on Sliding Mode Control Strategies.**

Abstract:

The fundamental problem in control is to find a technically feasible way to act on a given process (system) so that the process (system) adheres, as closely as possible to some desired behavior.

Traditionally, for chemical processes, a way to accomplish this requirement is using model based control strategies. In order to apply one of these control strategies the model of the process has to be known (obtained). Many common process control problems exhibit nonlinear behavior, in that the relationship between the controlled variables and manipulated variables depends upon the operating conditions. For example, if the dynamic behavior of a nonlinear process is approximated by a linear model such as a first-order transfer function, the model parameters (e.g. steady-state gain, time constant, time delay) depend on nominal operating condition. If the process is only mildly nonlinear or remains in the vicinity of a nominal steady state, then the effects of the nonlinearities may not be severe. In these situations, conventional feedback control strategies can provide adequate performance.

But many important industrial processes including high purity distillation columns, highly exothermic chemical reactions, pH neutralizations and batch systems can exhibit highly nonlinear behavior. These processes may be required to operate over wide range of conditions due to large process upsets or set point changes. When conventional PID controllers are used to control highly nonlinear processes, the controller must be tuned very conservatively in order to provide stable behavior over the entire range of operating conditions. But conservative controller tuning can result in serious degradation of control system performance. There are other situations where conventional PID controller is inadequate, for example, when the process gain changes sign (e.g. some reactor control problem).

The concept of sliding mode control is based on varying the structure of the controller based on the changing state of the system in order to obtain a desired response. A high speed switching control action has been traditionally used to switch between different structures and the system state trajectory is forced to move along a chosen manifold in the state space, called the switching manifold. The behavior of the closed loop system is thus determined by the sliding surface. The effectiveness of sliding mode control in the control of linear systems prompted the research of sliding mode control in other type of systems.

The sliding mode control technique results in controllers, which are insensitive to parameter variations and disturbances, and often decouples system variable dependencies. The controller is non-linear because the control input switches rapidly between two or more control limits. The control design problem is to choose a switching function, comprised of all the state variables Variable structure systems (VSS) are an independent class of control systems, in which changes can occur in the structure of system during the transient process. The structure of VSS is changed intentionally, in accordance with some pre-assigned algorithm or law of structural change. The basic principle of the variable structure control (VSC) approach is to use a high speed switching control law to drive the system's state trajectory i.e. representative point in the state space on to a desirable user chosen surface in the same space and maintain it there for all subsequent time. The user chosen surface is called as sliding or switching surface and the motion of the representative point on this surface is called as the sliding mode motion. The systems dynamics restricted to this surface represent the controlled systems behavior

During the control process, the structure of the controlled system varies from one structure to another and hence the name VSC. To emphasize the important role of the sliding mode, the control is also often called as sliding mode control. VSC system can be devised without a sliding mode, but such a system does not possess the associated merits. Systems employing VSC are referred to as variable structure systems.

6. Smart Grid

Name **MIS No.** **Guide**	**Mrs. Shalaka N. Chaphekar** **131105001** **Prof. A. A Dharme**
Title	**Power Management and Control of Micro-grid in Islanded and Grid Connected Mode.**

Introduction:

Significance of Topic

The level of reliability provided by traditional centralized generation / distribution strategy is unacceptable for many applications. Also a social and economic cost for centralized generation and transmission of electricity is growing. This resulted in increased penetration of Distributed Generation as an alternative to traditional centralized generation. The goals of Distributed Generation gave rise to a concept called 'Micro-grid'.

Micro-grids are small power systems with enough local power generation to supply entirely or significantly a local load demand. Thus Micro-grids are networks which efficiently make use of location specific Distributed Generation and distributed energy resources. Distributed Energy Resources (DERs) are considered as building blocks for the existence of sustainable Micro-grids. For Micro-grids to widely happen in rural and urban areas there needs to be a fundamental change from electric utility industry's traditional focus on supply side technology and infrastructure to demand side technology and infrastructure. The key driver for deployment of sustainable Micro-grids in developing countries like India is the need to provide electricity in remote & rural areas and energy security in urban areas, reduction in carbon emission and improved power quality

Need for Research

The practical implementation of Micro-grid includes economic analysis, power control strategies, grid connection issues, stability and protection issues etc.

Aims and Objectives

The conventional method of balancing between the demand and supply is maintained by the reserves of the generations. The on line energy management by the demand side can support

to reduce the situation of energy imbalance in Micro-grids. Hence it is necessary to develop optimum solution for the demand matching and to check the technical feasibility of the same.

The economical feasibility of such Micro-grid is required to be studied along with technical feasibility. The biggest hurdle is the economic viability of different DERs and implementing it with continued usage for sustainable future growth.

The issues of Micro-grid economics involve optimal mixing of renewable and relationship with main distribution system. Some emerging economic issues like joint optimisation of demand and supply, metering arrangement, connection charges, tariff mechanism are coming into picture to make Micro-grids public viable utilities.

Hence it is required to develop new techno-economical solution for practical implementation of Micro-grids in Indian power systems using appropriate software like MATLAB. There will be a check for a developed system to achieve the objective of techno-economical solution.