The basic need for safe, efficient, coveted and comparably less pollution prone form of energy is the prime factor in motivating the people to use electrical energy. The per capita energy consumption has been the index of overall development of a country in recent years. With developing trends and enormous growth in population, the demand for electrical energy has been increasing exponentially over the years. The power engineers are motivated to install increasingly large capacity generating stations and higher sizes of generating units to cope with these situations. Moreover, sharing benefits of utilizing variability in generation mixes and load patterns has further motivated engineers to operate the entire power system in interconnected manner meeting economical, technical and environmental constraints. Besides their merits, the rapid advancement in the application of EHVAC/UHVAC/HVDC transmission networks as system interconnection has contributed further to the power system complexities. Therefore, the entire system needs a careful planning and poses multifarious operational and control problems of such complex systems to utility engineers. From an engineering point of view, the main goal of power engineers is to provide electrical energy achieving the requirements of quality, reliability and economy as the main objectives. Since no ideal combination of the three above-mentioned objectives exists, the effort must be centralized to achieve a unique combination to obtain an optimal system performance. To achieve this goal, the power utilities need efficient tools and aids to ensure that electrical energy of desired quality can be provided at the lowest cost to the consumers. The operational and control philosophies of present day power systems have tremendously changed over last few decades from their earlier classical approaches to the application of modern control approaches. Modern ECC have to be designed to perform a broad range of control functions for an efficient, economic and reliable operation of the system. The various operational and control actions envisaged at different levels are highlighted in the ensuing.

1.1. OPERATIONAL AND CONTROL PROBLEMS

The actual operation of a power system may exist in one of the four operating states namely, normal state, alert state, emergency state and the restorative state as shown in Fig.(1.1). The main objective for operation is to keep the normal state as long as possible which can be achieved by fulfilling the following conditions [1];
(i) all the load demands are met and the load flow equations are satisfied.
(ii) the frequency is constant.
(iii) the bus voltage magnitudes are within narrow prescribed limits
(iv) no power system element is overloaded.

![Diagram](image)

**Fig. (1.1) : Power system operational states**

Generally most of the time the system remains in its normal operating state. Some times during normal operating conditions, a power system may face a contingency condition, such as total or partial outage of an area generation or of a transmission line, loss of a transformer and a sudden increase or decrease of the power demand on the system. At this stage the knowledge of highly probable contingencies helps in enhancing the system security. Therefore, the security assessment and its enhancement constitute an important part of the planning and operation of power systems. However, in the wake of these contingencies, the system security level is reduced and the system enters in alert or emergency state. The system remains stable and the operating constraints are satisfied in the alert state. The abnormal voltage and frequency may be caused which can be tolerated for some time. The system may therefore be brought in to normal operating state by preventive controls such as aiding the generation from stand-by generating units. If additional contingency takes place while system being in alert state i.e. loss of another generating unit
or tripping of another transmission line causing the overloading of a line, the system would now enter in emergency state. By means of emergency controls the overloading is prevented. In case of failure of emergency controls, the overloaded line has to be tripped and the system may completely be shutdown. To some extent, the system can be restored by load shedding. If system collapses, the restoration involves rescheduling of active and reactive power unit constraints, resynchronization and gradual load pickup. During restoration of system in normal state, the system may deviate from its economic generation criterion. Furthermore, a fast and smooth restoration of system is appreciable.

The power system has its variable characteristics in terms of production, transmission, distribution and consumption. The peculiarities of the equipment as well as physical and legally imposed constraints also vary to a great extent. Therefore, there exists no specific method for determining the operation of such power systems with diversified characteristics but there are certain norms laid down by each power utility which must be followed by its control centre for their successful operation. The main system operation and control can be grouped in major groups, reflecting the time horizon [1]. Moreover, the management and control of such power system from the power system control centre is a complex process requiring interaction between many levels of command hierarchy and on vastly varying time scales. The main elements of the control hierarchy and the approximate time scale on which it operates may be described by Fig.(1.2).

From the inspection of time scale of hierarchical control structure which is also responsible for the functional hierarchy of the control system, it is evident that the overall control process is being carried out manually as well as automatically through analogue as well as digital computers. Indeed, manual control is generally slower than automatic control. The availability of large scale process control computers enables power engineers to consider the implementation of digital computers for many levels which were previously under manual or analogue control schemes. However, there is still much scope for automatic control at the management level also besides at fast time control levels. The higher levels of control are ranging from few hours to ten years, to a great extent, involve a slower time scales. The maintenance scheduling and system planning do not strictly fall in to the category of control problems. Although these are implemented manually but frequently require extensive off-line computations to assess the effects of network availability or extension.
<table>
<thead>
<tr>
<th>Time scale</th>
<th>Function</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year - 10 years</td>
<td><strong>System Planning</strong></td>
<td>• weekly generation</td>
</tr>
<tr>
<td></td>
<td>• Network modifications/ extensions</td>
<td>• fuel management</td>
</tr>
<tr>
<td></td>
<td>• Generation development</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Resource scheduling</td>
<td></td>
</tr>
<tr>
<td>yearly</td>
<td><strong>System Maintenance</strong></td>
<td>• weekly network availability</td>
</tr>
<tr>
<td>few hours - 1 week</td>
<td><strong>Unit Commitment (UC)</strong></td>
<td>• hourly generation</td>
</tr>
<tr>
<td></td>
<td>• interchange scheduling</td>
<td>• interchange scheduling</td>
</tr>
<tr>
<td>few minutes - an hour</td>
<td><strong>Security Analysis and Control</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• security dispatch</td>
<td></td>
</tr>
<tr>
<td>5-10 minutes</td>
<td><strong>Economic Dispatch (ED)</strong></td>
<td>• base points</td>
</tr>
<tr>
<td></td>
<td>• participation factors</td>
<td>• participation factors</td>
</tr>
<tr>
<td>few seconds</td>
<td><strong>Automatic Generation Control (AGC)</strong></td>
<td>• set points for plant units</td>
</tr>
<tr>
<td>milliseconds</td>
<td><strong>Local Control</strong></td>
<td>• control orders for units</td>
</tr>
<tr>
<td></td>
<td>• relaying</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• voltage control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• excitation control</td>
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</tbody>
</table>

Fig. (1.2): Time hierarchy of power system operational and control problems
Plant ordering or UC problem is to calculate the minimum cost hourly generation schedule of each unit, availability for generation, for a period of one week, preferably is executed as off-line tasks. The UC have now been carried out by few control centres with the help of digital computers.

Treating the power system operational control problem in the real time environment, a shorter time perspective accomplished by the main on-line functions can be viewed in a multi level control hierarchy. In this control hierarchy, the long term tasks like planning, system maintenance and unit commitment, which preferably are executed as off-line tasks, are not considered.

The first level control i.e. local control is at the lowest level of time horizon. It is the fundamental to the operation of power system. It has been of esteem importance for power system engineers over the years. The fast control of voltage regulation, excitation control and fault isolation is required while dealing with local control. Due to various technical and economic reasons, it is obvious to keep the system frequency constant. For meeting this requirement, matching the generation and consumption of power system at every moment is essential. In short term it is achieved by the turbine governors adjusting power input to the system in response to frequency deviations. This is the only type of control needed on an isolated system. For complex and dispersed power systems, more than one generator has to participate in the frequency control or frequency stabilization. Due to different dynamic characteristics of the participating units causing oscillations in the network leading to network stability problems, another concept had been introduced in which each unit participating in the frequency control has a regulator in which frequency deviation is fed back only by means of a proportional regulator.

In this concept, if a certain control error exists, it should be taken care of. This error is taken care of from a secondary control discussed in the ensuing section. The local control is generally carried out with analog equipment which acts instantaneously. Today, these regulators are being replaced by digital or computerized systems but still fast acting equipment. All generating units have a sophisticated local control equipment (or turbine governor).

The second level control is AGC or as it was previously termed as LFC. The main objective of AGC is to match the generated active power to the varying load demand,
keeping the system frequency and net power exchanges close to scheduled values. In an
interconnected power system, the interconnections within the area are very strong and
between areas are rather weak. In the wake of disturbance due to load increase, the system
frequency decreases, which initiates the operation of the local frequency controller of the
turbine governing system of the individual power units in all areas and the new steady state is
reached after a short time, leaving the system frequency and power exchanges between areas
at a new set point different from preselected setpoints. At this moment, the operation of AGC
is initiated to reset the resulting imbalance.

Power system operational mode is functionally related to the type, magnitude and
location of disturbance occurred in the system and plays an important role for effective
implementation of AGC. Normally three classes of disturbances can be identified in power
systems based on magnitude and location of disturbance. The control action is dependent on
disturbance identification: small (less than 2% of rated area capacity), moderately large
(2% to 5%) and large (more than 5%) and also in identifying whether it originated in control
area or elsewhere for large disturbances. In normal mode of operation, the load disturbances
are such that each area is capable of taking care of load variations by itself. Such load
variations are small and are identified as class I type disturbances. The control action
required by AGC regulator is to change the generation meeting the economic dispatch
objective. However, it is important to emphasize that for small random load disturbances no
control action is required and therefore, filtering to smooth system variable estimates must be
adhered, thus reducing chasing of small random load disturbances.

In moderately large disturbance category identified as class II type disturbances, a
further distinction may be made on the basis of area of occurrence of disturbance i.e. base
area or other area. There may be instants when some control action is required for
disturbances in the areas other than area of disturbance. In case of load disturbances of class
II type occurring in base area, the control action is essentially needed and it is recommended
for reasons of security and economics. Some support from other areas over interconnections
will always be required. However, in both situations, a faster control strategy is aimed. Thus
in case of class I and class II types of disturbances in large interconnected power systems, the
system can maintain its steady state performance through the implementation of AGC
scheme.
In case of large disturbances identified as class III type disturbance occurrence in base area, the control objective is the allocation of the spinning reserve. In this class of disturbance, allocation of spinning reserve has to be done ON-line in advance ahead of time thereby adapting the generation to varying load demand and associated contingencies.

The third control level includes the economic dispatch. The optimal operation of power system is considered based on economic criterion and economic dispatch has been adopted for this job and widely accepted by utilities for its implementation in their computer aided dispatch centres. In economic dispatch, the optimal output allocation for each unit is calculated so that the overall fuel cost is minimized subject to various system operating constraints. In time hierarchy, usually the economic dispatch is executed after every 5-10 minutes. One of the objectives of optimal AGC is to share the generation in the most economic fashion hence to meet this objective with other objectives of AGC, economic dispatch has to be carried out in conjunction with AGC subject to system constraints.

Generally, in power system, besides the economic operation and reliability, the minimal impact on environment due to power system functioning is also an objective of prime importance which is to be achieved. The environmental pollutants contributed by fossil-fired electric power plants are very much related with the real power generation. The objective of economic/optimal generation dispatch is to minimize the total generation cost of an integrated power system but in present power scenario, to fulfill environmental regulations enforced by the environmentalists/government in recent years, emission control has become one of the important objectives to be incorporated while designing economic generation dispatch control strategy.

Next level control involves is the security analysis and control. As discussed earlier in this section that following the development of an abnormal operating condition in a power system, the security level falls below a certain limit of adequacy. Some preventive actions such as generation shifting or security dispatch or increased reserves are required. The commonly known strategy is generation scheduling which may offer a generation pattern for generating units for secure system operation which may be different from that dictated by economic generation criterion. Thus co-ordination of cost and security appears as an operational problem for such systems.
From the foregoing discussions, it can be concluded that objectives of overall control in power systems is to minimize the cost of generated power while maintaining its quality and satisfying the system security constraints. In the event of availability of an appropriate control scheme, selection of proper approach for its effective implementation on a particular system has a vital role.

The basic concept of the control problem of a system is to achieve the specific objectives for which the system is meant while operating the system within limitations imposed by physical and technical system constraints. The conventional classical control techniques primarily based on the frequency domain analysis are usually reserved for linear time-invariant single input - single output systems and allow the designer greater freedom for intuition and experience. Thirty years of work by a number of control engineers namely Bode, Nyquist, and Black have established links between the frequency response of a control system and its closed-loop transient performance in the time domain. The modern control theory applies the time domain approach for the problem formulation rather than frequency domain approach which is well known as state space approach. Using this approach linear time-invariant controllable and observable systems can be designed to achieve any target requirement to a great degree of accuracy by state feedback control methods. This approach is well suited for its real time implementation through digital computers and consists of some minimum set of variables which are essential for completely describing the internal status of the system.

The design of system regulators based on the classical control theory, in general do not yield optimal system performance, where as the regulator design using optimal control theory on the other hand, enables the designers to have optimal system design with respect to given performance criteria. The important feature of modern optimal control is the establishment of analytic PIx for the system and its optimization makes the system control more meaningful in the sense of its optimality.

The growth in the size of power systems at present scenario has increased enormously due to exponential rise in demand for electrical energy with the rising development trends. The motive of providing electric energy at reasonable costs coupled with the depleting reserves of non-renewable energy sources has led to the installation of power generating stations–predominantly fossil-fuel fired thermal stations at minemouths which are at remote
distances from the load centres. Environmental considerations are vital factors for the siting of nuclear power stations at a safe distance from human living areas. Large hydro stations are invariably at remote distances of hundreds of kilometres from load centres. Due to cost effective power generation at remote locations and sharing of benefits in utilizing variability in generation mixes and load patterns and other technological reasons, most of the systems are interconnected electrically in to vast power grids which are subdivided into regional operating groups called power pools. Each power system within such a power pool operates technically and economically independently, but is contractually tied to the other pool members in respect to certain generation and scheduling features. This led to the evolution of interconnected power systems consisting of a wide variety of generating units. Therefore, there is a further requirement of such transmission links which are capable of exchanging the large chunk of electrical power between widely spread power pools effectively and efficiently. Till seventies, this requirement was fulfilled by EHVAC transmission systems. Besides the other problems encountered with EHVAC interconnection between the power systems particularly in long distance transmission, the major problems associated with these lines are;

(i) the presence of large power oscillations which can lead to frequent tripping
(ii) increase in fault level
(iii) transmission of disturbances from one system to the other deteriorating the overall system dynamic performance.

To combat these problems, HVDC transmission has emerged on power scenario due to its numerous economical and technical advantages over EHVAC transmission especially for controlled transfer of power between areas operating even at different frequencies to enhance transient and dynamic stability in the associated AC networks, for fast control to limit fault currents in HVDC lines and to reduce ROW requirements. Many HVDC transmission lines are commissioned all over the world and several HVDC projects are envisaged in ensuing years. One of the major applications of HVDC transmission is operating a HVDC link in parallel with an EHVAC link interconnecting two control areas. With these developments, undoubtedly to an extent, the power utilities are capable to fulfill the requirements of good quality of electric power supply to consumers but on the other hand, the complexity of power systems has increased thereby. The operation and control of these interconnected power
systems is no longer a simple task for power engineers. In the ensuing, an important control aspect i.e. AGC of interconnected power systems is highlighted.

1.2. AUTOMATIC GENERATION CONTROL (AGC) PROBLEM

For successful operation of interconnected power system, total generation should match with total load demand and associated system losses. Due to ever present load perturbations, these systems may experience deviations in nominal system frequency and scheduled power exchanges to other areas which may yield undesirable effects. The control hierarchy for this has already been highlighted in the abovementioned discussion. The most important organ in the control hierarchy is AGC which has the following objectives;

(i) matching generation to load demands,
(ii) adjusting the frequency at every instant to its scheduled value,
(iii) the power system being divided into number of areas, adjusting tie-line power exchange to its scheduled value,
(iv) within each area, sharing generation in the most economic way.

The AGC concept spans about more than 30 years. This is based on tie-line load bias control concept. There are two variables of interest namely, frequency and tie-line power exchanges. Their variations are weighted together by a linear combination to a single variable called ACE. In conventional control strategy, P-I type control is implemented which can be mathematically expressed as;

\[ U_i(t) = C_P \times ACE_i + \frac{1}{T_N} \int ACE_i \, dt \quad \text{(1.1)} \]

The gains \( C_P \) and \( \frac{1}{T_N} \) determine the speed of response[2]. In early days, the AGC strategies were based on analog schemes. With the advent of digital computers, the AGC schemes were considered in digital form and hence it was possible to add other facilities, such as time error corrections and inadvertent interchanges, to the AGC concept. Practical experience has shown that a fixed setting of the three parameters namely, frequency bias coefficient, and the gains \( C_P \) and \( T_N \) can not cover the needs for all operating conditions, although the conventional approach is very simple.

The proportional and integral feedback gains selected in conventional control scheme are not based on any specific criterion, but are calculated on the basis of operating
experience. With the development of modern control theory, several concepts regarding AGC have been proposed which has numerous merits over the simple tie-lie load bias control concept. The application of modern control theory has been extended to carry optimal AGC problems to obtain an optimum system performance. Here the optimal feedback gains are obtained with respect to minimization of a selected performance criterion so as to regulate the system at a desired operating level. The implementation of AGC regulators designed based on optimal control theory offers an appreciably improved system dynamic performance as compared to that obtained with conventional AGC regulators.

In formulating the optimal AGC problem, the power system dynamic behaviour is represented by a set of non-linear differential equations and a quadratic performance index is defined in terms of system state and control variables which is to be minimized subject to system dynamic constraints. Finally, an optimal control feedback law is obtained by solving a resulting non-linear matrix Riccati equation using suitable computational technique. Generally, the controllers are designed considering nominal plant parameter values about which the system has been linearized. In practice, plant parameters are subjected to variations in their nominal values due to aging, environmental effects and other inaccuracies. In power systems, area load level changes may cause these parameters to deviate from their nominal values. Therefore, consideration of sensitivity to parameter variations is of utmost importance. The AGC regulator design techniques to achieve minimal sensitivity to such parameter variations are normally based on eigenvalue sensitivity, modal insensitivity, trajectory sensitivity and performance index sensitivity minimization approaches [3-5].

The trajectory sensitivity is a variation of a state trajectory due to first order variation of a parameter of the system. The approach involves minimization of a norm which is derived from trajectory dispersion from nominal trajectory in the wake of parameter variation. Accordingly, a complex controller is designed including sensitivity model to generate signal for feedback purposes. In case of multi-parameter variations, the state vector is augmented with a sensitivity vector function for each parameter variation. This approach is more practical and realistic as the dispersion of trajectories are directly involved in the problem formulation but its design procedure leads to increased computational complexities as number of varying parameters increases.
The eigenvalue sensitivity approach aims to synthesize feedback control law such that prespecified closed-loop eigenvalues are insensitive to system parameter variations. The approach requires a careful engineering judgment and is impractical to apply for large order sensitivity. Moreover, it also lacks in incorporating the effect of eigenvectors on various response modes. Through modal sensitivity approach the response mode shapes are made insensitive to small system parameter variations by assigning closed-loop system eigenvalues and eigenvectors arbitrarily with additional constraint of response modes being insensitive to parameter variations.

In performance index sensitivity approach, the performance index is modified to include the effect of parameter variations and the control law is obtained using an optimization technique. The trajectory dispersions in the wake of parameter variations are minimized with the implementation of designed system controller. The approach circumvents the problem of high order and is applicable to multiparameter variation cases with low storage and computational requirements. However, it usually requires trial and error procedure and hence is tedious to specify meaningful sensitivity features. Therefore, search for technique to design optimal AGC regulators which overcomes these limitations is worth investigating.

Recently, a system regulator design technique based on unity rank control concept has been proposed to design robust AGC regulators for the power systems having large order parameter variations from their nominal values. The technique involves only the bounds rather than the actual values of parameter uncertainties. The proposed technique offers simple controller structure and involves the modification of MR EQN for its solution. Many techniques are proposed for the solution of MR EQN in the literature with their merits and demerits. Therefore, a considerable attention is inevitable to carry out the efforts to propose effective solution technique to get the fast and more reliable solution of MR EQN.

The use of HVDC link for power transmission has various technical and economical advantages over the EHV AC transmission systems as discussed in section 1.1 earlier. Due to these merits, the HVDC link has been utilized for various applications in power systems. The major and most important use of HVDC link is its operation in parallel with AC transmission link/links between two power networks which results in increased stability margins and better
damping effects on transmission link and associated AC power networks. With increased stability margins, the existing transmission lines could be used to transmit power at levels that are close to their thermal and surge impedance loading capabilities. The study of interconnected power systems with parallel EHV AC/HVDC links has always been important for power engineers. The different configurations of power system and various control strategies based on conventional, linear optimal, sub-optimal, modal control concepts etc. have been considered for AGC studies. The implementation of these studies result in a favourable effect on overall damping of the system.

The AGC of interconnected power systems with asynchronous tie-lines offers a new and challenging problem in the control of power systems due to its complex organizational structure. The concept of multilevel control is well suited for the large-scale power systems where different kinds of controls at various levels are required for efficient and economic control. Then, the AGC can be treated as a multi-level optimal control problem. Considering this, the AGC scheme has been tested on interconnected 2-area power systems with asynchronous tie-lines. The test results show that using the DC power flow as a control variable in AGC strategy justified to be an effective means for improving power system dynamic performance and achieving the goals of AGC successfully in the wake of load disturbances in the system. The system dynamic performance can be improved using the DC power flow as a state variable as well.

1.3. OBJECTIVES OF THE THESIS

Keeping in view, the foregoing discussion, the objectives of the thesis are set forth as follows:

(i) to propose optimal AGC regulator design using full state vector feedback control strategy considering 2-area interconnected power systems having plants with similar and widely different characteristics as;
(a) 2-identical areas with reheat thermal power plants.
(b) 2-identical areas with hydroelectric plants and
(c) 2-unidentical areas with reheat thermal and hydro plants.

(ii) to demonstrate the effectiveness of the proposed optimal regulator designs in the wake of 1% step load perturbation in either area. A comprehensive study of system
dynamic performance has been carried out by obtaining the system closed loop
eigenvalues and time response plots in all case studies.

(iii) to advocate the power system area interconnections with EHVAC link in parallel with
HVDC link. Through the implementation of designed optimal AGC regulators, the
appreciable improvement has been demonstrated by using the HVDC transmission
link in parallel EHVAC link as an area interconnection as compared to that obtained
with considering the system interconnection as EHVAC link only. The HVDC link is
considered to be operated in constant current control mode. The incremental HVDC
link power flow is modelled by considering it as a function of;

(a) frequency deviation at rectifier end only
(b) frequency deviations at both rectifier and inverter ends.

The comparative study of system dynamic performance carried out shows that
the implementation of optimal AGC regulators designed considering the model of
incremental HVDC link power flow stated above in (b) gives rise to a superior system
dynamic performance over that stated above in (a).

(iv) the optimal AGC regulator designs using feedbacks of all the states which may or may
not be accessible and available for measurement pose problems for their practical
realization and implementation. Hence the efforts have been carried out to propose
sub-optimal AGC regulators using only feedback of states which are available as
output variables only thereby enhancing the feasibility of implementation of such
AGC regulators.

(v) to propose optimal AGC regulators incorporating sensitivity to system parameter
variations. The unity rank control concept [6] is discussed for the design of optimal
AGC regulators which are insensitive to system parameter uncertainties varying over
a wide range. The uncertainties in the parameters associated with transmission links
like, synchronizing coefficient of EHVAC link and time constant of HVDC link are
considered. The implementation of these regulators show a considerable improvement
even in the nominal system dynamic performance besides improving off-nominal
system performance.
1.4. CHAPTERWISE SUMMARY

The brief description of the chapterwise contents of the work reported in this thesis is outlined as:

Chapter 1 introduces the need for interconnected power systems, associated operational and control problems, transmission through HVDC links and its application to operate in parallel with EHVAC transmission link. The requirements of AGC regulators using best suited control strategy i.e. optimal control strategy, to provide ameliorated dynamic system performance are summarized.

Chapter 2 is devoted to review the literature in the area of power system operation and control. Emphasis has been given to present the research contributions focusing on the central part of control hierarchy i.e. automatic generation control (AGC) of interconnected power systems. Most recent research contributions in the area of AGC incorporating the advanced control concepts like, self tuning, adaptive, fuzzy and neural network are also reviewed. A due attention has also been paid to incorporate the studies on power systems interconnected via EHVAC, HVDC and parallel EHVAC/ HVDC links.

In chapter 3, the approaches to design techniques of AGC regulator for interconnected power systems based on optimal control theory are introduced. A new algorithm to obtain positive definite solution of MR EQN is also described. The investigations on 2-area interconnected power systems consisting of plants with similar characteristics have been carried out. First, the state space model is discussed and then selection of state cost and control cost weighting matrices involved in the system performance index is highlighted. The models of incremental power flow through HVDC links are presented. The numerical values of system parameters including those related with EHVAC and HVDC links are reported with resulting coefficient matrices for different case studies. The simulation results are reported for all case studies under consideration. For investigating system dynamic performance in the wake of load disturbances, the time response plots are obtained. From system stability point of view, the closed-loop system eigenvalues are obtained and their investigations are presented.

Chapter 4 presents the investigations on 2-area interconnected power systems consisting of area plants with widely varying characteristics. A 2-area interconnected power
system consisting of area plants with reheat thermal and hydro turbines is considered and its state space model, coefficient matrices, associated vectors are presented. The system dynamic performance is investigated based on the analysis of closed loop system eigenvalues and response plots for various system variables with 1% load perturbation in either areas. A comparative study of these plots in reference to the effect of area characteristics is also reported.

Chapter 5 presents the sub-optimal AGC regulator designs using output feedback control strategy. The 2-area interconnected power system with plants of similar characteristics i.e. identical plants with reheat thermal turbines] and plants with widely varying characteristics [ i.e. plants with reheat thermal and hydro turbines are considered for the study. The power system performance is analyzed based on simulation results and time response plots. A comparative study of system dynamic performance is presented in this chapter.

Chapter 6 deals with the optimal AGC regulator designs incorporating the sensitivity analysis to system parameter variations. The unity rank control concept is discussed and consequently optimal AGC regulator designs which are insensitive to system parameter variations are presented. The chapter concludes with the presentation of investigations carried out with regulators based on URC concept.

Chapter 7 contains an overview of the work carried out in the present thesis. The scope for further research in this area is highlighted in the end.