

GIS database management for planning of Hydel Power Generation

Ashok Kumar Sinha

Professor of Instrumentation and Control Engineering
Bharati Vidyapeeth's College of Engineering
A-4, Paschim Vihar, New Delhi-63

Surekha Dudhani

Assistant Professor of Electrical Engineering
Bharati Vidyapeeth's College of Engineering
A-4, Paschim Vihar, New Delhi-63

Abstract:

This paper presents a methodology for using GIS database for site location and preparing layout for transmission lines for Hydel Power System. The present method of surveying and investigation has certain limitations and it is not cost effective either. FCC images obtained from IRS-1B/1D satellite are used to study the geographical features of the region for estimating the Hydro Power potential of the area. Visual interpretation is accomplished in knowledge base environment, which yields a cost effective method for preparing feasibility studies. Artificial Intelligence technique is used to develop decision rule for planning of Hydel Power System in the area. The GIS images are used to prepare transmission network layout in cost minimizing optimal framework with geophysical and natural resource constrains. An expert system has been developed which interprets the FCC images for obtaining land use and land cover data and prepares an optimal layout of transmission network. The proposed method is found to be cost effective when compared with the conventional method.

1. Introduction:

Hydropower is one of the most common renewable, economic, non-consumptive, non-radioactive, non-polluting and environmentally benign sources of energy. Hydropower stations have an inherent ability for instantaneous starting, stopping, load variations, etc, and help in improving the reliability of power system. Hydro stations are the best choice for meeting the peak demand. The generation cost not only inflation free but reduces with time. Hydroelectric projects have a long useful life extending over 50 years and help in conserving scarce fossil fuels.

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 hydel 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 unexplored.

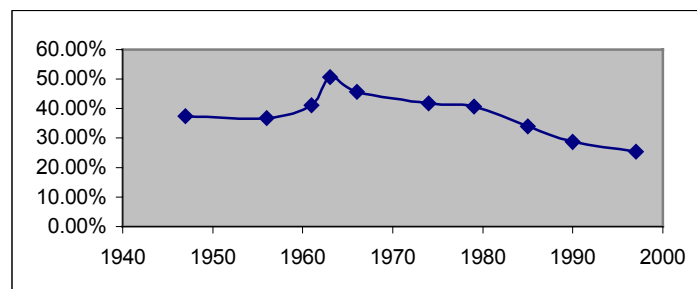


Fig.1. Rise and Decline of Hydro Share in India:

The decline of hydropower in the total power generating capacity of India is not due to non-availability of exploitable hydro potential but because of the following **constraints** that have slowed down the hydro development.

- ❖ Technical
- ❖ Financial
- ❖ Geological surprises
 - Tariff related issues and managerial weaknesses (poor contract management)
 - Problems due to delay in land acquisition
 - Resettlement of project-affected families
 - Law and order problems in militant-infested areas.
- ❖ **Technical (difficult investigation, inadequacies in tunneling methods)**

The maximum exploited potential is in the Northern and North Eastern Regions, followed by Eastern, Western and Southern Regions respectively. Bulk of the hydropower potential of the country exists in Himalayan region. Assessment of water resources, other investigation, survey and execution of such geological difficult project adds in terms of time and cost.

- ❖ **Financial (deficiencies in providing long term financing)**

A major part of money and time for developing hydro projects goes into civil work. The rough terrain and difficult work conditions ensure long gestation periods for such projects; in some cases, taking eight years or even longer. Large number of hydro projects taken up in the 1970's and 1980's still continue to languish resulting in large-scale time over-runs and heavy cost escalations year after year. In some cases the costs have gone up 5-6 times of the original estimates. However large hydro power plants are not being taken up for execution in sufficient number as the planning and construction period is very high. Therefore small hydropower projects have accelerated in recent years.

- ❖ **Geological surprises**

Especially in the Himalayan region where the water resource potential is high by means of glaciers and intensive rainfall updating of the information is required frequently, which is time consuming by conventional method.

Most of the power projects in these regions demands for underground tunneling which is most difficult and expensive affair.

Present means to conduct survey using remote sensing, aerial survey, and GPS based survey have certain limitations

1. The topological maps used for walkover survey and preliminary can be very old and recent changes in inhabitation pattern, vegetation coverage and water bodies etc. are not updated frequently.
2. The surveying staff does not have bird's eye view of the present ground condition, which may result in large inaccuracies in estimation of civil works.
3. There is every possibility of error in recording the ground data and subsequent transfer on the route map.
4. Expensive: Require lot of expertise, specialized equipment and time consuming.

The conventional method of assessing hydro potential could not be directly adopted in the inaccessible areas like Himalayas where the water resource potential is high by means of glaciers and intensive rainfall. Similarly the geological, structural configuration is essential to study and to understand the strength and weakness of the area so that the project will be implemented in the suitable terrain. For geologic mapping, reflectance information of the rocks is very important.

Study of alternative ranking and taking optimal decision require lot of time in co-ordination of data (topology, hydrology, geology, geographic, meteorology and environment etc.) from various departments and preparation of maps of updated informations. These factors are great deterrants to faster implementation of hydropower projects.

In the proposed methodology the satellite images obtained from IRS-IB/1D is used to develop GIS database for, identification of source, selection of site, environmental planning, digital terrain model data (DTM), transmission line network and ranking of the sites. A rule-based expert system is developed on Prolog platform for decision support at each stage of modeling.

2. Development of GIS in Knowledge-Base environment:

Geographic Information System (GIS) is a computer based information system used to digitally represent and analyze the geographic features present on the Earth surface and the events that are taking place. It is not restricted to the conventional view of geography, i.e. that of people and places on the Earth's surface, but GIS is the perfect tool to discover hidden geographies, to explore the hidden facts of World Wide Web, the complex geography of a printed circuit, the architecture of a combat aircraft, or layout of high-tension transmission lines.

The planning for the Hydel Power generation can be accomplished in the following steps.

2.1: Remote sensing and Image processing:

Remote sensing technique has witnessed a wide range of application in natural resources database management in recent years. In satellite-based remote sensing data collected by satellites are processed by digital computer or optical techniques to extract valuable informations for scientists and engineers. One of the most widely used data format for information extraction is the infrared False Color Composite (FCC) image. The extraction of information from such images about ground reality is done by image interpretation for which generally three methods namely photo interpretation, spectral analysis and data integration are used. In this paper our concern is with photo interpretation method and the development of a rule based expert system for image interpretation of the region and planning Hydel Power Generation. Photo interpretation is the visual interpretation of images based on features like tone, pattern, shape, size, shadow, texture and association. Most of the conventional digital images processing techniques are based on color or size or texture or tonal variation of each pixel in the image.

In contrast to digital analysis of the images, a human interpreter exploits the aggregate information related to various basic image-features of unknown object along with his scientific knowledge, general knowledge of the phenomena as well as experience of doing classification rather than analysing the image pixel by pixel. As a consequence, the interpretation result for land use and land cover produced by a well-trained human interpreter is often less crude than the same obtained using digital techniques. For human interpreter it is easy to interpret natural color image but the interpretation of FCC image becomes difficult and requires adequate training and experience. Also different band combinations of satellite data for three primary colors result in different FCC images, which are suitable for different application. Every application of remote sensing deals with a specific subject or integrated process of different subjects. Thus the process of visual interpretation of wide variety of remotely sensed data is a complex intuitive process of combining evidential information from different sources and subjecting such information to an expert's knowledge, experience and heuristics at each levels namely detection, identification, analysis, recognition and classification of the process. It calls for the analysis of a number of related information by a domain expert. So even with on- going advances in digital image processing technique the importance and role of human photo interpreter can not be ignored and it is required to train human resources to gain this skills .In future the scope of on-screen interpretation of high resolution remote sensing data will increase and image identification system providing way to combine together human interpreter and machine interpretation accuracy achieved using digital image processing technique has been reported up to 70% to 80%. The associated information and logical reasoning that are used by a well-trained human interpreter can be encoded in the form of rules and facts to create knowledge-based systems. The activity of image interpretation has similarity with the nature of explorative and qualitative reasoning in the line of Artificial Intelligence (AI) and expert system. Since the interpretation of each FCC images requires different skill and experience and thus even for a human interpreter it becomes difficult to manage properly application of huge knowledge while making decision in photo interpretation. Also the human interpreter may be absent or not easily available. The knowledge used in photo interpretation can be represented in logical paradigm that makes the logical programming language like Prolog highly suitable for expert development.

2.2: GIS Database:

After image interpretation a relational database is created. A GIS stores a representation of the world in the form of layers connected by a common geographical frame of reference. Each of the features on a layer as shown in fig2.

has a unique identifier, which distinguishes it from the rest of the features on the layer, and allow us to relate it to relevant information stored in external databases, etc. This allows us to capture only those elements of the world that are of interest to us, like catchment area, under forestation, covered under snow etc.

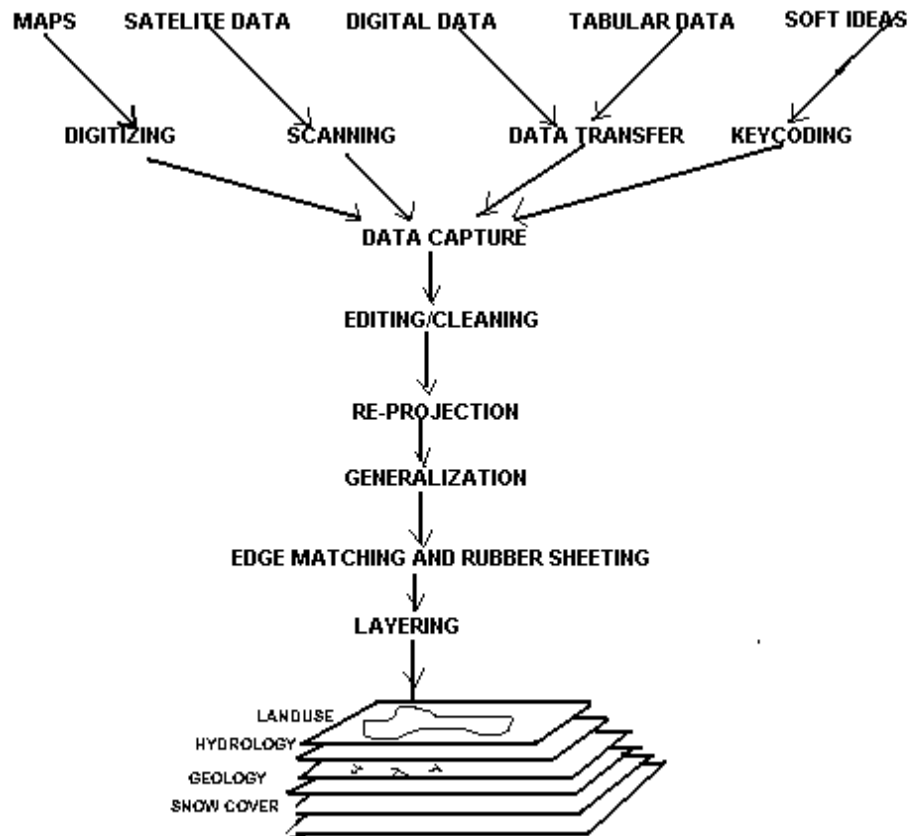


FIG.2: INTEGRATED GIS DATABASE

2.3: Knowledge based expert system:

Expert system contains knowledge and experience gleaned from human experts of the domain. The program asks users series of questions about their problem and gives them advice based on its store of knowledge and responses received from user against the queries made. The system developed here is rule based system and has following four functional modules like other rule based systems:

(i) Knowledge base (ii) Inference Engine (ii) Explanation facilities (iv) user Interface. The functional flow and organization of these modules is shown in fig.3. The development of ES requires creation of this entire module. The overall development process of rule-based expert system is shown in the Fig.4 In the present work the knowledge-based system has been developed in Turbo-Prolog environment. This AI language provides almost all facilities for the development of rule-based expert system. Turbo-Prolog works as an inference engine in backward chaining mechanism and supports logic based knowledge representation. Thus the development of ES in the turbo-Prolog requires only creation of knowledge base and suitable users interface.

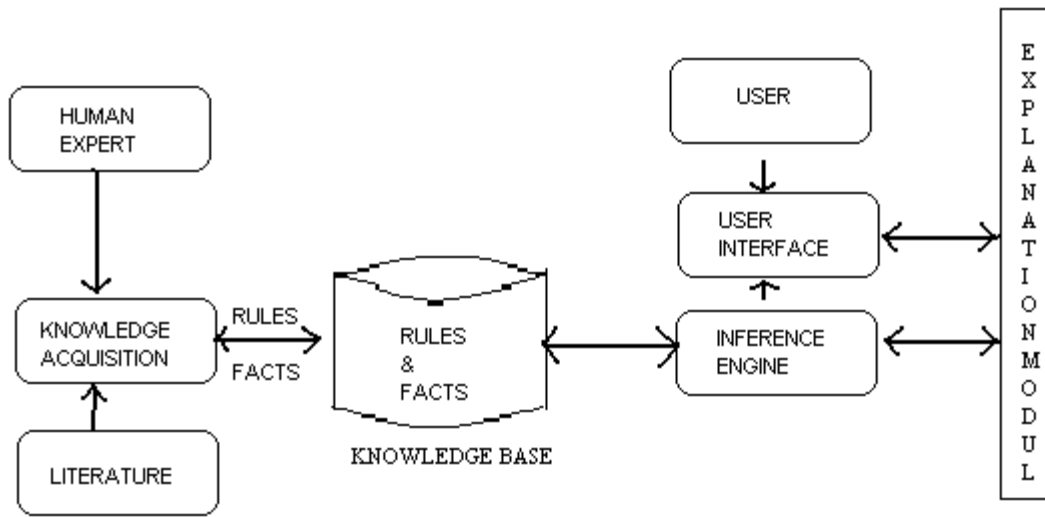


FIG.3: COMPONENTS OF PROPOSED EXPERT SYSTEM

The explanation of the reasoning of the system can be seen by tracing the sequence of rules framed in the system while executing the program for which turbo-Prolog provides in-built trace facilities. It can be activated at any particular point of the trace window. However, for more complex system the more user-friendly explanatory system can be designed. We have adopted the top down design approach. As shown in Fig.5. To develop the system, which emphasizes the division of a main goal of image interpretation into simpler sub goals. These simpler goals create opportunity to gear up the questions related to knowledge base of the system to simpler level, which make the system useful even for the very beginner in the photo interpretation.

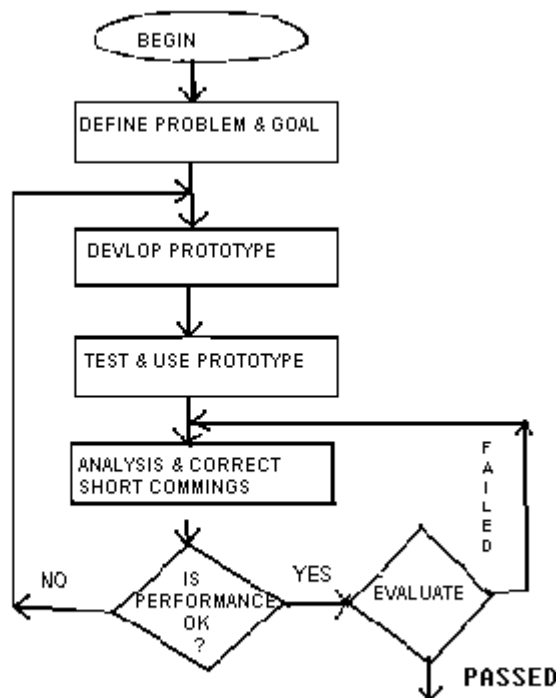
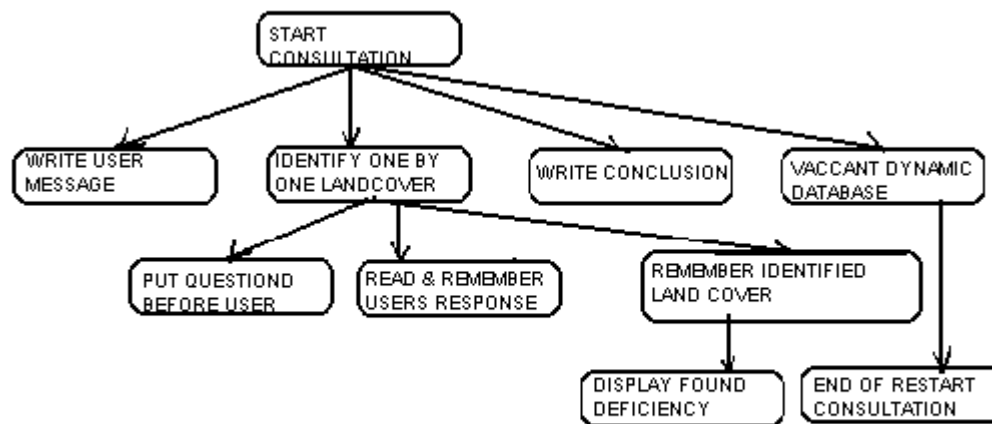


FIG.4: EXPERT SYSTEM DEVELOPMENT PROCESS

Expert System Development:**FIG.5: ADOPTED TOP-DOWN DESIGN APPROACH****Knowledge base development:**

The knowledge base of the system has been organized in the two parts, the static database and the dynamic database. The facts and rules related to the visual interpretation of the satellite imagery have been placed in the static database. The steps involved are, Knowledge Acquisition, Knowledge representation, User representation.

2.4: Sources of Spatial Data:

Accurate and current information is vital for maintaining and improving customer service. Through the computerized environment, a GIS can keep information accurate and current.

There are number of other sources of Spatial Data,

- Census and Survey data
- Arial photographs
- Satellite Images and Global positioning systems
- LIDAR (Light detection and ranging)
- ALTM (Air born laser Terrain Mapping)

Census and Survey data are collections of related informations.

Aerial photography is the first method of remote sensing, it is capturing of images from a position above the Earth's surface. Wide availability, relatively low cost, wide area views, time freezing ability, high spectral and spatial resolution, three dimensional perspective, of aerial photographs make immense value as a data source for GIS. Satellite images are collected by sensors on board a satellite and then relayed to earth as a series of electronic signals, which are processed by computer to produce an image. Most of the GPS receivers will store collected co-ordinates and associated attribute information in their internal memory so they can be downloaded directly into a GIS database.

Light detection and ranging (LIDAR) and Air borne Laser Terrain Mapping (ALTM), are the latest sources in the transmission sector. Laser mapping produces equivalent data that are produced by GPS and land surveys at a faster rate.

For GIS remotely sensed data offers many advantages. First images are always available in digital form, so that transfer to a computer is not a problem. However some processing like reduction of volume, adjust resolution, change pixel shape or alter the projection of data. There is opportunity to process images or use different wavebands for the collection of data to highlight particular feature.

3. Proposed Methodology:

In major hydel projects data collection is a very difficult job, due to the inhospitable environment in most of the construction sites. Hence taking into account such hazards or any unforeseen circumstances, GPS and remote sensing technologies will provide not only fast and accurate but also reliable geomorphologic and geological data, which can be very successfully analyzed by GIS in knowledge base environment to give complete picture about the stability and durability of the structure, which in turn helps to get alternative solution to take optimal decision.

Following are the important steps for developments of hydropower project.

3.1: Source identification:

The remote sensing technology is an effective tool for the identification of suitable sites for locating new hydropower projects especially in the inaccessible areas like Himalayas where the water recourse potential is high. Remote sensing data available in the near infrared region (0.8um – 1.1 um) provides clearly the contrast between land and water features can easily be discernable.

Most of Meteorological data (river flow data, temperature, solarly, relative humidity, wind speed etc.) and Aerial Climatographical data (digital/paper maps of precipitation, evaporation, temperature, snow cover, relative humidity, wind direction etc.) are obtained and interpreted with the help of GIS in knowledge base environment.

3.2: Site selection:

Building a hydropower station in a rugged terrain such as in the Himalayas requires thorough studies of geological lithologies, water drainage patterns, surface and subsurface structures. The geological, structural configuration is essential to understand the strength and weakness of the area so that the project could be implemented in the suitable terrain. If hydropower is to be generated from dam water then selecting suitable dam sites requires careful consideration of environmental impacts. Satellite imagery is used for the identification of catchment boundary; drainage network, perennial streams, land use and vegetations cover for these projects. Remote sensing and GIS have the potential of relatively accurate analysis of a site location. Digitizing the elevation contours and spot heights from topographic maps and using capabilities of various GIS softwares generate Digital Elevation Model (DEM) of these catchments. The catchment boundary, drainage network and location of major habitation are overlaid on these DEMs for further analysis.

3.3: Environmental planning:

Basic environmental issues for hydropower project developments, catchments area treatment, afforestation and rehabilitation and resettlement are solved with the help of GIS solutions.

3.4: Digital Terrain Model Data (DTM):

Digital Terrain Models are prepared for computation of slope, channel length, catchment area, head available for power generation and location of suitable sites for civil structures. Repetitive satellite data for these catchments are effectively used to locate the region of deforestation and impact on forest development.

3.5: Transmission Line Network:

To execute transmission line network, precise planning, costing, scheduling etc are required. To optimize the cost of transmission line lot of survey is required like,

1. Shortest and alternative route from the generating station to load centers
2. Topographical and geographical nature of the terrains
3. Physical constrains (railway crossings, road crossings expansion of villages and towns, etc.)
4. Environmental factors (reserved forests and high tree areas, national parks and wild life sanctuaries etc.)
5. Soil condition

6. Costing etc.

Selection of suitable areas, the optimum path finding, the profile analysis, the engineering design of towers and wires and the cost estimation can be done using GIS and satellite images. The steps involves,

- Planning of master guidelines of route construction including voltages, number of lines, starting and ending substations.
- By interpreting the satellite images of the area depicting its geographical features, environmental features, several alternative routes can be designed and compared. In comparing the alternative, technical cost and social cost (environmental impact, rehabilitation, irrigation etc.) of laying of the transmission lines can be included in the model.
- Preparing basic routes
- Preparing detailed route with optimal concept
- Implementation of an actual route.

3.6: Ranking of the sites:

All infrastructure development for hydel projects follow a set procedure of survey and investigation before taking up implementation.

These steps involve, Pre-Feasibility Report, Feasibility Report, and Detailed Project Report. Since the balance potential hydropower sites in the country are of the order of 450. At the pre-feasibility report stage a 'Ranking' or 'Order of Priority' should be evolved so that least socio-economic, environment and infrastructure development costs and best return in hydro-power generation ensuring river basin-wise resource optimization .

The technical and non-technical criteria are,

- (i). Reconstruction and rehabilitation
- (ii). Accessibility to site
- (iii). Height of dam
- (iv). Length of tunnel/ channel
- (v). Hydro-power potential
- (vi). Type of scheme (run-of-the river or storage development)
- (vii). Status of project
- (viii). Status of upstream or down stream hydel development
- (ix). Inter-state aspects
- (x). International aspects.

Central Electricity Authority has adopted certain maximum and minimum value between number range from 6 to 15 for each of the above 10 criterias. Accordingly sites have been graded from 'A>80' to 'E<20'.

Space technology using satellite and aerial remote sensing with GIS technology provide faster result in terrain mapping and scientific assessment of the ground conditions especially for mountainous regions where majority of sites are located. Image analyses of satellite digital data and creating spatial geo-reference information of terrain, using GIS tools, provide basis to address indices in the ranking study faster than the traditional method at comparatively comfortable cost.

4. Conclusion:

Interfacing geographic information system with knowledge-based expert system enhances the GIS capability by adding new dimension to it and future scenarios for study. With the launching of Indian remote sensing satellites (IRS) high-resolution data are available with repetitive coverage over same region.

GIS technique is found to be suitable and cost effective for the identification of hydel sources, mapping suitable sites, environmental planning, digital terrain modeling, transmission line network planning and ranking of the hydropower projects.

6. References:

1. Power on demand by 2012 "The role of GIS, GPS and Remote sensing in power sector", published by, CSDMS, IT for geography.
2. Proceedings of workshop on 'Remote Sensing and GIS applications in Water Resources Engineering', organized by CBIP in association with geographical Committee of International Water Resources Association (India).
3. Ian Haywood, Sarah Cornelius, and Steve Carver 'An Introduction to Geographical Information Systems', published by Pearson Education Asia.
4. Ivan Bratko, 'Prolog, programming for Artificial Intelligence', published by Pearson Education Asia.
5. Ranking studies of Hydro Electric Project, published by Central Electricity Authority of India, Oct.2001.
6. Power line Magazines.
7. Workshop on Managing Hydroelectric Power Plants, by Power Management Institute, (Feb. 4-8, 2002)
8. Hydro Electric and pumped Storage Plants, Book by M.C.Jog.
9. Eugene Charniak, "Artificial Intelligence", published by Pearson Education Asia
10. Rich nad Knight, "Artificial Intelligence", published by Tata McGraw-Hill
11. Dan W. Patterson, "Artificial Intelligence and Expert System" published by PHI