MODERN HYDROELECTRIC ENGINEERING PRACTICE IN INDIA
ELECTRO-MECHANICAL WORKS

• MEGA • LARGE • SMALL • MICRO

OVERVIEW

1. Introduction

Hydro energy is a clean renewable energy resource. Rapidly rising cost of electricity generation using fast depleting fossil fuel energy sources and acute environmental degradation caused by these resources has resulted in a demand for development of abundantly available, hydro energy resource which can be converted into electricity very efficiently. It is a non consumptive use of water.

Large amount of energy available in our flowing rivers, streams, canal falls etc. remains untapped. There are large seasonal variations in availability of this resource. Initially small scale isolated development of hydro electric power in India was confined to providing a reliable and continuously available electric energy for the load and was accordingly based on minimum dependable dry period stream flows so that curtailment of load during dry period is minimized. Very large wet period inflows were not utilized. Change to this defective design principle is called for because of the following reasons in addition to rising cost of power generation.

i) A large integrated hydro thermal power system is developing in which thermal nuclear generating capacity is very large portion of total capacity.

ii) Induction of large thermal/nuclear generating capacity in the interconnected grid provide dependable energy at flexible rate which is not dependent on vagaries of stream flow and thus provide for deficiency of energy during periods of low stream flow.

It is now being recognized that hydro energy is an alternate renewable source of energy and maximum possible hydro energy be converted into electricity. Installations at all existing stations be uprated and new hydroelectric installations designed accordingly for maximum economical energy. The hydroelectric is the cheapest form of clean energy. Accordingly great stress is being laid in India and other countries on development of enormous undeveloped hydro power potential and uprate/modernizes existing installation for optimum cost effective sustainable development of this renewable resource. Modernizing of existing hydroelectric practices to meet National requirement (Hydropower Development National Policy) in accordance with National and International Standards and Technology advance is required.

2. Hydro Power Development and Potential

2.1 Hydropower is a renewable economic, non polluting and environmentally benign source of energy. Hydro power stations have inherent ability for instantaneous starting, stopping, load variations etc. and help in improving reliability of power system. Hydro stations are the best choice for meeting the peak demand. The generation cost is not only inflation free but reduces with time. Hydroelectric projects have long useful life extending over 50 years and help in conserving scarce fossil fuels. They also help in opening of avenues for development of remote and backward areas.

Hydro power potential as per Govt. of India Policy Statements – 1985.

Our country is endowed with enormous economically exploitable and viable hydro potential assessed to be about 84,000 MW at 60% load factor (1,48,700 MW installed capacity). In addition, 6781.81 MW in terms of installed capacity from small, mini and micro hydro schemes have been assessed. Also, 56 sites for pumped storage schemes with an aggregate installed capacity of 94,000 MW have been identified. However, only 15% of the hydroelectric potential has been harnessed so far and 7% is under various stages of development. Thus, 78% of the potential remains without any plan for exploitation.
2.2 National Electricity Policy (2005 & 2008)

National Electricity Policy reiterates as follows:

i) Hydroelectricity is a clean and renewable source of energy. Maximum emphasis would be laid on the full development of the feasible hydro potential in the country.

ii) Harnessing hydro potential speedily will also facilitate economic development of states, particularly North-Eastern States, Sikkim, Uttaranchal, Himachal Pradesh and J & K, since a large proportion of our hydro power potential is located in theses states.

iii) The states with hydro potential need to focus on the full development of these potentials at the earliest.

iv) Develop requisite transmission lines

Technology Development: National electricity policy (2005) recommends as follows regarding technology development for power generation including hydro development (Extracts).

Effective utilization of all available resources for generation, transmission and distribution of electricity using efficient and cost effective technologies is of paramount importance. Operations and management of vast and complex power systems require coordination among the multiple agencies involved. Effective control of power system at state, regional and national level can be achieved only through use of Information Technology. Application of IT has great potential in reducing technical & commercial losses in distribution and providing consumer friendly services. Integrated resource planning and demand side management would also require adopting state of the art technologies.

Special efforts would be made for research, development demonstration and commercialization of non-conventional energy systems. Such systems would need to meet international standards, specifications and performance parameters.

Similarly, cost effective technologies would require to be developed for high voltage power flows over long distances with minimum possible losses. Specific information technology tools need to be developed for meeting the requirements of the electricity industry including highly sophisticated control systems for complex generation and transmission operations, efficient distribution business and user friendly consumer interface.

Induction of modern technology, International standards and continuous research and development inputs are required to modernize engineering practices for hydropower development.

Rural Electrification by Small & Micro Hydro Projects: The development objective of the power sector in the country is supply of electricity to all areas including rural areas as per Indian Electricity Act.

Reliable rural electrification systems with small and micro hydro projects especially in Northern states which aim at creating the following are required.

(a) Rural Electrification backbone (REDB) with at least one 33/11 kV (or 66/11 kV) substation in every block and more if required as per load, networked and connected appropriately to the state transmission system.

(b) Emanating from REDB would be supply feeders and one distribution transformer at least in every village settlement.

(c) Household Electrification from distribution transformer to connect every household on demand.

(d) Wherever above is not feasible (it is neither cost effective nor the optimal solution to provide grid connectivity) decentralized distributed generation facilities together with local distribution network would be provided so that every household gets access to electricity. This would be done either through conventional or non-conventional methods of electricity generation whichever is more suitable and economical. Non-conventional sources of energy could be utilized even where grid connectivity exists provided it is found to be cost effective.
**Renovation, Modernisation & Uprating:** Renovation, Modernisation & Uprating of old hydro power plants is to be accorded priority as it is a faster and cheaper way of capacity addition than installing new capacity. Guidelines are required.

**Inter State Mega Projects:** A substantial hydro power potential has remained locked up and many mega hydro projects could not be taken up for implementation, even though these projects are well recognised as attractive and viable. The selection and design of project is required to be based on integrated basin wise studies. Basic parameters involved and mechanism through which each project should be constructed and operated by the basin states need formulation. As far as possible, there would be preference to take up simple run-of-the-river schemes that do not involve any major storage or consumptive uses. These projects have to be designed as the backbone for the stability of the National Grid system and parameters need to be designed after careful studies.

3. **Development of Water Resources for Irrigation, Drinking Water and Flood Control**

Urgent development of water sources is required to meet following urgent needs for sustainable development.

a) Increased irrigation for agriculture to meet food demands.
b) Provide drinking water to towns/villages.
c) Recharge depleting ground water to provide water for irrigation and drinking.
d) Minimize huge annual flood loss to life properly and crops.
e) Electricity to meet energy needs.
f) Industry

Rain water is our only source of potable water. Only a limited quantity of rain water can be conserved in the catchment, conservation and storage of this rain water in a series of dams/barrages at feasible locations along the entire length of our streams and rivers is a major option to meet the demand of increasing population for food (increased irrigation), drinking water etc. and control flood loss. In the plains barrages may be used to spread floods waters within the existing flood zones along the streams and rivers to minimize flood damage. Stored water may be released for consumptive use in neighborhood for drinking purposes and irrigation. Spread of water may help in recharge of ground water.

Hydropower is non consumptive use of water and can produce energy from water when released for irrigation, drinking and other consumptive uses. This power can be fed into grids as clean renewable source of energy displacing fossil fuel energy and will be economical. Bhakra, Tehri Dam etc. store rain water not only to meet increased irrigation, drinking water needs and control floods but also provides stable low cost clean power energy to the grid.

Ararhat (4 x 3 MW) and Bathnahan Small Hydro Project (4 x 2 MW) of Bihar State Hydro Electric Power Corporation Ltd. are examples of flood control barrages.

UNDP/World Bank Project for cost effective irrigation Mini Hydro Schemes in India under Energy Sector Management Programme (ESMAP) is notable effort in this detection.

Hydropower development may have adverse effects by way of submergence of land leading to destruction of forest and displacement of people. It may also have adverse environmental consequences. These concerns should be addressed and solved for sustainable development.

Detailed studies at basin level are required for such multipurpose project for irrigation, drinking water supply, ground water recharge, flood control and hydro energy development.

4. **Modern Engineering Practice in India**

4.1 **Hydro-Electric as Energy Source - Installed Capacity**

Hydro-electric engineering practice developed for supply of dependable electricity to towns and isolated systems and installations was based on dependable dry period
inflows and designed for operation in small system need a change. Hydro is value-able renewable energy resources and optimum utilizations of energy resource is required. The energy is to be fed into the grid and with the provision of banking and other measures now available installed capacities are required to be based on dependable flows available throughout the year and energy produced can be utilized displacing fossil fuel energy. The basis for development of hydro power project is to be modified so that hydro power projects are developed as Alternate source of energy. Criteria for development of resource has to be optimum utilization of the energy resource as dependable electrical energy in the grid in integration with other energy sources.

4.2 Small and Mini Hydro Projects

Feasible potential of small hydro is also needed to be exploited fully to create additional power generation capacity. Small and mini hydro potential can provide a solution for the energy problems in remote and hilly areas and also along the canal systems having sufficient drops. The small hydro potential could be developed economically by simple design of turbines, generators and the civil works. Criteria for installed capacity simplified guidelines for design of electro-mechanical equipment and system is required for rapid development.

4.3 Micro Hydro Projects

Energy problems in remote and hilly areas where extension of grid system is uneconomical can be met by micro hydro. Guidelines for developing these micro hydro to meet energy needs is required which can be operated by type of man power available and is economically viable. A cluster approach of development of micro hydro in an area for economic viability is considered necessary.

4.4 Modern Engineering practices for hydro power development incorporate significant changes in existing guidelines and practices as high lighted below.

i) Techno-economic studies are required to be carried out to determine capacity, unit size, and type for optimum utilization of hydro energy resource at new power stations.

ii) Recent technology advances in all fields requires existing engineering practice to be modified/updated.

iii) Computerized control system and microprocessor based protection relay technology has almost completely changed control and protection system of hydro plant.

iv) Detailed studies are required for optimizing selection of equipment parameters and field adjustment of variable parameters etc. as per present guidelines and standards.

v) Formation of large power grids require careful selection of economic parameters of generating equipment for stable grid operation, Islanding etc.

vi) Manpower costs are rising, human errors at all levels can be very costly. Non attended operation, intelligent control and protection system design is becoming increasingly important.

vii) Development of small hydro from micro hydro (up to 100 kW) to 25,000 kW require very special consideration to make them economically viable suitable for unattended operation due to non availability of suitable manpower for operation and grid interconnected to improve load factors. Modern practice in accordance with UNDP Hilly SHP Project and UNDP/World Bank Project for cost effective irrigation Mini Hydro Schemes in India under Energy Sector management Programme (ESMAP) is a notable effort in this direction.

viii) Development of dependable micro hydro and small hydro for rural electrification of far flung areas as per rural electrification norms.

ix) Development of cost effective low and ultra low head canal fall and head works small hydro for utilizing the energy available near load centres.

x) Renovation, modernization and uprating (RMU) of existing projects is required to utilize maximum available water power potential, improve efficiencies and reduce forced outages.

xi) Small hydro development in conjunction with other renewable energy sources for maximizing SHP benefits in hybrid system is a matter of development and research.

5. Basis for Modern Engineering Practices and Guidelines for Design of Hydro Stations and Schemes

Engineering practice and studies carried out for selected typical existing power plants for selection, performance and testing of equipment parameters and design of power house based on standards etc.
prevailing at the time of planning and design of large and small hydro projects have been discussed in details and form the basis of modern guidelines. Modern practice based on the current standards and guides are brought out in the book. Central Board of Irrigation and Power is the nodel agency in India for this purpose.

5.1 Mega Projects (high capacity interstate projects)

Mega projects are discussed with special reference to Bhakra and Beas interstate projects. These represent deigns of Mega Projects in the country. Detailed design of Bhakra Left Bank Powerhouse was done in India and Bhakra Right Bank was designed with the help of Russian design organisation Lengidep in Russian and India. The power plants have been renovated, modernized and uprated.

Bhakra Power Projects – Left Bank (5 x 90 MW) and Right Bank (5 x 120 MW) are the first projects of the country. Beas Project Power Plants - Dehar (6 x 165MW) and Pong (6 x 60 MW) were the first power plants for which indigenous equipment was supplied by M/s Bharat Heavy Electricals Bhopal.

Detailed studies were carried out for initial design of these power plants for determining capacity, unit size, generator parameters and excitation system response. These form the basis of modern practice for Mega projects.

Bhakra power plants are shown in figure 1 and Dehar Power plant in figure 2.

Recent trends in hydro-electric engineering design of electro-mechanical works is discussed with reference to 2400 MW Tehri Hydro Power Complex which was specially visited for the purpose. Figure 3 shows Tehri and Koteshwar power plants recently commissioned.

5.2 Small Hydro Projects

Modern Design of small hydro projects are discussed with special reference to Sobla power house (2 x 3000 kW); Kanchauti (2 x 1000 kW); Chirkila (1 x 1000 + 1 x 500 kW) and Kulagarh (2 x 600 kW) typically shown in figure 4. These are the first small hydro power projects of Uttar Pradesh Small Hydro Power Corporation which were designed/guided by the Author.

Figure 1: Bhakra Power Plants (Country’s first Mega Project)
Dehar and Pong Power projects Country’s first Project for which Indigenous Equipment was supplied by M/s BHEL Bhopal

(Hydroelectric Power Station in Operation in India CBI & P Publication No. 288-2003)
5.3 Low and Ultra Low Head Small Hydro Projects

Low and ultra low head (below 3 meters) to extract power from existing and proposed irrigation canal system are specifically discussed. It may be mentioned that 1.6 m head Kakroli Fall project (Figure 5) is one of the lowest head economically viable project in the world and is in successfully operating. The project was undertaken under INDO - US Collaborative programmes.

In all these cases changes which could be incorporated due to modern standard and practices is brought out.

5.4 Micro Hydro Projects

Micro hydro projects are based on a large number of these projects designed in AHEC and Electronic Load Controller specifically designed for these projects by Pradeep Digitek Pvt. Ltd.
6. **Organization of the Book**

Major components of a hydroelectric plant for design practices are as follows:

a) Planning for capacity, type and unit size  
b) Main generating equipment  
c) Control and protection systems  
d) Auxiliaries Systems  
e) Switchyard equipment and layout

The book is divided into TWO volumes as follows:

**VOLUME I: MAIN GENERATING EQUIPMENT AND PLANNING**

**Overview**

Chapter – 1 Type of Hydro Electric Development

Chapter – 2 Techno-Economic Studies for Capacity and Unit Size of Hydro Electric Schemes (Reviewed by Dr. S. K. Singal)

Chapter – 3 Hydraulic turbine classification and Selection

Chapter – 4 Turbine, Regulatory Characteristics

Chapter – 5 Turbine performance characteristics (Reviewed by Dr. R. P. Saini)

Chapter – 6 Hydro-turbine governing system

Chapter – 7 Turbine & governor specification

Chapter – 8 Turbine & governor testing (Reviewed by Dr. R. P. Saini)

Chapter – 9 Hydro generator, characteristics and performance

Chapter – 10 Hydro generator excitation systems

Chapter – 11 Generator technical & excitation system specification

Chapter – 12 Hydro generator and excitation system testing

Chapter – 13 Low head small hydro development

Chapter – 14 Recent Trends in Hydro-Electric Engineering Practice

**VOLUME II: CONTROL, PROTECTION, AUXILIARY SYSTEMS AND STEP UP SUBSTATION**

**Overview**

**Section – 1: Control and Protection Systems**

Chapter – 1: General Considerations, Technology Development

Chapter – 2: Control System

- Conventional control
- Modern control of large hydro station
- Modern Control of small hydro stations
Modern Control of micro hydro

Chapter – 3: Protection System

- Design consideration
- Instrument transformer
- Generator protection
- Generator transformer protection
- Bus bar protection
- Line protection
- EHV Relaying
- Typical specifications for protection system (Large hydro)
- Typical specifications for protection system (Large hydro)

Section – II: Auxiliary Systems

Chapter - 4: Electrical Auxiliary System

- General requirements
- Auxiliary power system
- DC system
- Power and control cables and cabling
- Lighting system
- Grounding system
- Communication system

Chapter -5: Mechanical Auxiliary System

- General requirements
- EOT cranes of power house
- Cooling water system
- Drainage and dewatering system
- Compressed air system
- Water level measuring & transmitting devices
- Fire protection system
- Oil purification system
- Ventilation and air conditioning system

Section – III: Step up Substation

Chapter – 6: Generator Transformer

Chapter – 7: H. V. Circuit Breaker

Chapter – 8: Switchyard Equipment

Chapter – 9: Switchyard Layout

Chapter – 10: Design of EHV and UHV Sub-Station

7. Hydro-electric Equipment Manufacturers

List of major Indian Manufacturers (as per Indian Manufacturers) alongwith their collaborators is given in table 1.
Table 1

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Manufacturers</th>
<th>Collaboration</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>BHEL, Hardwar &amp; Bhopal</td>
<td>Fuji, Japan</td>
<td>Technical</td>
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<td>2.</td>
<td>Alstom, Baroda</td>
<td>Alstom, France</td>
<td>JV</td>
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<td>3.</td>
<td>Boving Fouress, Bangalore</td>
<td>Kavernaener Boving now GE UK/Norway</td>
<td>JV</td>
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<td>4.</td>
<td>HPP, Delhi</td>
<td>HPP France</td>
<td>JV</td>
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<tr>
<td>5.</td>
<td>Jyoti, Vadodra</td>
<td>Gilks, UK (now expired) Turbo Institute of Slovenia</td>
<td>Technical</td>
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<tr>
<td>6.</td>
<td>Kirloskar, Pune</td>
<td>Ebara Corp, Japan</td>
<td>Technical</td>
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<td>7.</td>
<td>ANDRITZ Hydro Bhopal</td>
<td>VA tech, Austria</td>
<td>JV</td>
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<td>Steel Industries, Thissur</td>
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<td>10.</td>
<td>Flovel Faridabad</td>
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<td>Technical</td>
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References

3. [www.power.min.nic.in](http://www.power.min.nic.in) Govt. of India Hydropower Policy 1998, 2005, 2008 and other publications
4. [www.bbmb.gov.in](http://www.bbmb.gov.in) – Rénovation, modernisation and upgradation of hydro plants in Bhakra Beas River Valley Development – Chairman BBMB.