Chapter 6

RESEARCH AND DEVELOPMENT

6.0 INTRODUCTION

Depleting energy resources and environmental pollution are the biggest challenges facing the Indian power sector. Hence, there is an emergent need for developing efficient power plants which are eco friendly. The modern power plant should be capable of making optimum and effective use of depleting resources like coal, and natural gas. Development of hydro and renewable sources of energy needs to be encouraged due to their inherent advantages.

Power Sector being highly technology intensive, Research and Development (R&D) plays a major role in the developmental plans, especially while considering introduction of new and advanced Technologies for strengthening the power sector. The adoption and absorption of new technologies in a phased manner is essential towards a balanced growth of this Sector. It is of vital importance to focus our attention now on ways and means to build expertise within the country, to find solutions for the problems existing in the system and also for the problems that may arise in the future. To absorb high technology, the indigenous R&D base is important to understand the various technicalities involved to apply the same to Indian environment.

Collaborative Research in a phased manner is needed to bridge the gap between knowledge and technology (with rapidly changing technology), build expertise to find solutions for the problems existing in the system and also for problems that may arise in the future. There is a need to form a proactive & collaborative R&D Policy to develop innovative solutions to strengthen the Indian Power Sector through networking with research organizations, academic institutions and the power industry.

6.1 OVERVIEW OF R&D IN POWER SECTOR

R&D in the power sector is presently in the domain of following organizations:

- R&D Wings of Corporations like the BHEL, NTPC, NHPC, SJVNL, PGCIL and other units of the Ministry of Power (MoP).
- R&D in private sector i.e. TATAs, Reliance, Crompton Greaves, L&T, TERI, GE, SEIEMENS etc.
- R&D under MoP: National Perspective Plan (NPP) for R&D in Indian Power Sector, Research Scheme on Power (RSoP), and Research projects of CPRI.
- R&D laboratories of CSIR working on energy related areas and sponsored projects of DST.

In the thermal generation sector commendable work has been done by NTPC and BHEL in the areas of stabilization of supercritical units of capacity 660 MW, efficiency improvement of Thermal Power Plants, control, instrumentation and loss minimization. Similarly in the area of hydro generation, BHEL, NHPC and other hydro utilities have contributed in uprating of old units, improving turbine design etc.

In the transmission field, commendable work has been done by POWERGRID such as introduction of 1200kV Ultra High Voltage (UHV) AC system with totally indigenous development under public private partnership model. POWERGRID has associated 34 manufacturers in this developmental work. This commendable work of POWERGRID needs to be supplemented with further development in 800kV & 1200kV indigenous equipment development. POWERGRID have also introduced many new technologies like Series Compensation, Thyristor Controlled Series Capacitor, Transformer Online Monitoring system, Compact towers, High temperature low sag conductors, Controlled Switching of reactors etc. They have also contributed significantly to the development of high temperature conductors, development of insulators, planning of 1200kV AC and ± 800 kV DC first time in the country.

6.2 REVIEW OF R&D ACTIVITIES DURING 11th PLAN

i. Details of R&D activities by NTPC are in the following areas:

Development of IGCC Technology, Solar Thermal Platform & Solar Photovoltaic Research set ups, Waste heat recovery from flue gas for air conditioning, Development of aqueous-ammonia technology, Establishment of integrated biodiesel pilot plant, Development of robotic based inspection systems for boiler tubes, Set up of Solar thermal based HVAC system, Development of Water & Waste Treatment Technology, Set up of Pressure Swing Adsorption (PSA) based pilot plant for CO_2 capture, Studies on fixation of CO_2 through Microalgae, Studies on aqueous mineralization of fly ash by flue gases, Feasibility studies on Extraction of moisture from flue gas, Development of PDC-RVM instrument and expert system for moisture measurement in insulating papers of transformers, Retrofitting of VFD drives in existing cooling tower fans, Development & installation of artificial intelligence based software for plant performance improvement, Development & installation of online boiler water chemistry monitoring & advisory software, CFD modeling of flue gas ducts to improve temperature & velocity imbalances, etc

Scientific & technical support provided to all NTPC stations as well as many outside stations by NETRA plays a definite role in increasing the availability & reliability of stations in terms of failure investigations, corrosion analysis & control, water & waste water treatment, condition monitoring, health assessment, etc.

ii. Research projects taken up by BHEL during 11th plan under transmission sector are as follows:

a) 2.5 MVAr STATCOM: This project has been taken up jointly with CPRI and the system was developed and successfully commissioned at BHILAI steel plant.
b) Development of IEC 61850 Compliant Substation Automation System. Under this project IEC 61850 client has been developed. Bay Control Unit (BCU) has been developed. Based on this, a 132 kV substation of AP TRANSCO at Chintal has been provided with BHEL developed SAS under a field trial project.
c) Based on the development of 33kV Phase Shifting Transformer (PST) with Thyristor controlled static tap changer, BHEL has made efforts to develop and manufacture PST suitable for transmission applications. In this regard, with the help of CEA and APGENCO, system studies were made and a proposal for the design, manufacture and commissioning of 400kV, 315 MVA +/- 15 degree PST was proposed at KTPS stage VI . Based on the proposal, APGENCO has awarded a commercial order on BHEL. The project is under advanced stage of execution.

d) BHEL is working on the development of 400kV GIS and all the systems have cleared required dielectric tests and the efforts for field trial of the developed GIS is proposed in 2012. The field trail may spill over to 12th plan.
e) BHEL has developed IEC 61850 Process Bus requirements. In this regard, A Merging Unit (MU) has been developed and successfully tested at KEMA in the beginning of 2011. Field trail of full scale SAS along with process bus is contemplated in 2012 and the same is likely to come up in 12th plan.

iii. National Perspective Plan (NPP) –Initiative of MoP in R&D

R&D projects are executed through National Perspective Plan (NPP) Scheme of MoP in a collaborative mode. During the 11th plan period, thrust was given to new technologies such as: High temperature superconducting (HTS) systems, National Effort to Develop Custom Power Devices, Development of materials to address Silt erosion, Grid integration issues with renewable generation such as wind. These are addressed in a project mode.

The projects taken up during the period are:

a) Development of 630kVA HTS transformer for Distribution system application, project executed by M/s EMCO, Mumbai. Field trials are in progress.
b) Development of HTS based Fault Current Limiter (FCL), being executed at Crompton Greaves, Mumbai.
c) Development of 500kVAr STATCOM for IT-Park. Successfully developed by CDAC, Trivandrum, field trials are in progress.
d) Development of 2.5MVAr STATCOM for Bhilai Steel Plant. by BHEL, Hyderabad, field trials are in progress.
e) Development of new materials for hydro turbine components for silt mitigation issues. New material is developed by NML, Jamshedpur. IIT-Roorkee is focusing on developing new coatings for silt mitigation. NHPC and SJVNL are collaborating in these projects, which are relevant to hydro sector.

The total fund spent so far in 11th Plan R&D works is 352 Crore only. Thus, MoP has initiated R&D Plan in new and emerging technologies, which need to be continued during the 12th plan.

6.3 INFRASTRUCTURE DEVELOPMENT FOR R&D IN POWER SECTOR

The in-house R&D setups of major utilities like NTPC, NHPC and POWERGRID address introduction and absorption of new technology by applied research primarily through project routes. Major manufacturers like BHEL, Crompton Greaves, EMCO have their own R&D set up, focusing on product development. Central Power Research Institute (CPRI) is provided with capital funds from the Ministry of Power for in-house research as well as funds to coordinate and manage MoP's research schemes. Central Electricity Authority has a role in identification of appropriate new technologies for the country. Twelve projects are in progress under National Perspective Plan (NPP) on R&D, which are collaborative research projects involving more than one organisation. The R&D policy of the Government is to promote R&D projects that help the nation to become self reliant in technology.

The RGGVY scheme of MoP launched in 2005 has earmarked Rs.160 Crores amounting to 1% of scheme cost, for enabling activities including technology development

R &D in power sector and consequent changes has resulted in developing a sound generation base, a reliable grid and an upcoming modern distribution system. Continued and sustained efforts are

required through various science and technology laboratories of CSIR, DRDO, BARC, TIFR and through Government bodies of DST, such DSIR, TIFAC and others, for promoting technology in India.

6.4 PROPOSED R&D PLAN FOR 12TH PLAN

In the present scenario it is proposed to categorize the R&D initiatives into four different conventional sectors, viz. Generation, Transmission, Distribution and Environment. Under each Sector different technologies are listed for development of prototypes and pilot plant demonstration. The different areas in these sectors are as below:

a. Generation Sector:

- Thermal and Fuel
- Hydro
- Renewable Energy and Distributed Generation

b. Transmission sector

The adoption and absorption of new technologies in transmission sector can be implemented by further classification in to following sub-sections:

- Design and development of equipment, real time simulators and controllers
- Creation of data-bank
- Automation
- Pilot plant/Demonstration
- Development of alternative materials
- Equipment performance
- Biological effects
- Concept proving / Exploratory studies

c. Distribution sector:
Smart Grid, Distributed generation

d. Environment

- Clean Development Mechanism
- Bulk utilization of fly ash
- SOx, NOx, and mercury control.

Details of projects proposed to be taken up for R&D are furnished below (list not exhaustive)

6.5 R&D IN GENERATION SECTOR

6.5.1 Technological Advances and R&D in Thermal Generation

(a) Ultra Super Critical (USC) and Adv- USC Plants

Ultra super-critical plants operate at higher temperature and pressure (approximately 32 MPa and 600°C) resulting in higher efficiency. This translates into lower coal usage per kWh of power and less CO2 emissions. A few such plants have been built in Europe and Japan. The efficiency of these plants goes up to 44% leading to lower carbon emissions of 0.7 kg per kWh. However the extreme operating parameters impose stringent requirements on materials.

Considering that coal shall remain as the mainstay of India's power industry and the inevitability of pressures India will face to reduce emissions due to global climate concerns, Development of Advanced Ultra Supercritical (Adv-USC) Technology for Power Plants has been taken as one of the four Sub-Missions as part of the above National Mission under the guidance of the Principal Scientific Adviser to the Government of India.
Under this initiative, it is proposed to develop and establish an 800 MWe Adv-USC Power Plant on a Mission Mode, as a collaborative project involving IGCAR, NTPC, BHEL and CPRI. Material degradation issues and Condition assessment programmes are also to be investigated.

(b) IGCC TECHNOLOGY

IGCC integrates a coal gasifier, a gas clean up system and gas turbine in a combined cycle mode where coal is gasified with either oxygen or air and the resulting synthesis gas (or syngas) consisting primarily of hydrogen and carbon monoxide is cooled, cleaned and fired in a gas turbine. The technology has shown capability of power generation at higher efficiency and lower emission level with respect to pulverized coal combustion technologies as demonstrated in Wabash and Tampa in USA, Buggenum in Netherland and Puertallano in Spain. Various studies conducted in the 11th Plan by NTPC (NEXANT) and BHEL indicates that high ash Indian coal (> 40% ash) combined with its high ash fusion temperature (1300-1500 deg C) may not be suitable for entrained bed gasification as it will require gasifier operating temperature beyond 1500 deg C. The studies supported by pilot plant testing and simulation also indicated that IGCC technology with fluidized bed gasifier will be most suitable for Indian coal with gap areas in carbon conversion and syngas calorific value which may be overcome by using enriched air and fines recycling.

The other important aspect of IGCC where technological advances are continuously made is in the syngas cleaning especially at higher temperature. This removes the efficiency penalty of cooling the syngas to ~90 deg C and again heating it to the required temperature for the gas Turbine. These demonstration plants should have sufficient slip stream facilities where the upcoming warm gas cleaning technologies can be tested in actual operating condition.

Furthermore, IGCC technology opens up new product area along with electricity generation like liquid fuel generation, hydrogen production, pre-combustion CO2 capture and integration of fuel cell which may provide future options of zero emission coal technologies with higher efficiency.

To demonstrate these aspects and to take forward the studies carried out in pilot plant it is felt that there is a greater need to demonstrate and improve the performance of IGCC for high ash Indian coal in a higher scale plant. There is a need to set up 100 MWe (Net) project involving NTPC, BHEL and APSEB.

(c) Waste Heat Recovery Systems

The thermal power plants operating on Rankine power cycle normally achieve power generation efficiency in the range of 35-40 % depending on various site conditions, turbine inlet steam conditions and design of equipment etc. Balance of the heat input is essentially lost as condenser losses (about 48-50%) and boiler exhaust gas losses (about 6-7%) besides other nominal losses viz. radiation losses, un-burnt carbon losses etc.

In a 500 MW unit, about 25 MWth of thermal heat would be available if the flue gas temperature is dropped, say, from 140 to 110 Deg C. The major challenge in low temperature heat recovery system is the requirement of large heat transfer area and thus additional pressure drops, which increases the cost of the system. Use of waste heat recovery system, though desired for obvious cost benefit, is

equally important for environment protection as lesser quantity of fossil fuels shall be burnt for same quantum of useful energy.

Integration Options:

Waste heat can be gainfully recovered and applied to: (i) Produce refrigeration / air-conditioning using Vapor Absorption Machines based on Li-Br, Ammonia absorption system. (ii) Plant cycle efficiency improvement using condensate pre-heating. (iii) Produce electric power independent of the main plant TG set using aqua-ammonia Cycle or Organic Rankine Cycle.

Before integrating the recovered heat with power cycle of boiler, to begin with it is necessary to prove the design in the following:

(i) Vapor Absorption Air-conditioning
(ii) Aqua-Ammonia Cycle
(iii) Organic Rankine Cycle

It is suggested to take up on a Pilot scale, installation as retrofit to the existing power plant and on its successful completion, scaling up can be initiated.

(d) Development of Artificial Neural Network based Power Plant Optimization, Advisory and feasibility of Integrating Supervisory Controls

Real time Boiler operation under optimum conditions implies efficient fuel combustion and reduced fuel cost for the same amount of electricity generated. A modest efficiency improvement of 0.5% in boiler efficiency for a 500 MW boiler at a pithead station should result in a huge annual saving. Boiler operation control and optimization envisages variation of controllable parameter viz. excess O2%, wind box pressure etc. On the other hand TG cycle heat rate improvement by reduction in left/ right steam temperature imbalances, reducing spray, maintaining metal temperature at its best, further involves real time adjustment of above said controllable parameters.

Therefore real time optimization is an important need of the day. The challenges for meeting these operational goals in real time require that an increasing amount of information be simultaneously evaluated. As more complex emission control strategies are applied to the system, the complexity of the problem increases significantly.

As a result of this increasing complexity, traditional single-value cause and effect models have reached a peak in their ability to address these operational goals. Artificial Intelligence (AI) is a modern tool that can be assigned the task of constantly reviewing recent data to aid in making multivariable decision to achieve goals. AI attempts to model complex processes using various operating parameters that are involved in control and optimization of power plant's overall efficiency. Various nonlinear parameters viz. WB press, FAD position, burner tilts, Metal temperature etc. for which writing mathematical equations for plant efficiency is not possible, can be correlated with plant efficiency using Artificial Neural Network (Branch Of AI). Online retraining of ANN, addresses the model development for modified operating conditions, seasonal variations etc. very efficiently. Application of Evolutionary algorithms like Genetic Algorithm (GA) (another branch of AI) known for searching global optimum conditions eliminates the problems of incorrect advisory due to local optima in any other traditional optimization techniques. Further with advent of sensor, other monitoring techniques viz. flame imaging and advance control like model predictive control etc. this real time optimization using AI shall be able to give very accurate and powerful solutions to plant optimization.

Concerted R&D effort is needed to develop such ANN based software for fossil fired power plant.

(e) Advanced Non-Destructive Testing (NDT) Inspection Technologies (Robotic Boiler Tube Inspection, and phased array technology)

Robotic based boiler tube system for water wall tubes through eddy current based robotic system. The water wall tubes in the primary pass of thermal power plant boiler are subjected to severe corrosion problems especially in the burner zones leading to loss in thickness. The wall thickness of each tube needs to be monitored during annual shutdown periods for ascertaining their suitability for continued service and schedule for replacement if necessary. In view of the short shut down periods, it is not possible to measure the thickness of all tubes using conventional ultrasonic technique. In a robotic based system, the probe/magnetizing coil is supported on robotic device which can crawl along the whole length of the water wall tubes and maps the tube thickness or detects abnormality.

Second pass of boilers consists of bank of LTSH and economizer tubes having 1.5-2 mtr height and coils are so close together that making difficult for inspection. Robotic inspection devices are to be developed for inspection of these tubes resulting benefits in down time and higher reliability.
Phased array technique is a specialized type of testing that utilizes multi element array transducers and software controls for steering the ultrasonic beam. In view of complexity in shape & geometry of component of turbine components such as blades, rotor steeple and disk rim attachments, the conventional techniques suffer by reliability, accuracy & reproducibility. The advanced linear phased array ultrasonic technology wherein multiple UT probes mounted in a single holder is used for this purpose and reported that the reliable and redundant results can be obtained in respect of defect detection, sizing and shape.

HP / IP rotors suffer in-service degradation from rotor material temper embrittlement. The rotor material fracture toughness, which governs the size of the critical flaw for fracture, is hence adversely affected. A reliable assessment of the fracture toughness properties of steam turbine rotor requires sampling of material from in-service rotor. A miniature sample removal and small punch testing technique for direct estimation of fracture toughness provides a rational basis for reduction of conservatism during RLA of rotor.

The adoption of advanced RLA methodologies leads to the emergence of sophisticated practice in RLA with reliable and upgraded assessment technologies in the short time available during periodic maintenance, application of Robotics, improved deterministic routes and evolution of technology options.

The project envisages development of state-of-art technology in the area and adopts them in a few thermal power stations. The project will support a number of spin off research in the related area.

(f) Development of advanced NDT based diagnostics and inspection tools for condition assessment of plant components

Establishment of Centre of Excellence for Non-Destructive Testing and development of advanced Remaining Life assessment(RLA) methodologies (robotic corrosion mapping, phased array technology, digital radiography, remote eddy current, residual stress measurements etc.) for condition assessment of plant components, development of inspection methodologies and field implementation programmes as a part of Remaining Life assessment studies

(g) Development of Pressure Swing Adsorption (PSA) process for CO_2 capture

PSA is a technology used to separate some gas species from a mixture of gases under pressure according to the species' molecular characteristics and affinity for an adsorbent material. Special

adsorptive materials (e.g., zeolite) are used as a molecular sieve, preferentially adsorbing the target gas species at high pressure. The process then swings to low pressure to desorb the adsorbent material.

PSA based process is an alternative of the energy intensive amine based process for CO2 capture from power plant flue gas. As CO2 capture and storage (CCS) is a global concern, more so for India which is likely to be dependent on fossil fuel for several years to come for electricity generation, a concerted R&D effort is necessary.

There is a need to undertaking development and set up of a three bed bench scale PSA test unit for CO2 capture from flue gas.

(h) Development of Microalgae process for CO_2 fixation

Biological fixation of carbon dioxide is an attractive option because plants naturally capture and use carbon dioxide as a part of the photosynthetic process and discharge gases from heavy industries commonly contain sufficient carbon dioxide levels for algae growth. Therefore, it would be wise to develop strategies to limit this value.

Biofixation of CO2 from the power plant flue gases through microbial and microalgae processes is one of the important approaches for CO2 mitigation. CO2 is converted into biofuel and other useful products without risk of CO2 leakage as may be in CCS. Thus, combination of flue gas utilization and biofuel production is a very promising alternative in the present scenario.

Microalgae are capable of producing more than 30 times the amount of oil (per year per unit area of land) when compared to best known terrestrial oil seed crops. The productivity can further go up many times if instead of open pond, algae are grown in bioreactors.

There is a need for R&D to explore and prove biological route for CO_2 utilization / fixation.

(i) Boiler combustion Computational Fluid Dynamics, CFD modelling of sub and Supercritical boilers

Boiler is the one of the key equipment governing the overall cycle efficiency of coal fired power stations. Performance of a coal fired boiler depends on several design and operating parameters. It is essential to develop a comprehensive understanding and be able to model the influence of varying coal quality, coal blend, ,coal flow, burner design, burner tilt, flow rates of primary and secondary air on combustion efficiency overall performance of a boiler.

Knowledge of temperature distribution within the boiler, flue gas velocity distribution and localised heat transfer at boiler tubes are also of interest to reduce boiler tube failures. Knowledge of particle trajectories (bottom ash as well as fly ash) is also one of the key interests in understanding slagging, ash deposition and erosion behaviour. A validated CFD modelling of the complex processes of coal-gas turbulent flow with devlolatalization, combustion, heat transfer and ash formation modelling providing a visual parametric profile within the boiler is such a tool.

There is need to develop a fully validated CFD model for boiler, turbine and other aux components of a power station to optimise the design , manufacturing and in situ modification to increase efficiency and availability of power station with reduced cost.

In the 12th Plan, the CFD model should be expanded to encompass, dynamic behaviour of steam and gas turbine by manufactures and boiler modelling with ash formation and deposition model. For the supercritical boilers where the water to steam formation is not at a constant temperature as is in case of sub critical boilers, CFD modelling is a challenge that may be taken up by /with manufacturer.

(j)Advanced surface engineering technologies for higher life expectancy of Thermal plant components

The surface engineering technologies are becoming essential in critical applications of power plants involving wear, erosion as well as corrosion. Thus the immediate technological requirements to be addressed in respect of damage tolerance capacity of materials are: (i) High temperature wear and erosion resistance of thermal components (Burner, liner, and shield) (ii) Silt erosion resistance of hydro parts

The crucial R&D needs are: (i) CVI SiCf-SiCm (500% improvement in wear resistance & meeting the required toughness & stiffness, higher oxidation resistance up to 15000C and superior corrosion resistance) (ii) Nano High Velocity Oxygen Fuel (HVOF) sprayed coatings viz., Tungsten carbide, Titanium carbide, complex carbide, Alumina (100% improvement compared to conventional coatings) (iii) Cladded titanium carbide, tungsten carbide plates/flexible clothes brazed with parent materials which gives very effective and good adhesion bond characteristics.

The research focus shall address: (i) Development of small coupons in respect of SiC based advanced ceramics by CVI method, nano materials (like Alumina, Silicon Nitride, tungsten carbide) by HVOF spray process and cladding of WC/TiC to the base plate/flexible cloth (ii) Performance evaluation of materials under simulated conditions (iii) Computational fluid dynamics approach to study and analyze the performance of the developed materials (iv) Large scale production of SiCf-SiCm based composites, HVOF nano coatings, cladded plates/clothes and followed by simulated and accelerated tests for performance evaluation (v) Establishment of advanced center of excellence on surface engineering technologies (CVI based SiCf-SiCm CMCs, WC/TiC cladded plates, HVOF nano coatings) followed by field demonstration in burner nozzle, boiler tubes, coal conveying systems, pulverizers and promoting new developments to the power sector (super critical boilers).

(k) Design & Development of Last Stage Steam Turbine Blades and balancing of flue gas flow inside boiler for Improved Performance

The forced outages due to boiler components is considered significant compared to other components such as Turbine, generator, auxiliaries, etc. Considerable scope exists to improve the overall efficiency of the plant by controlling the heat loss of the last stage of low pressure turbine blades, balancing of flue gas flow inside boiler, optimization of air/fuel ratio for a specific grade of coal etc.. The major problems for the low efficiencies in steam turbine are due to aerodynamic & secondary losses due to inadequate blade profiles (geometry) and other clearances of the last stage blades. The other problems are erosion of blades, deposition on blades, breaking of blades, leakages from condenser, feed water heaters, valves, man hole gaskets, etc. The fluid flow in thermal plants is quite complex in view of its high turbulence and multi-phase nature. The quality of coal used by varies utilities varies from time to time. The utilities are posed with challenges for balancing the flue gas flow inside the boiler, as the efficiency of heat transfer gets affected readily due to imbalanced gas flow.

There is a scope for improvement in heat rate and efficiency in the existing plants by adopting latest design developments in blade profile by using numeric / CAD modeling, CFD, aerodynamic & stress analysis, etc. The potential for improvement is very large in small size turbines (though capital intensive) and even in bigger turbines (210 MW and 500 MW). Opportunity exists for effecting upto 5% improvement in the efficiency. However owing to service degradation improvements up to 3% in existing turbines appears possible and thus provides unique opportunity forgetting higher output from the running power plants. The scope of research shall focus on: (i) Design & development of Low Pressure Steam Turbine last stage blades through CAD modeling and CFD based analysis for determination of efficiency (ii) Modeling of utility boiler (250/500 MW) with simulated imbalance conditions and assessment on plant performance and control measures for achieving uniform flow

conditions (iii) Production of proto-type new turbine blades (iv) performance evaluation of new blades.

(l)Improvement of ESP performance
To study the effect of fly ash characteristics viz ash resistivity, composition, size, unburnt carbon on the efficiency of ESP components, and improved efficiency through Flue gas flow modeling.

(m)Establishment of Advanced facilities for coal combustion / blended coal combustion evaluation studies

To study the coal /blended coal combustion characteristics of different coals under simulated conditions in an advanced laboratory scale combustion test facility. CFD simulation of combustion process covering issues like burning profile, slagging and fouling problems, coal reactivity , emissions, hot spots and burning efficiency in a typical utility boiler.

- *Application of technologies for on-line measurements of coal flow, fineness , heating value, and balancing for combustion optimization in utility boilers*
- *Development of Hot Gas Cleanup Systems for Integrated Gasification Combined Cycle*
- *Optimization of Boiler and Turbine steam cycles and balance of plant for improved energy efficiency*

6.5.2 Technological Advances and R&D in Hydro Generation

Hydro power development in the country is of great significance due to the inherent advantages. For obtaining high reliability operation of the forthcoming large hydro electric power projects, it is essential to keep pace with the technological development and improvements taking place in the developed countries. Also, considering the problems of silt erosion damages, which are typical for Indian conditions, corrosion etc. in the existing power stations, the required technology development in hydro power sector needs a big thrust. Specially to mitigate the problem of silt erosion in the run of river Hydro Power Station under operation, construction & Planning stage in Himalayan region, big thrust is required to find indigenous solution through continual research & development.

Required areas of research in Hydro Power Generation are as follows:

(a) Integrated Operation of Cascade Hydro Power Plants
The optimal management of the hydro cascade plants includes determining of each hydro plant and the operating regime in which it operates. The optimal operation of cascade plants aims at meeting the demand with minimum water consumption. The analysis of loading profile under various constraints can be of immense use at planning stage as well as during operation.

Studies based on actual data for various river basins making use of innovative methods may be taken-up by an educational institute in collaboration with Govt./ Pvt. Agencies.

(b) Optimization Studies for Exploitation of Hydro Potential
Power Potential studies are carried out for assessment of available Power Potential of a river/basin based on a set of inflows and available head conditions under various operating policies. These studies play an important role in the optimization and design of new hydro facilities. They are used for examination of various configurations and their integration into existing networks. The studies

are carried out for optimization of project parameters and for evaluation of Energy and Power benefits.

Studies proposing innovative methods may be taken-up by an educational institute in collaboration with Govt./ Pvt. Agencies for Optimization studies for exploitation of hydro potential.

(c) Studies on Benefits of Pump Storage Schemes in the Indian Context

More Pump storage schemes are required to be taken up in areas where run of river schemes have either exhausted or are not feasible. Studies proposing innovative methods may be taken-up by an educational institute in collaboration with Govt./ Pvt. Agencies for working out Benefits of Pump Storage Schemes in Indian Context.

(d) Technological Advancement in Investigation of Hydro Projects and use of GIS/GPS

Geological investigations of hydroelectric projects are of paramount importance in understanding the geological set up of varied terrains and their geo-dynamic development. The purpose of most engineering geological work is to ensure that a proposed structure is built at the lowest cost consistent with currently accepted safety standards. The "need base" of survey and investigation module for hydroelectric projects constitutes delineation of lithology, stratigraphy and geological structure of the area, geo-mechanical properties of the ground and identification of extraordinary phenomenon, if any.

The accuracy and reliability of Survey and Investigation (S&I) data is very important for subsequent techno-economic evaluation and project implementation. Detailed explorations may sometimes reveal adverse geological features which in turn may either lead to drastic changes in the design or even render a particular structure un-feasible. To avoid adverse surprises during the implementation, the improved technology needs to be adopted by the S&I agencies. There is an immediate need for acquiring/ developing software, instrumentation and techniques for engineering geological, geophysical, Seismological and Construction material surveys. Application of GIS/GPS in river inflow/ discharge measurement, flood forecasting etc needs to be considered.

This development work can be taken-up by an educational institute in collaboration with Govt./ Pvt. Agencies involved in S& I work.

(e) Numerical Flow Simulation using Computational Fluid Dynamics (CFD) tools for Hydro Turbine Optimization and Enhanced Efficiency

The hydraulic design of turbines needs to be developed by means of CFD (Computational Fluid Dynamics) simulations and model studies in order to optimize and enhance efficiency. With these technologically advanced tools important flow features could be predicted with high accuracy. This allows the performance, efficiency and cavitation limits of a turbine to be predicted realistically for different operating conditions.

The development work using CFD flow simulations could be undertaken by domestic manufacturers in association with educational institutes for wide range of turbines.

(f) Technology for Spilt Runners/ Site Fabrication of Runners

It has been observed that owing to transportation limitation in India we are unable to plan hydro stations with large capacity units. While in other countries units up to 700 MW has been installed, we are still struggling with unit size of 300MW or so. The constraint is very large diameter runners of high capacity machines and this could only be overcome through the technology of runner with split type or site fabricated runners.

Technology for the design and manufacturing of such runners is not available in the country. R&D efforts are needed to assess the performance and life of these types of runners by interacting with the firms who have developed this technology and look into absorption of this technology for the Indian conditions.

(g) Development of Facilities for Large Size/Weight Casting and Forging Facilities

There is no facility in India for large size/weight casting and forging components, therefore there is a total dependence on foreign supplier. There is a need of development of such facility in India.

(h) Development of Shaft Seal for Silty Water

It is well known that water in most of Himalayan region rivers have silty water and there is a need to develop shaft seal for such conditions. This is one area where the hydro utilities are facing problem and there is urgent need to develop reliable shaft seal specific to Indian condition. The large manufacturers may take a lead in such development.

(i) Generator Modernization to Increase Efficiency.

Presently Generator efficiency is between 98% to 98.8%, however, there is a scope for further improvement in efficiency and reliability of Generators. Globally lot of work is going on in this direction particularly with respect to better insulation material which occupies lesser slot area leaving more space for the conductor, improvements in ventilation, utilization of magnetic wedges and improvements in material quality of the pole sheets which would reduce the losses.

There is a need for acquiring / developing techniques for improving efficiency of Generators. This development work can be taken-up by the large Generator manufacturers in house or in collaboration with foreign institutions or consultants.

(j) Variable Speed Drive for Pump Storage Schemes

The technology of variable speed drive for pump storage schemes is not available in the country. As more and more pump storage scheme would come in future, there is need to fill this technology gap keeping future market in India and the World.

Large unit manufacturers may be encouraged to develop the technology of variable speed drives for large unit sizes.

(k) Site Assembly & Acceptance Testing of 400kV Generator-Transformer to overcome Transport Limitations.

As indicated previously, the constraint of transportation is preventing us from installing higher unit size and one such item is generator transformer for large unit. There is an urgent need to find technological innovations whereby 400kV Generator-Transformer could be transported in parts and assembled/ tested at site. Any breakthrough in this direction would a landmark development as it has not happened anywhere in the World so far.

Large transformer manufacturers may be encouraged to do R&D in this field.

(l) Modernization of Automation, Control and Protection

The implementation of modern automation, control and protection equipment offers safety and operational advantages. There is a continuous development in this field and the recent development is implementation of control & protection system to comply IEC 61850 requirements.

Development project may be undertaken by control & protection manufacturer to implement IEC 61850 as it would provide immense benefits to the upcoming projects.

(m) Monitoring System for On-line Measurement of Turbine Efficiency & Silt Monitoring System

The real cost benefit of turbine efficiency is realized only when it is maintained during its lifetime. The sudden/gradual degradation of efficiency may point to some problem and may provide valuable information to O&M staff.

Although the technology of on-line measurement techniques are available in the world, but the same needs to be evolved in India also to make it suit site specific conditions. The entrepreneurs in association with educational institutions may be encouraged to develop reliable on-line monitoring system suiting Indian conditions.

(n) Solving silt Erosion Problems

In the 11th Plan period lot of R&D has been carried out to understand the silt problem and make the components wear resistant by way of development of new material/alloys as well coating techniques. The R&D in this field needs to be continued and improved upon.

(o) Simulation Test Facility to Study the Coating Material Characteristics

There is a need to set up simulation test facility to study the coating material characteristics. This facility could be set up in CPRI or some other institute so that effectiveness of coating material could be studied.

(p) Monitoring Cavitation Causing Erosion

Development of innovative methods like sensing & interpretation of vibration signals or any other method to monitor the cavitation problem in hydro plants may be taken up. This project could be jointly undertaken by an educational institution in association with the utility/equipment manufacturers.

(q) Development of PTFE (Poly Tetra Fluoro Ethylene) Material

For higher thrust the use of PTFE (Poly Tetra Fluoro Ethylene) type material on bearing is advantageous, however the technology is not available in India and we have to depend on imports. The domestic manufacturers may be encouraged to develop this material keeping in view vast Indian and International demand.

(r) Measures to tackle Corrosion/Erosion Problems in Acidic Water

In one of the project in north-east, the problem of corrosion/erosion has occurred due to acidic water having PH of about 4. Studies to understand & find ways to encounter such situation may be undertaken.

(s) Construction Methodology for Arch Dams

The technical knowledge of arch gravity dams needs to be built up in the country as the same has not been designed & constructed in the country. Idukki dam in Kerela is the only arch dam that was built in sixties with the Canadian assistance. The arch dam is of great relevance to accelerate the power development in the **country. The technology could be acquired through project route from other countries where such design exists.**

(t) RCC Dams - Construction Techniques and Construction Material

The recent advances in the dam construction using roller compacted concrete had made it feasible to commission hydro-power plants sooner than the normal schedule. State-of-the-art technology in this sphere has not reached to the extent desired in India. Transfer of technology would be very useful in this sphere as it would help speed up projects in remote areas in shorter durations.

(u) CFD (Computational Fluid Dynamics) Analysis for Improving Desilting Chamber Efficiency

Due to high silt content in our rivers, the efficacy of desilting chamber is very important. CFD (Computational Fluid Dynamics) analysis projects for improving desilting chamber efficiency may be undertaken.

(v) Measures to Increase Service Life for Silt Flushing Gates

It has been observed that due to high quartz content in silt, the service life of silt flushing gate is less. Studies to find measures to increase service life for these gates may be undertaken.

(w) Excavation of Large Size Cavern with Stabilization Technology and Soft Rock Tunneling

The future hydropower development will be concentrated in the Himalayan region and most of them would be under ground with long head race tunnel(HRT). At present the experience available in the country is for the cavern width up to 23-25m is possible and HRT diameter of 11m. However for larger size cavern & higher diameter HRT, it would be desirable to develop the technology in house or acquire the technology from the developed countries.

(x) Measures to tackle bad geology in Dam Foundation and Cutoff Wall

In some of the recent projects unexpected geology has been encountered and considerable time has been lost in the process. The advantages of application of jet grouted wall versus plastic concrete cutoff wall may also be analyzed.

A study on above may be undertaken to predict the geology of dam foundation and measures to tackle the bad geology.

The following studies may be undertaken:

i) Estimation of variation in flows due to environment changes
ii) Environmental sustainability of Hydro Projects

(y) In stream Power Generation: Power generation technology assessment and development

In stream hydrokinetic uses the river flow to generate the electricity. Installation of turbine farm without restricting the flow course can be useful for country. As our country is blessed with river resources, successful implementation of present proposal will help in mitigating energy problem (may be in small percentage). But this scheme is environmentally and eco friendly. The goals of the project are: (i) Acquiring river characteristics in North-eastern region of India (ii) Locating suitable section for implementation of such project (iii) Suitable region will be downscaled so that lab realization and experimentation can be performed (iv) Successful lab experiments may then scale up to field experiments (v) Design of Turbine farm and (vi) Life cycle assessment of such scheme.

(z) Performance optimization of hydro plant components through Computational Fluid Dynamics (CFD) approach

i) Hydro-turbine blade profiles for runners

The performance of hydro unit is affected by the complex blade profiles as the water flows through the turbine. The 3D profiles need to be optimized for a given capacity and head conditions. The problems become more acute in plants utilizing silt laden water. Elaborate de-silting arrangements are made for preventing the large size particles above 200 microns to alleviate erosion problems.. The high hardness quartz rich silt particles travelling at very high velocities causes severe erosion problems in the under-water parts of the turbine leading to loss of operating efficiencies. Computational modelling of silt particle trajectories and identification of critical erosion prone regions in turbines is still a challenging issue need to be addressed.

ii) De-silting Chambers

The size of the de-silting units is very large and performance evaluation through proto type systems is not possible. The geometry of silt chambers should be tailored for achieving effective sedimentation of silt particles through modeling and thus considered important for achieving improved efficiency and availability of plants under high silt conditions of flow.

The R&D shall focus on: (i) Design of 3D vortex shaped blading systems –full and half blades of hydro turbine runner through CFD approach (ii) Numerical analysis of pressure drop along the blades and optimization of blade profile for achieving lowest outlet pressure for a specific head & flow conditions. (iii) Fabrication of protype blade as per the finalized design and estimation of efficiency through experimental setup. (iv)Prediction of efficiency of silt chambers in use and modification of geometry and flow circuit for achieving improved efficiency.

6.5.3 R&D in Renewable Energy and Distributed Generation

Hydrocarbon resource limits are bound to force the world away from fossil fuels in coming decades. In addition, the environmental and health burdens arising out of the use of hydrocarbons may force mankind towards clean energy systems. Therefore there is need for electric power industry to look at other technologies of power generation through solar, wind, biomass, fuel cells, geothermal etc.

Technologies related to Wind, Biomass, Solar, Geo thermal, Fuel Cells, Waste to Energy (Wte) need to be identified. Research focus is on grid connectivity of large wind mills, self healing wind connected micro grids, distributed generation and large use of ethanol for energy products. Development of micro & mini grids and larger penetration of renewable energy is an important area for research.

The main areas of R & D in renewable and Distributed Generation are:

- Primary converter: developments for enhancement of efficiency, cost reduction and new technology routes
- Energy storage: electrical and thermal storage with enhanced charge-discharge efficiencies and new technology routes
- Electrical energy distribution and gridding: conventional grid-renewable grid ties, micro grids, domestic grid tied systems, etc.
- End use equipment for efficient interface to renewable power

6.5.4 Application of Nano materials in Generation sector

Nano materials technology is considered to involve the manipulation of matter on a near-atomic scale to produce new structures, materials, systems, catalysts, and devices that exhibit novel phenomena and properties. Nanotechnology offers the possibility of introducing technologies that are more efficient and environmentally sound than those used today.

The R& D focus shall include,

- Nano-optimized cells (polymeric, quantum dot, dye, thin film) and antireflective coatings for photovoltaic application
- Nano-composites for lighter and stronger components with wear and corrosion protection for thermal, hydro and wind energy applications.
- Nanostructured compounds for waste heat conversion to electricity
- Nano-ceramics and composites for superconducting power applications
- Nano-optimized membranes and electrodes for fuel cell and energy storage devices.

- o Nano-coatings for efficient lighting
- o Nano-catalysts for hydrogen generation and biofuels.

6.6 R&D IN TRANSMISSION SECTOR

Implementation of new technologies aim towards increasing stability of the system, availability of transmission network and in maintaining reliable and efficient operation and control of transmission network. Therefore, several technologies are being developed to support these goals such as: bulk power transfer over long distances, enhancement of loadability of lines and maintaining system stability. The key technologies that are being considered include development of controls, EHV and UHV AC and DC transmission systems, compact towers that significantly reduce RoW requirements, application of High Temperature Superconducting technology in developing transformers, cables, fault current limiters, motors etc, Gas Insulated Substations that require about 80% less area than conventional substations, substation automation and remote operation systems.

The Technical developments in communication technology and measurement synchronization for reliable voltage phasor measurements have made the design of system wide protection solution possible. The introduction of Phasor Measurement Units (PMU) has greatly improved the observability of Power System dynamics. Based on PMU's, different kinds of Wide Area Protection and emergency control and optimization systems can be designed.

Additionally, Smart Grids to support utilities in making optimal usage of the transmission grid capacity and to prevent the spreading of disturbances are also being considered. By providing on-line information on stability and safety margins for dynamic condition monitoring, smart grids would serve as an early warning system in case of potential power system disturbances.

Further, 1200kV UHV AC Transmission Technology is in evolving stage and is not available worldwide. A number of countries are working on UHV AC technology but it is still in evolving stage and international standards are also not available. In view of the above, need arises for indigenous development of 1200 kV system.

6.6.1 Transmission Projects for 12th Plan

A number of projects have been identified/ suggested to be taken up in 12th Five Year Plan for transmission sector. The projects identified for indigenous design, development, manufacture and commission in Indian power network are as given below:

1 Design and development of Equipment for UHV AC System

(i) Design and development of equipment for 1200kV AC System

Power sector growth necessitates development of indigenous technology for absorption in to network at higher voltage levels, mainly to strengthen the system and power evacuation. The key equipment proposed for indigenous development: 1200kV sub-station, Circuit Breakers, Shunt Reactors and Controlled Shunt Reactors for dynamic reactive power compensation. Development of High Energy (55MJ) ZnO blocks for Lightning Arrestor of class 5 duty is required for dissipation of High energy. Development of operating mechanism 1200kV disconnector is essential in the light of UHV transmission system technology.

(ii) Design and development of Equipment for 765kV AC system

The Power Transmission network is strengthened through a strong 765kV AC system, which will be the main corridor for transmission. Thus, infrastructure facilities for equipment development are

essential, especially for Controlled Shunt Reactors, Phase Shifting Transformers and seismic qualification of substation equipment is required.
The existing test facilities at UHV class would be utilized optimally, and additional facilities will be augmented. Also, suitable maintenance techniques for maintenance of UHV lines under live conditions are to be evolved.

2 Advanced technologies in Transmission

Transmission towers and conductors play major role in power transfer. To meet the growing demand for power in urban and industrial areas requires transfer of huge power. Due to the constraints in getting environmental clearances, and acquiring right of way, introduction of compact transmission lines is an alternative choice. The **compact transmission lines** have the advantage of reduced RoW, reduced tower dimensions. The compact lines invariably require polymer or long rod insulators for effecting reduced dimensions of tower. Re-conductoring of existing lines with High temperature & Low sag (HTLS) conductor is a viable option to increase the power transfer capacity. Design aspects of compact towers and feasibility study of different types of HTLS conductors are to be explored for implementation.

(i) Compact Transmission Line support using FRP is gaining importance and adopting compact transmission lines in Indian power network has become essential due to increase in load growth and difficulty in building new lines due to RoW issues. The main features of compact lines are reduced RoW and tower dimensions. The compact lines have reduced clearances and require polymer or long rod insulators for effecting tower dimensions. The aspects need to be addresses are: Design, development and testing of 220kV and 400kV towers and implementation in a utility as a pilot project.

(ii) Development of high temperature electrical conductors for Transmission lines is essential, keeping in view of transfer bulk power. The major challenges are to overcome the Transmission losses, increase the power transmission on the existing lines and the development of more efficient power conductors for new lines. The development of efficient power transmission system seems to have the major stake in the future of Transmission system and will become the national priority keeping in view the current scenario. One of the major requirements of conductors is to have high ampacity and low sag properties. In this direction, high temperature conductors which can withstand temperatures well above 250^{o}C is required to meet the growing demand to transfer power.
Recent developments have demonstrated that 6201 and Al59 are the two major alloy conductors in use. However, further enhancement is possible by designing new alloys and economically viable processing techniques. The present alloy conductors use alloying elements such as Zr and/or mischmetal to restrict the re-crystallization temperatures of the alloy conductors so that the conductor can withstand high temperatures. The strength and conductivity of conductors need to have a best compromise so as to get the maximizing benefit during power transmission.

Research in **developing high temperature All Alloy Aluminium Conductors (AAAC)** for transmission and distribution line applications is needed specially developing new materials for this purpose, and exhibit through pilot project. The aimed high temperature conductor will have an allowable temperature of 300 ^{o}C in emergency condition and 250-260 ^{o}C in continuous transmission.

(iii) Design and development of Seismic Resistant Substation is necessary to maintain reliability and safety of electrical equipment after an earthquake depend on the seismic response of individual substation components such as transformer, bushings, switchgear etc. The use of seismic qualification of electric equipment is one of the most cost effective methods for reducing the damage and disruptions from earthquake. Thus, equipment and supporting structures for power generating stations, and substations located in seismically sensitive regions / zones have to be designed and standardized to with stand possible earthquakes.

3 Pollution and Lightning mapping studies: Creating Data Repository / bank

Tripping of transmission lines and failures of insulators due to Pollution and Lightning has become routine especially NR and NER regions. Thus Pollution and Lightning Mapping Studies, and creating data bank are essential. This would help in analyzing the operational problems. Frequent tripping of EHV lines on account of accumulation of atmospheric pollution in the insulator surface leading to tripping of lines, which is common near coastal areas. In view of the huge expansion plan of EHV/UHVAC and Dc transmission system pollution mapping studies play key role, and helps in designing the line insulators. The lighting mapping studies helps in determining the actual causes of line tripping & insulator failure. These study results become guideline for remedial measures and creating data repository / bank is essential.

4 Composite insulators for power engineering applications

Polymeric insulators are in service in the country for more than a decade. They have been employed for both distribution and transmission lines. The in-service reliability of polymeric insulators appears to be satisfactory both from pollution performance and dielectric strength. Considering the large life span of transmission lines, it is necessary to evaluate their performance at various stages of their service and also under different electrical and environmental stresses they are subjected to. In this connection, it is to be noted that standardization of ageing tests on polymeric insulators is still under way in leading laboratories of the world.

At present, manufacturers in the country are capable of manufacturing polymeric insulators used up to 765kV class transmission system. However, their field ageing performance, particularly with respect to the FRP rod, behavior of polymeric material under different pollution conditions, exposed to different intensities of UV radiation, different type and severity of surface contaminations, etc. need to be studied in order to assess their reliability levels and to enhance reliability for improved transmission system availability.

Moreover, 1200 kV AC and ± 800 kV DC systems are becoming operational in the country prompting indigenous development of reliable polymeric insulators to be used in them.

Considering all the above and to asses the reliability of in-service polymeric insulators – there is a need to address the design and operational problems and explore new materials for composite insulators to make them preferred insulators in all classes of transmission (AC & DC) and distribution system.

5 UHV DC +/- 800kV

Considering the implementation of next DC transmission at +/- 800 kV, and substantial requirement, indigenous manufacture of equipment is required, and also the research focus will cover the following aspects: (1) DC electric field, corona studies on equipment and electrodes; (2) Effect of pollution on insulator surface; selection of insulator profile, configuration to Withstand DC stress under normal and polluted conditions. (3) Performance of bushings under DC electric stress. (4) Effects of DC stress on transformer insulation, ageing studies, diagnostic tools (5) Overhead Transmission Lines (6) Bushings and Transformers

(i) VSC based HVDC transmission has become an attractive option for bulk power transfer between meshed grids. The advantages of VSC based HVDC transmission is: high controllability of active and reactive power at the converters terminal and the ability to improve the stability. The project envisages design, develop and deployment of 50MW VSC based back-to-back HVDC system, as a pilot project study.

(ii) High Speed Grounding Switches (HSGS) for HVDC systems is required for to connect the station neutral to the station ground, if the ground electrode path becomes isolated. The

development of Indigenous HSGS will be carried out as a pilot project study for installation at HVDC substation.

(iii) The concept of **Transformer less HVDC transmission** is under active research at various institutions. A pilot project study is proposed to evaluate various aspects.

To adopt the VSC based HVDC transmission technology, High Speed Grounding Switches for HVDC systems and to absorb the concept of transformer less HVDC transmission system in power sector, pilot project study is required to be undertaken to gain the experience for wider acceptability for implementation.

6. **Automation**

(i) To address the natural calamity, fire in substation, for quick restoration **Emergency Restoration System (ERS)** for substations is necessary to implement. Design and deployment of mobile substation is considered necessary for implementation.

(ii) Considering the advantages of **process bus technology** over the conventional station bus technology, it is proposed to take up pilot project. Process bus technology has the advantage of reduction in huge copper wiring, integration of any number of IEDs at bay level etc. Integration of optical Current Transformers in place of conventional current transformer is to be considered.

(iii) Demonstration project of IEC 61850 substation automation comprising of both process bus and station bus, along with interoperability.

7 System performance improvement

(i) Development of **On-line monitoring system** for transformers, optical CTs, breakers etc., is an essential task, which helps in taking remedial measures before occurrence of fault. The condition based maintenance on-line diagnostics techniques will be developed.

(ii) **Condition monitoring** of polymer insulators include: Visual inspection of Polymer Insulators and inspection using Corona camera. Certain guidelines will be specified for assessing the defects at the initial stage, which helps is taking preventive action.

(iii) Robotic inspection of transmission system involves use of remotely controlled machines that incorporate imaging, sensing, and other technologies to assess the condition and status of transmission system components. The robot will be equipped to collect the data pertaining to lightning strikes, wind related damage and corrosive conditions. Application of robotics in transmission lines inspection is proposed to carry out in association with experts like Hydro-Quebec, in Indian environment.

(iv) NIFPES: A feasibility study is proposed for introduction of NIFPES, while reviewing the existing provisions of fire protection of transformers.

Feasibility study of use of **advanced sensors** for overhead lines inspection is considered through application of advanced communication and sensor technology.

8 Development of controllers for FACTS devices

(i) Application of FACTS devices in Indian Power System is proposed extensively supported through system studies. Research in the direction of developing indigenous **development of FACTS devices and its controls** are essential and the objective is to design, develop controls for FACTS devices such as: Static Compensator, HVDC, multi-terminal HVDC, switchable shunt reactors, series and shunts HVDC taps, UPFC, IPFC, STATCOM and deploy in network. The controller performance is to be studied in real time.

(ii) There is a need to develop controller for **controlled switching of circuit breakers**, which is used to close or open the contacts of circuit breaker by time dependent control of trip coils, to eliminate undesirable transients. Substantial research in this direction is required.
Thus, design, develop and implementation of controllers is required to be carried out by application of advanced control techniques such as: adaptive control, fuzzy logic control, ANN etc.

9 Advanced Technologies in Transmission

The ever increase in demand for bulk power transmission, and huge requirement in urban areas, there is need for implementing advanced technologies for power transmission such as: Gas Insulated Transmission Lines, EHV Cables and Submarine cables (34, 35, 36). These technologies would help power sector in meeting the projected load demand.

(i) Gas Insulated Transmission Lines are means for bulk power transfer at EHV/UHV levels. The application of GIL is viable option in densely populated areas or in environmentally sensitive regions, and where application of cables is not possible or reaches technical limits. An exploratory project to study the feasibility of application of GIL is necessary. The study results would help in popularizing the technology. There is a need for developing GIS substation technology.

Superior technology and excellent know-how are required to ensure quality and reliability of GITL. This uses SF6 tubular conductor technology, which has been around for several decades. GIL consists of a central aluminium conductor with a typical electrical cross section of up to 5,300 mm^2. The conductor rests on cast resin insulators, which center it within the outer enclosure. This enclosure is formed by a sturdy aluminium tube, which provides a solid mechanical and electro technical containment for the system. To meet up-to-date environmental and technical aspects, GIL is filled with an insulating gas mixture of mainly nitrogen and a smaller percentage of SF_6. For increased lifetime, the "performance line" product series has a longitudinal particle trap installed over the entire horizontal route section. An automated orbital

Welding procedure, accompanied by tailored ultrasonic inspection techniques, ensures perfect gas-tightness of the aluminum tubes. During service, the fully encapsulated design completely protects the GIL against environmental influences. Thanks to the technologically clear-cut, logical design and the use of high-quality materials, an absolutely maintenance-free product is achieved which requires external inspection only. And at the end of its service life, the issue of de-installation has to be addressed. The GIL tubular system with all its components and the insulation gas mixture are 100 percent recyclable. These factors help to minimize lifetime costs.
(ii) Application of **EHV class cables** is gaining importance owing to many advantages, such as: reduced emission into the surrounding area, of electromagnetic fields and reduced space. An exploratory project is necessary to promote the application and this would help Indian cable industry to produce indigenously.
(iii) Application of **submarine cable** for power transmission becomes unavoidable where there is no feasibility of overhead lines. The application of submarine technology in the proposed India – Sri Lanka interconnection as an exploratory project would give big boost to transmission planners.
These advanced technologies in power transmission are is necessary to take up to gain experience and meet the future challenges in transmission technology.

10 Indigenous Development of power system equipment and components, accessories and materials

Considering the growth of the Indian power network size, the requirement of new power system equipment is also growing proportionately, thus necessitating the development indigenous equipment, through technical collaborations with leading manufacturers around the world. Most important are: **CRGO steel for transformers**, **High Quality Pressboard Insulation** for transformers of class 400kV and beyond, **Resin Impregnated Paper** (RIP) Condenser bushings, Maintenance free

Vacuum type on load tap changer (OLTC) for Transformers, **SF6 filled** large capacity **power transformers technology**, which is more suitable for installations at underground stations, GIS stations and fire prone stations**. Mixed Technology Switchgear** (MTS) facilitates area space optimization to install a high number of bays. The MTS is compact, modular and easy exchange of modules. The indigenous development of MTS technology is to be introduced in Indian context.

11 Promising Technologies for future

(i) The objective of **Innovative Visualization** with sustainable self-awareness feature is to serve real time data for different level of users with the specified authorization and based on their usability which leads visualization to self-awareness. For this purpose it is required to maintain customized data repository and intended data set to be visualized for particular user/EMS operator.

(ii) The power trading is becoming important aspect in the present competitive electricity market, and also to meet the load generation balance. This necessitates the requirement of a comprehensive proposal to include the design and development of an Application framework with Software Sub Modules for Energy Trading, Billing, Pricing and Tools for Load Forecasting in the form of Software as a Service (SaaS).

(iii) With the increase in size of the network, **data mining and repository** aspects needs to be considered while carrying out the real-time simulation studies. In the era regulatory regime, energy trading, pricing and tools for load forecasting is essential to build up. The data analysis in energy domain shall cover advanced forecasting techniques, tools for operation, simulators and training for system operation and security assessment. This would cover Energy Management System aspects also.

(iv) Real-Time Power System Simulator: The Power system analysis and studies is a continuous process. This requires the maintaining of system data repository for carrying out planning and operational studies. Developmental studies especially the development of new controllers is to be studied in real-time. The indigenous development of real-time power system simulator is required in the context of training the personnel for system operation and developmental activities. The simulator development requires involvement of academicians, hardware and software experts and system operational experts, to various aspects of system performance. The simulator is tool to understand the behaviour of power system including distributed generation, and take possible remedial measures for reliable operation. The aspects like steady state, dynamic and testing of controls in real time need to be considered.

6.6.2 Indigenous Development of Power System Equipments & Components, accessories and materials

(a) Alternatives to minerals based Transformer oil: GREEN TRANSFORMER OIL

Transformer fluids are generally petroleum based fluids and are non-bio-degradable, non-renewable and non-environmental friendly and their availability is limited and are very expensive. Substitution of the mineral based dielectric oil with a new environmental-friendly dielectric fluid is an immediate requirement in our country.

An ideal liquid dielectric has very good electrical, physical and chemical properties along-with stable ageing characteristics. It should be compatible with electrical equipment construction materials like paper, press board, copper, metal housing, polymer containers etc.

A practical study is proposed to test suitable vegetable oil, as a replacement for mineral oil.

(b) Vegetable based transformer oil

Raw vegetable oils are not suitable for use as dielectric fluids because of poor dielectric strength and lack of hydrolytic/thermal stability. However, certain chemical/physical modifications are required to overcome these deficiencies.

The Research in this area should focus:

- The substitute oil should be developed from non-edible, indigenous oil
- It should be Eco-friendly (i.e. biodegradable), renewable hence provide safer disposal methods and avoid environment hazards
- Ensure very high class quality
- Provide safety margin for flash point by double than that of mineral oil
- Reduced fire hazards since the fire point should b e above 300°C
- Enhance the service life of transformer by absorbing moisture from the paper during normal service life and therefore, less shut down and reduced investment on filtration etc.
- More useful for remote, pole mounted, sealed distribution transformer which are normally unattended
- Improved Reliability of Power Apparatus
- Total absence of corrosive sulphur and PCB

Further studies are required for:

A **methyl ester** of rapeseed oil (MRSO) has also been tested for possible use in power capacitors Soybean based transformer oil

Insulation systems for electrical distribution transformers are being re-evaluated based on their total life cycle cost from both an economical and an environmental perspective. Due to the inherently higher efficiency design offered by liquid cooled transformers, development has focused on fluids having improved environmental and health properties while maintaining the fire resistant properties of “less-flammable” fluids. Because esters have lower inherent resistance to oxidation and differences in the type and magnitude of oxidation by-products, a novel insulation system has to be developed to overcome this potential handicap.

(c) Development of CRGO Silicon Steel for Transformer core

There is no indigenous manufacturer for CRGO Steel required for magnetic core of Transformers. Annual requirement for CRGO Steel is about 150,000 T. **India requires foreign collaboration to adopt the technology successfully for commercial production**.

(d) High Quality Pressboard Insulation for transformers

For application to UHV/EHV class transformers, presently available materials are inadequate in terms di-electric strength and chemical purity. India has manufacturing capability for press board insulation for transformers up to 220kV only. For transformers of 400kVand above; press board is imported. For making Indian Transformer competitive, it is necessary to have indigenous production

In order to manufacture pressboard insulation for 400KV class and above, the Indian manufacturers will have to upgrade their manufacturing and processing capability.

(e) Resin Impregnated Paper Condenser bushing (RIP)

RIP Bushing technology is to be adopted by Indian bushing manufacturers, by upgrading the existing manufacturing process.

(f) Maintenance free Vacuum type on load tap changer (OLTC) for Transformers

Resistor type on load tap changer is mainly used for transformers. Due to operation of tap changer under load, heavy arcing is experienced in Diverter chamber of the tap changer. This arcing damages the contact and also the oil. In order to avoid the wear and tear, vacuum bottle is used for making and breaking of contact. Vacuum type tap changers have almost same price as that of resistor type tap changers. At the same time, it is more reliable and has very long contact life. This helps longer life for the tap changer

At the moment, Indian customers are specifying VAC type tap changers only for Furnace transformers and few selected transformers. IF VAC type tap changers are produced in India, price will be comparable to resistor type changers and many customers will prefer VAC type tap changer.

(g) SF6 Filled large capacity Power transformer Technology

SF6 filled transformer is an advanced technology for manufacture of transformers, for installation at underground stations, GIS Stations and fire-prone stations. This technology is very much advanced in Japan and other ASEAN Countries. Even transformers of 300MVA, 300kV class are in operation

SF6 gas is used as insulation in Circuit breakers up to 765kV class in India.SF6 filled Technology is yet to be developed. Nevertheless, transformer is ready to adopt the technology. The basic transformer technology is similar to oil filled transformer. The main difference is in insulation materials and pressure vessel. Major transformer manufacturers will be able to develop the product.

6.6.3 Advanced technologies in Transmission

(a) Gas Insulated Transmission Lines

Gas Insulated Transmission lines offer flexibility either above- or below the ground. Second-generation gas-insulated line Power transmission is the best option where environmental or structural considerations rule out the use of overhead transmission lines. The outstanding features of a GIL system are its high transmission capacity, superior electromagnetic compatibility (EMC) to any other transmission system, low losses, high safety (no fire hazard) and flexible installation options. GIL can be laid aboveground, installed in tunnels or buried directly in the soil, depending on individual requirements.

(b) Application of EHV class power cables

The demand for EHV cables is expected to grow tremendously in the coming years. A large part of the requirement would come from underground cables that would replace overhead lines. Besides, industrial consumption to sectors like steel, cement, petroleum refineries, special economic zones, industrial parks, etc. would substantially drive demand for EHV cables. R&D concerning reactive power management in 220kV and 400kV voltage underground cables and issues for maintenance need to be explored, as there is a need to equip with state-of-art technology to meet challenges of HV underground cables due to constraints in overhead transmission.

(c) Application of submarine cables

Application of submarine cables in areas where there is no feasibility of overhead lines. Alternating-current (AC) submarine cable systems for transmitting lower amounts of three phase electric power can be constructed with three-core cables in which all three insulated conductors are placed into a single underwater cable. Most offshore-to-shore wind-farm cables are constructed this way.

For larger amounts of transmitted power, the AC systems are composed of three separate single-core underwater cables, each containing just one insulated conductor and carrying one phase of the three-phase electric current. A fourth identical cable is often added in parallel with the other three, simply as a spare in case one of the three primary cables is damaged and needs to be replaced. This damage can happen, for example, from a ship's anchor carelessly dropped onto it. The fourth cable can substitute for any one of the other three, given the proper (and complicated) electrical switching system. Application of sub-marine cables can be considered as pilot project at suitable locations.

6.6.4 Promising Technologies for future

(a) Innovative Visualization with sustainable self-awareness feature

The Perspective of the real time data set at different levels is required for different aspects. It is required to have customized and intended data set to be visualized for particular user/EMS operator. The objective of Innovative Visualization with sustainable self-awareness feature is to serve real time data for different level of users with the specified authorization and based on their usability which leads visualization to self-awareness. The System will depict the required real time data efficiently with the expert system/intelligent system.

The proposed System has user adaptive and self aware UI which has ability to adapt itself according to the user's preferences. In real time application like SCADA/EMS, the HMI should be person centric where different users and SCADA operators have their own perspective to visualize the real time data set. In order to incorporate adaptive and sustainable self–awareness UI, there must be an intelligent system to track the user's behavior and to depict the UI accordingly. The adaptive self awareness UI can be adaptable in the present context.

(b) Next Generation Data Analytics in Energy Domain: Data Analytics for Power System Analysis could be efficiently implemented on Cloud Infrastructure. Project shall include the design and development of an Application framework with Software Sub Modules for Energy Trading, Billing, Pricing and Tools for Load Forecasting in the form of Software as a Service (SaaS). Data Analytics assist in Analyzing specific consumer benefits, support efficient delivery and investment in the electric system, Facilitate Customer Choice etc on which exhaustive and heuristic analysis can be done.

Using Data Analytics, it is becoming possible to run simulations or models to predict the future outcome, rather than to simply provide backward looking data about past interactions, and to do these predictions in real-time to support each individual business action. While this may require significant changes to existing operational and Business Intelligence (BI) infrastructure, the potential exists to unlock significant improvements in business results and other success rates. Next-generation Analytics can support BI search tools that can find reports and generate SQL queries, (2) visual discovery tools to slice/dice data intuitively at the speed of thought.

Application & Features:

- Advanced forecasting techniques for sustainable operations
  - Novel Forecasting Techniques
  - Advanced modeling tools
- Architectures & tools for operations
  - Self Healing Grids
  - Control Methodologies for Sustainable self aware services
- Simulators and training for operations of smart grids

- ❖ Transmission grids, real time security assessment
  - Innovative solutions to demands of real time security analysis
- ❖ Prognostic Health Management in the Smart Grid.

(c) Real-time Power System Simulator

Power Systems cannot be tested at full power rating in the labs, and simulation is an extremely valuable tool for designing, operating and understanding complex systems. The ability to simulate the sequence-of-operation using real-time data is of fundamental importance & Real-time simulation can avoid inadvertent outages caused by human error, equipment overload, etc. Furthermore, the proliferation of distributed generation plants, often based on the use of renewable energy resources, presents significant challenges to the design and stable operation of today's power systems. The idea is to develop indigenous real-time simulator to study the various aspects in power systems like Load flow, Short circuit, Transient stability, Optimal dispatch of generating units, Transmission, power quality issues etc.

The goal is to develop a Power System simulator that solves transient and steady state simulation in real time. The following areas need to be focused: (i) Distributed generation - wind, solar, fuel cells (ii) Real time response for closed-loop testing (iii) Protective relay testing - line, transformer, generator etc. (iv) Control system testing - HVDC, SVC, FACTS. (v) Large scale real time simulations (vi) Smart grid applications.

Developments are required in hardware, high speed parallel architecture and Power system applications. The major areas are: (i) High speed CPU & Powerful parallel processing hardware and custom I/O (ii) Advanced and comprehensive user interface (iii) Extensive, well proven power and control system component libraries (iv) High power digital current and voltage amplifiers (v) Power System Application development with the help of experts.

The indigenous development of real time simulator shall aim at cost effectiveness, flexibility to handle large scale systems and capability to handle user defined models.

6.7 R&D IN DISTRIBUTION SECTOR

Distribution system needs careful attention in the areas such as reduction in losses, metering, distribution automation, planning, harmonic pollution, custom power devices, demand side management etc. High Voltage Distribution System is an effective method for reduction of technical losses and improved voltage profile. Application of IT has great potential in reducing technical & commercial losses. Integrated resource planning and demand side management also needs special attention and implementation. Substantial efforts are required for capacity building, so that the present day Distribution system would be transformed into a modern day distribution system namely Smart grid. Smart grid represents a vision for a digital upgrade of Power Distribution system to both optimize current operation as well as open up new avenues for alternative energy production. Improvement in reliability of **distribution network** can be achieved with deployment of SCADA/ DMS for remote monitoring and control of various network elements, obviating need for manned substations. Distribution Management System (DMS) extends the monitoring and control functionality of SCADA to distribution transformers. Remote Terminal Unit's (RTU) and Fault Passage indicators (FPI's) are installed at substations. This improves reliability indices by over 50%.

Design and development of High Temperature Superconducting transformers, and compact transformers in distribution systems needs careful attention and applied research in this area in phased manner is proposed.

6.7.1 Areas of Research in Distribution

In the distribution sector, areas such as Methods to reduce losses, Advanced metering, Distribution Automation, Custom Power Devices, Power quality analysis, Distribution System Planning tools, demand side management, development of solid state transformer for distribution systems, utility automation covering SCADA, mapping and GIS, outage management system, advanced metering infrastructure and distribution automation covering customer level intelligent automation systems, substation and feeder level automation, data communication and standardization of distribution automation needs R&D activities. Application of Smart Grid technology and concepts in distribution systems need special attention.

6.7.2 Distribution Automation: Research Work Initiative

The research work should be aimed at developing indigenous know-how of full scale Distribution Automation system, which can cover from primary substations to consumer level intelligent automation. The future research initiatives for power distribution automation are:

- Customer level intelligent automation system
- Computer aided monitoring and control of Distribution Transformers
- Substation and feeder level automation
- Data communication system for Distribution Automation
- Distribution Control Centre (DCC) software

(i) Customer Level Intelligent Automation System

(a) Automated Meter Reading
(b) Prepaid Metering
(c) Embedding Harmonic Detectors in the Meters

(ii) Computer Aided Monitoring and Control of Distribution Transformers

(a) Remotely Operable Load Break Switches
(b) Low Cost Controllers for Capacitor Switching
(c) Low Cost Pole Top RTU

(iii) Substation and Feeder Level Automation

(a) Indigenous Auto Reclosures and Sectionalizers
(b) Intelligent Electronic Devices (IEDs)

(iv) Data communication system for Distribution Automation

(a) Interfaces for Code Division Multiple Access (CDMA) and Wireless in Local Loop (WLL)
(b) Interfaces for Global System for Mobile (GSM)
(c) Interfaces for Distribution Line Carrier Communication (DLCC)
(d) Cost Effective Substation RTUs

(v) Development and Standardization of Distribution Automation software

(a) Master Distribution Automation Software
(b) Application / Engineering Analysis Software
(c) Integration of GIS
(d) Energy Audit and Accounting Software (EAAS)
(e) Trouble Call Management Software (TCMS)
(f) Customer Information System (CIS)
(g) Web Based Metering, Billing, and Collection System

(h) Web Based Monitoring of Distribution System
(i) Pilot level Demonstration Projects

6.8 ENVIRONMENT

Areas of research in Energy - Environment are as follows:

Clean environment mechanism at thermal power stations, creating data base for ash quality, advanced ash management schemes, sustaining coal based power generation considering new and emerging environmental issues, effects of electromagnetic waves on human beings with specific reference to up-gradation of transmission voltages, ec0-design and energy efficient power transformers, utilization of CO_2 from flue gas for aqueous mineralization of fly ash, development of water & waste water treatment & recycling technologies, emission control technologies for NOx, SOx and mercury are some of the areas where R&D activities are required for improvement of environment and for sustainable development.

6.9 ATTRACTING AND RETAINING OF YOUNG TALENT FOR R&D IN POWER SECTOR

First of all the young engineers should be trained in all aspects of Power Engineering. Training shall include:

- Field exposure
- System simulation for carrying out system studies
- Any other specialized areas in which they are supposed to work
- The problems faced in the Power sector shall be obtained from utilities Specific areas for R&D should be identified by experts; young talent can be used to solve the problems under the guidance of experts
- Incentives should be given for good R&D work.

(a)To retain engineers/ young talent they should be allowed to pursue higher studies such that the research work they are carrying out becomes their project work for their masters or doctoral work.

(b)Institute should go for campus interviews in IIT's /NITs/Universities, explain to them the importance of R&D, the facilities and avenues for research, so that they make a proper choice of their future work.

(c) The problems faced in power sector should be made known to the researchers so that they can appreciate and take up such research work.

(d) More job opportunities should be created to absorb engineers for a job placement who are successful/excel in R&D.

(g) Researchers should be rewarded suitably, and if the research works ends up in patent he should also be eligible for the royalty, awards and citations etc.

(h) Researchers should be sent to training programs on advanced topics for research.

(i) Curriculum at degree level should be revamped to make students to realize the importance of R&D in power sector, so that they can pursue R&D

(j) Educational institutions should provide motivation to students to take up research work.

(k) R&D jobs should be paid on par with IT professionals else there is every chance that power engineers also take up IT related work and there is no brain drain.

(l) There should be an increased emphasis on induction level and advanced training focusing on career development of individuals and organization.

The educational institutions in the order of IIT/NIT/ Universities where the staff of Electrical Engineering Department is active should be identified for carrying advanced research and identifying as centres of excellence in specific fields.

Changes at graduate and post-graduate curriculum to create opportunities for getting exposed to all aspects of Generation, Transmission, Distributions and other areas of power sector is suggested.

6.10 R&D POLICIES AND GUIDELINES

With the opening up of the Indian market, foreign companies are now allowed to set up their own 100 percent subsidiaries and tap the domestic market demand. Technology transfer was considered to be one of the most important benefits of permitting FDI into a country. This is however not happening. International technology leaders are not willing to share technology with Indian companies and insist on "business sharing" approach. Hence, it is becoming difficult to purchase state-of-the art technologies. In this context, following issues need to be addressed at policy level:

(A) Corporate R&D

The Planning for R&D should commence with the Corporate R&D policy of the company which every CPSE must have. This Corporate R&D policy should align itself with the Company's Vision and Mission. The Corporate R&D policy should also have IPR policy for protection, maintenance of IP generated.

Based on the R&D policy, the CPSE must develop R&D manual and R&D plan. R&D plan should contain long, medium and short term plans as per need and have clearly earmarked objectives, scope, expenditure, benefits expected, deliverables, time periods etc. It may also include details of expected tax benefits. To achieve the objectives and goal, it is necessary to prioritize R&D projects depending on the benefits that are likely to accrue.

R&D plans should also contain details about implementation as well as procedures and methodologies for monitoring results and modalities of concurrent and final evaluation. It should also specify about mandatory documentation of the R&D efforts as well as results achieved. It should also include plan for obtaining / maintaining recognition of its R&D center with DSIR, so that applicable tax / duty benefits can be claimed by CPSE.

R&D plans shall contain projects to be undertaken. The target to be achieved against each project should be clearly defined. The plan should clearly specify:

- Projects to be undertaken;
- Activities to be undertaken for each project;
- Budget allocated as a percentage of PAT;
- Responsibilities and authorities defined;
- Major measurable and perceivable results expected;
- Knowledge management systems and HR issues of manpower, incentives and rewards;
- Proposed net working with academic/research institutions, customers and vendors.
- Projects labeled as R&D should not overlap with projects under Corporate Social

- Responsibility or Sustainable Development.

(B) Need for Domestic R & D

1. It is well recognized that domestic Research & Development is an important ingredient in self sustenance effort of the country. However, efforts being made in this regard require to be further strengthened. National Level Policy changes are needed to encourage indigenous development of technologies with focus on the following specific aspects:

    a) In the context of Power Sector, for indigenously developed products, especially those involving substantial developmental investment, the qualification requirements pertaining to equipment performance over a minimum period specified by customers like Electricity Boards, NTPC, etc. should be removed. This would enable domestic companies pursue product development, testing and marketing of indigenously developed products & systems. At the same time user's interests can be safeguarded by the product developers by way of recourse to deferred payments, extended guarantees or insurance cover to indemnify them against the risk of failure. Further, development of indigenous products must be encouraged by providing an opportunity to the developers to carryout field trials on no cost no commitment basis.

    b) To support commercialization of indigenously developed products, an acceptable mechanism/ enabling provision is needed for risk mitigation. This could be in the form of insurance scheme to cover any potential risk over and above the normal warrantees and guarantees offered by the product developer and funded through the aegis of a R&D cess.

    c) As per the Research & Development Act, 1986, as amended in 1995, a cess of 5% is being levied by Government on all payments made towards import of technology, etc. The Government should encourage R&D in capital goods sector and other critical areas of strategic importance by providing funding from this cess. Further, additional R&D funds can be created by imposing a nominal cess on the turnover of every company, on the lines of the cess on petrol and diesel for developing national highways.

    d) In certain specific areas identified for attracting FDI, policy changes are necessary to include transfer of technology to an Indian company as a mandatory condition to allow access to our huge domestic market.

    e) A few developing countries including India, Indonesia, Pakistan, Tanzania, etc. have set up a Working Group on Trade and Transfer of Technology for discussions within the WTO and have put up a draft proposal to the WTO Secretariat in Geneva. In this document, currently under discussion, it is clearly mentioned that special treatment will be given to developing countries for transfer of clean coal technology on reasonable terms and conditions and in a manner that contributes to the long-term developmental prospects of the host developing country. This must be vigorously pursued.

    f) Enunciate a clear policy to provide incentives for the commercialization of products developed through indigenous R&D efforts. The incentive could be among others, in the form of excise duty exemption at least for a period of five years from the date of commercialization.

g) Application of BIS standards in power industry to be made mandatory

h) Rationalization/acceptability of new materials by statutory authorities like IBR for boiler applications must be permitted. If alternate materials for usage not codified by ASME are available, the same should be permitted provided these alternate materials have been codified by any other international specification formulating agency or certified by reputed national laboratories that are approved by IBR.

i) Huge investments are needed in R&D, skill base development and new technologies to foster innovation. For example, research in the field of combustion process, gasification process, nano technology, high temperature steels, etc. find application in a variety of sectors like energy, automotive, ship building, etc. Such inter-sectorial innovations can be effectively steered at Government level for bringing out the synergy. Policy framework must support such research involving various sectors of industry with appropriate funding mechanism.

j) Identify and support certain high cost domestic R&D efforts of Indian companies through government funding through grants and soft loans with the purpose of establishing references for technologies/ products thus developed. For demonstration projects, a collaborative approach involving the developer, the user and the Government with appropriate equity participation could be considered. For example, BHEL has made a beginning in terms of a tie-up with APGENCO for 182 MW IGCC project. There is a need for financial support from the Government for such projects. It should also be extended to other areas like development of 765 kV transmission equipment, Advance Ultra Super Critical Technology, etc. It may be pertinent to mention here that U.S government has already extended 50% funding on such demonstration projects.

k) Consider appropriate delegation to Maharatna, Navaratna and Min-Ratna CPSEs boards for outsourcing of expert knowledge/ technology in niche areas for carrying out R&D from international experts/ institutions on exclusive basis giving consideration to quality and capability rather than price determination on L-1 basis.

C. Strengthening R&D Infrastructure

1. R&D Infrastructure at National Level needs strengthening in terms of facilities especially for type testing of prototypes with a view to minimize development/commercialization cycle. The areas to be considered for strengthening are:

a) Prototype and material development in case of special castings and forgings used in power generating equipment requires infrastructure supplementation at national level to improve their development pace.

b) Testing Laboratories in India are to be upgraded to address capacity & availability issues obviating the need for sending the equipments abroad for type testing.

c) Promote Joint endeavors of Indian companies with IGCAR, MIDHANI etc. to develop and commercialize production of prototypes.

D. Intellectual Property Rights and Commercialization

It has been found that Indian brain working on new technologies for multi-nationals in India are made to file patents on behalf of MNCs in India and in their country of origin and

products designed, engineered and manufactured on the basis of these patents are commercialized at premium prices in our own country. A mechanism should be developed to take care of this aspect while framing the policies so as to empower the technology base of the country.

The projects executed through the scheme of NPP of MoP, the guidelines as stipulated by MoP shall be followed from time to time.

Project implementing organization shall furnish all details documents/test reports etc. as required for registration of patent. *The patent will be jointly held by CPRI and project implementing organization. All other commercial benefits will be available equally to both CPRI and project implementing organization.* CPRI and project implementing organization will jointly patent the product/Technology/process developed. The patent rights will vest with CPRI and project implementing organization.

Technology developed through the projects will be available to everyone however at a commercial cost. Transfer of technology to a third party on mutual consent between CPRI and project implementing organization, all commercial benefits, such as royalty, shall be available equally to both CPRI and project implementing organization. Royalty covering Technology transfer fees, commercial production etc. shall be decided by mutual consent after achieving key milestones.

6.11 INSTITUTIONAL AND FUNDING FRAMEWORK FOR R&D

Government should fund the R&D programmes through various schemes such as National Perspective Plan (NPP), Research Scheme on Power (RSoP). Some of them can be in collaborative mode with participation from CPSU's, Industry and academic institutes and utilities.

CPRI, NTPC, NHPC, SJVNL, PowerGrid, DISCOMs, BHEL, CSIR, Crompton Greaves, CSIR laboratories, IITs, NITs will execute the projects identified, which shall be coordinated and managed by CEA and CPRI on behalf of MoP. The financial requirements to execute the projects outlined through NPP R&D scheme of MoP are to the tune of Rs 1,500 Crores. The proposed budget requirement thrust area wise is as follows:

Sl.No	**Thrust area**	**Proposed budget in Crores**
1	Generation: Thermal, Hydro, Renewables and Distributed generation	Rs 400
2	Transmission	Rs 600
3	Distribution	Rs 150
4	Energy & Environment	Rs 50
5	Centre of Excellence: (i) Energy Storage Devices (ii) High Temperature Superconducting (HTS) technology in Power Sector (iii) Power Electronics (iv) Smart Grid Technologies	Rs 100
6	Power - Academy	Rs 200
	TOTAL	**Rs 1,500**

Out of the Rs 1,500 crores proposed for R&D, direct government grant should be to the tune of Rs 750 crores and balance can be through participation from CPSUs, Utilities and industry.

Fund requirement of CPRI

With a view to take up R&D projects under major thrust areas, and to establish new facilities and augment existing facilities the following capital projects amounting to Rs 2,668 crores is proposed.

DETAILS OF PROPOSALS

Sl. No.	Capital projects in Testing and Consultancy	Amount (Rs. In Crores)
I.	Up-gradation of Short Circuit Test facilities including Addition of 2500 MVA Short Circuit Generator	1379.00
II	Up-gradation of High Voltage/Ultra High Voltage Test facilities	79.00
III.	Augmentation of Power System, Custom Power & Electronics.	15.00
IV	Augmentation of test facilities like Energy Meters, SPV, Energy Efficiency Motor	81.00
V	Augmentation & Modernisation of Diagnostics, Cables, Capacitors, Temperature rise, Environmental test facility	109.00
VI.	Establishment of New Transmission Tower and Seismic Test Facility	150.00
VII.	Augmentation of existing testing Regional Testing Laboratories at Kolkata & Guwahati and Establishment of new Regional Testing Centres	420.00
VIII.	Infrastructure improvement for Business Development and Protection	32.00
IX.	Setting up of Advanced Research facilities like Superconductive Technology, Nano, Super grid laboratory etc.	253.00
	Research & Development Projects	
X.	CPRI Research Contingency (Plan R&D) projects and Research Scheme on Power (RSoP).	100.00 50.0
	Total	**2,668.00**

Thus total requirement of fund during 12th Plan for R&D works out to Rs. 4168 Crore.

6.12 PROMOTION OF R&D IN POWER SECTOR

The Standing Committee on Research and Development (SCRD), which is presently managing NPP R&D, should be strengthened and empowered to make policy document on R&D for the power sector and prioritize problems of National importance having short, medium and long term impact. This should be the apex committee for R&D of power sector. This committee should be well represented by senior executives of central R&D institutions, CPSUs, Utilities and industry.

(a) Utilities should have collaboration with research institutes so that the problems faced by them can be taken up as research work and will also have immediate application.

(b) Manufacturers should also participate and sponsor the research program relevant to power sector.

(c) The successful R&D projects should be given a wide publicity within the power sector

(d) The power sector should have joint collaboration with similar research institutes abroad to have exchange of know-how and latest methods.

The proposed 'POWER – ACADEMY' should be entrusted with complete research need of country, and shall work in coordination with SCRD. All the manufacturing firms, utilities and all concerned even remotely with power sector should be reporting their problems, R & D requirement to this academy.

The recommendations can be implemented by R&D institutions which are financially and administratively autonomous. Such institutions can draw road map for R&D for the next decade.

6.13 KEY ORGANIZATIONS TO ACHIEVE THE R&D TARGETS OF THE TWELFTH PLAN

The research projects proposed will be executed through NPP scheme of MoP, in a collaborative manner involving, CPSUs, utilities, research organizations and academic institutions as mentioned below:

1. Generation – NTPC, NHPC, SJVNL and NPCIL will be the key central agencies in the generation sector. They will be complemented by state generation companies and IPPs

2. Transmission - At the center POWERGRID will play a critical role with the state transmission and private transmission companies.

3. Distribution – The state DISCOMs will be the key agencies in the distribution sector apart from private distribution licensees and input franchisees

4. Nodal Centre for R&D: MoP through CPRI and CEA.

6.14 CONCLUSION AND RECOMMENDATIONS

1. Power Sector, being highly technology intensive, there is need to promote extensive Research and Development (R&D) in the country, especially while considering introduction of new and advanced
2. Collaborative Research in a phased manner is needed to bridge the knowledge and technology gaps, build expertise, to find solutions for the problems existing in the system and also for problems that may arise in the future.
3. Technologies such as FACTS and HVDC transmission have played a crucial role in alleviating transmission system constraints. More R&D in these area need to be promoted.
4. Special attention is needed for the development of the eight States of the NE Region of the country through a separate R&D Programme on renewable energy.
5. It is proposed to institute Scholarship schemes in some of the Engineering colleges in North East, institute Cash incentive schemes for students and encourage students to take up Masters and Doctoral Programmes in Engineering.
6. Human Resource and Competence building Development for R&D in power sector would require creating a separate cadre for research in taking up application oriented research. The success of the R&D projects will largely depend upon quality of manpower, freedom for research and continuity. Keeping this in view, special schemes such as: attractive fellowships, provision to improve qualification and exposure will be introduced, for attracting young talent and to retain them in power sector.
7. With a view to strengthen the multi disciplinary collaborative research activity amongst CPSUs, utilities, industry and academic institutions, ***Centres of Excellence (CoE)*** need to be

created to take up application oriented research projects in strengthening the performance of power sector.

8. There is a need to establish ***'Power – Academy'*** in line with the 'CSIR-Academy', ISRO – Indian Institute of space science and Technology, to attract young engineers, and provide scope to build professional carrier in R&D.
9. Thus total requirement of fund during 12th Plan for R&D works out to Rs. 4168 Crore.

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