CHAPTER VI

Estimating Marginal Cost Based Price Structure
Uttar Pradesh Electric Power System

Uttar Pradesh State Electricity Board (UPSEB) was constituted on 1st April 1959 under section 5(1) of the Electricity (Supply) Act, 1948 and was entrusted with the responsibility of promoting a coordinated development of Generation, Transmission and Distribution of electricity within the State of Uttar Pradesh, in the most efficient and economical manner with particular reference to the development in areas not served or inadequately served by any licensee.

The capital requirements of the Board are largely met out of the loans and subventions made available by the State Government loans from the open market, financial institutions like Life Insurance Corporation, Rural Electrification Corporation, other financial institutions like Industrial Development Bank of India and Commercial Banks, deposits from consumers, contractors, Board employees and internal resources like accumulations in the form of contribution to depreciation, general reserve, other reserves, staff provident fund, consumers' contribution for service lines and retained profit, if any.

The installed capacity of the State of Uttar Pradesh including that of private licensees\(^1\) was only about 179 MW at

\(^1\) These were private companies running electric utilities in some of the towns in the State. They have now been completely nationalised.
the commencement of the First Five Year Plan in 1951. UPSEB at present has a mixed electric power system consisting of both hydro and thermal power stations. The Board's installed capacity at the end of March 1987 was 4810.85 MW of which 1422.35 MW (29.6%) was hydro and 3388.50 MW (70.4%) was thermal power. This included Renusagar which is a captive thermal generating station of Hindustan Aluminium Corporation (a private sector unit) with an installed capacity of 270 MW. Of the total hydel capacity 56 per cent is run-of-river or pondage type and the balance 44 per cent is storage capacity part of which is tied to irrigation. Till recently UPSEB system had some old diesel and gas stations. These, however, have been wound up since 1983-84. Besides this UPSEB has 35 per cent share in the Singrauli 1000 MW Super Thermal Power Station.

Uttar Pradesh is rich in hydro-electric power potential. Most of the large river systems of northern India originate in the hill region of the State and flow through its plains. The river systems of the Lesser or Middle Himalayas in the reach through the Duns and the Shivaliks provide the maximum potential for hydro power generation in view of the fact that they afford possibilities for construction of large storage dams for the control and regulation of the flows of these rivers. Scope for run-of-river hydro development also exists in the river systems in the Lesser Himalayas. The State has some of the oldest canal systems in the country among which are the eastern Yamuna Canal, the Upper and Lower Ganga, Agra Canal, Betwa, Sarda, Dhassan and Ken Canal.
Utilisation of water power started very early in Uttar Pradesh with the setting up of Ganga Canal Power Stations at Bhola and Palra in 1929 and Sumera in 1931. However, only 18.6 MW of hydel capacity was installed during the pre-plan period. Accelerated development took place only under the successive five year plans. Several important single and multi purpose hydro-electric projects were commissioned in Uttar Pradesh during the last 38 years of plan period which, inter alia, included 300 MW Rihand single purpose hydro-electric project, 240 MW Chibro power house of Yamuna Stage II and 198 MW Ramganga hydro project.

Vast coal reserves are also available in the eastern region of the State and areas of neighbouring states which is now called the power-hub of the country. The thermal capacity of UPSEB is made up of several major stations in the region which include Obra(T)-250 MW, Obra Extension I, II & III - 1300 MW, Harduaganj 'A', 'B' and 'C'-530 MW, Panki and Panki Extension-284 MW, Parichha - 220 MW and Anpara 'A' - 420 MW. Thus there have been considerable additions to the power generating capacity of the State during the plan period. Some 120 MW of capacity is available to the State from the 300 MW Central Sector Badarpur Thermal Station. The atomic power station in Rajasthan has also at times come to the rescue of Uttar Pradesh but only after meeting the full power needs of Rajasthan. Uttar Pradesh also draws power from the neighbouring State Grids of Bihar and Madhya Pradesh whenever they have surplus supplies.
Table: 6.1

UPSEB: Installed Capacity

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the Plant</th>
<th>No. of Units x capacity (MW)</th>
<th>Derated Capacity as on 31.3.87 (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. HYDRO</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Bhola</td>
<td>4x0.375</td>
<td>2.7</td>
</tr>
<tr>
<td>2.</td>
<td>Palra</td>
<td>3x0.200</td>
<td>0.6</td>
</tr>
<tr>
<td>3.</td>
<td>Sumera</td>
<td>2x0.600</td>
<td>1.2</td>
</tr>
<tr>
<td>4.</td>
<td>Salawa</td>
<td>2x1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>5.</td>
<td>Chitaura</td>
<td>2x1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>6.</td>
<td>Nirgazni</td>
<td>2x2.5</td>
<td>5.0</td>
</tr>
<tr>
<td>7.</td>
<td>Mohamedpur</td>
<td>3x3.1</td>
<td>9.3</td>
</tr>
<tr>
<td>8.</td>
<td>Khatima</td>
<td>3x13.8</td>
<td>41.4</td>
</tr>
<tr>
<td>9.</td>
<td>Pathri</td>
<td>3x6.8</td>
<td>20.4</td>
</tr>
<tr>
<td>10.</td>
<td>Rihand</td>
<td>6x50</td>
<td>300.00</td>
</tr>
<tr>
<td>11.</td>
<td>Matatila</td>
<td>3x10</td>
<td>30.00</td>
</tr>
<tr>
<td>12.</td>
<td>Dhakrani</td>
<td>3x11.25</td>
<td>33.75</td>
</tr>
<tr>
<td>13.</td>
<td>Dhalipur</td>
<td>3x17</td>
<td>51.00</td>
</tr>
<tr>
<td>14.</td>
<td>Obra Hydel</td>
<td>3x33</td>
<td>99.00</td>
</tr>
<tr>
<td>15.</td>
<td>Chhibro</td>
<td>4x60</td>
<td>240.00</td>
</tr>
<tr>
<td>16.</td>
<td>Kulehal</td>
<td>3x10</td>
<td>30.00</td>
</tr>
<tr>
<td>17.</td>
<td>Ramganga</td>
<td>3x66</td>
<td>198.00</td>
</tr>
<tr>
<td>18.</td>
<td>Chilla</td>
<td>4x36</td>
<td>144.00</td>
</tr>
<tr>
<td>19.</td>
<td>Khodri</td>
<td>4x30</td>
<td>120.00</td>
</tr>
<tr>
<td>20.</td>
<td>Maneri Bhali</td>
<td>3x30</td>
<td>90.00</td>
</tr>
<tr>
<td><strong>Total Hydro (1-20)</strong></td>
<td></td>
<td>65</td>
<td>1422.35</td>
</tr>
<tr>
<td><strong>B. Thermal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Varanasi</td>
<td>3x4</td>
<td>8.5</td>
</tr>
<tr>
<td>2.</td>
<td>KESA Kanpur</td>
<td>5x15</td>
<td>65.0</td>
</tr>
<tr>
<td>3.</td>
<td>Gorakhpur</td>
<td>3x5</td>
<td>15.0</td>
</tr>
<tr>
<td>4.</td>
<td>Talkatora</td>
<td>1x10</td>
<td>10.0</td>
</tr>
<tr>
<td>5.</td>
<td>Panki</td>
<td>2x32</td>
<td>32.0*</td>
</tr>
<tr>
<td>6.</td>
<td>Panki Extn.</td>
<td>2x110</td>
<td>220.0</td>
</tr>
<tr>
<td>7.</td>
<td>Harduaganj 'A'</td>
<td>3x30</td>
<td>30.0**</td>
</tr>
<tr>
<td>8.</td>
<td>Harduaganj 'B'</td>
<td>2x50)</td>
<td>210.0</td>
</tr>
<tr>
<td>9.</td>
<td>Harduaganj 'C'</td>
<td>2x60)</td>
<td>230.0</td>
</tr>
<tr>
<td>10.</td>
<td>Obra Thermal</td>
<td>5x50</td>
<td>250.00</td>
</tr>
<tr>
<td>11.</td>
<td>Obra Extn.I</td>
<td>3x100</td>
<td>300.0</td>
</tr>
<tr>
<td>12.</td>
<td>Obra Extn II&amp;III</td>
<td>5x200</td>
<td>1000.0</td>
</tr>
</tbody>
</table>

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Note: 1. Thermal Plants at Agra Fort, Agra Yamuna Bank, Aishbagh Lucknow, Sohawal Faizabad, Mainpuri, Mau, Chandausi (new & old) and Gas Turbine Muradnagar and Balrampur have been permanently closed due to obsolescence, wear and tear and other reasons. Their Installed/Rated capacities have, therefore, not been stated.

@. This does not include micro-hydel/diesel stations in hill region. This is given separately.

* Unit-II excluded from capacity on 6.5.1986.

** Unit I & II excluded from capacity w.e.f.1.1.1987

### TABLE 6.1.1

<table>
<thead>
<tr>
<th>District</th>
<th>Name of Power Station</th>
<th>Micro Hydel</th>
<th>Diesel Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almora</td>
<td>Bageshwar</td>
<td>1x50</td>
<td>1x50</td>
</tr>
<tr>
<td>Chamoli</td>
<td>Badrinath</td>
<td>1x30</td>
<td>1x25) 1x56)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3x200</td>
<td>2x50) 1x100)</td>
</tr>
<tr>
<td></td>
<td>Chamoli Ext.</td>
<td>1x200</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Guptakashi</td>
<td>2x100</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Joshimath</td>
<td>-</td>
<td>1x100</td>
</tr>
<tr>
<td></td>
<td>Pandukeshwar</td>
<td>3x250</td>
<td>-</td>
</tr>
<tr>
<td>Dehradun</td>
<td>Galogi</td>
<td>2x500) 2x1000)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Kaulagarh</td>
<td>-</td>
<td>3x300) 4x600)</td>
</tr>
<tr>
<td>Nainital</td>
<td>Durgapur</td>
<td>2x350) 3x150)</td>
<td>-</td>
</tr>
</tbody>
</table>

UPSEB: Installed Capacity of Micro Hydel and Diesel Stations in Hill Region
<table>
<thead>
<tr>
<th>District</th>
<th>Town</th>
<th>Units</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pauri Garhwal</td>
<td>Deoprayag</td>
<td>2x50</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Genthicheera</td>
<td>2x100</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Pauri</td>
<td>-</td>
<td>700</td>
</tr>
<tr>
<td></td>
<td>Syunsi</td>
<td>-</td>
<td>121</td>
</tr>
<tr>
<td>Pithoragarh</td>
<td>Champawat</td>
<td>2x100</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Dharchula</td>
<td>2x100</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>Didihat</td>
<td>-</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Lohaghat</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Munsiyari</td>
<td>-</td>
<td>165</td>
</tr>
<tr>
<td></td>
<td>Pithoragarh</td>
<td>-</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>Sureingad</td>
<td>1x400</td>
<td>400</td>
</tr>
<tr>
<td>Tehri Garhwal</td>
<td>Tehri</td>
<td>-</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td>Tilwara</td>
<td>2x100</td>
<td>200</td>
</tr>
<tr>
<td>Uttarkashi</td>
<td>Barkot</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Bhatwari</td>
<td>2x25</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Gangori</td>
<td>3x200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>Gangori Ext.</td>
<td>1x200</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Harsil</td>
<td>2x100</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Koti</td>
<td>2x100</td>
<td>200</td>
</tr>
</tbody>
</table>

Total (38 Units 7730 kW + 53 Units 6192 kW) = 13922 kW
Uttar Pradesh power system has the unique feature that its major thermal power generation is concentrated in south-east in the proximity of coal fields, while the major hydro power generation is in the north-west due to concentration of hydro-resources in the Himalayan region. The load centres are scattered all over the state with greater concentration in north-western region where a large concentration of industries has taken place in towns and cities like Kanpur, Lucknow, Varanasi, Ghaziabad and Meerut. This topography of generation/consumption centres, therefore, involves long distance transmission lines in the State which covers approximately 300,000 square kilometers. To transmit bulk power generation from the Mirzapur district of eastern Uttar Pradesh, which has become Asia's largest power complex with the completion of Singrauli, the first 400 KV transmission line in the country was strung between Obra-Sultanpur in 1977 which was extended to Lucknow in 1978 and to Azamgarh in 1985. Uttar Pradesh, therefore, was the first state in the country to introduce 400 KV lines in late seventies on its EHV net work. UPSEB's transmission and distribution network at the end of March 1987 had 16374 ckt kms of fully energised primary transmission lines (400 KV: 1867 ckt kms, 220 KV: 5106 ckt kms, 132 KV: 9401 ckt kms) and 354705 ckt kms of secondary lines (HV and LT lines). The grid, therefore, consists of lengthy lines of EHV transmission, which is very expensive.

Growth of Consumption

Electricity is the most important infrastructure for the
development of this most populous state of the country having 12 crores of people. Despite abundant hydro resources in the Himalayas and coal deposits in the south-eastern part of Uttar Pradesh, the State has lagged behind in power development. Its rate of growth has not been able to keep pace with the potential and capacity of the State to develop. Of the 112, 568 villages only 39,404 villages were fully electrified by laying LT mains although 71,564 villages were considered electrified as per Central Electricity Authority definition after two years of Seventh Five Year Plan. The annual per capita energy consumption in the State at the beginning of Seventh Plan was 109 kwh against the Tamil Nadu consumption of 228 kWh, Punjab 354 kWh and Maharashtra 292 kwh and the all India average of 167 kwh. The state ranked thirteenth against the fifth position of Tamil Nadu amongst the 17 major states of the country. However, the demand of energy is increasing rapidly with increasing pace of economic activities. The demand is also increasing with improvement in social and economic conditions of the population.

Though power development is still far behind that of many other states, the growth in the number of consumers of different categories as well as the connected load has been quite significant. In 1968-69, the total number of consumers was 6,13,633 with a total connected load of 1710326 kW and total sales of 3,562 million kWh. The number of consumers

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2. As per CEA, a village is treated as electrified if the village Panchayat is connected to the distribution feeder in the area.
### TABLE 6.2

**UPSEB: Comparative Investment in Generation, Transmission, Distn. and R.E.**

<table>
<thead>
<tr>
<th>Period</th>
<th>Additions to instal-led capacity in Public Sector (MW)</th>
<th>Investment in Rs. Crores.</th>
<th>Percentage to total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Pre-Plan Capacity</td>
<td>124.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Plan (1951-56)</td>
<td>90.8</td>
<td>17.55</td>
<td>5.72</td>
</tr>
<tr>
<td>Second Plan (1956-61)</td>
<td>74.4</td>
<td>41.27</td>
<td>6.67</td>
</tr>
<tr>
<td>Third Plan (1961-66)</td>
<td>570.9</td>
<td>97.58</td>
<td>34.88</td>
</tr>
<tr>
<td>Annual Plans (1965-69)</td>
<td>274.9</td>
<td>84.73</td>
<td>45.14</td>
</tr>
<tr>
<td>Fourth Plan (1969-74)</td>
<td>393.5</td>
<td>241.13</td>
<td>130.45</td>
</tr>
<tr>
<td>Fifth Plan (1974-79)</td>
<td>1532.7</td>
<td>628.91</td>
<td>385.79</td>
</tr>
<tr>
<td>Annual Plans (1979-80)</td>
<td>192</td>
<td>120.31</td>
<td>99.36</td>
</tr>
<tr>
<td>Sixth Plan (1980-85)</td>
<td>902</td>
<td>1279.92</td>
<td>630</td>
</tr>
<tr>
<td>1951-85</td>
<td>4031.2</td>
<td>2511.4</td>
<td>1338.01</td>
</tr>
<tr>
<td>Seventh Plans (1985-90)</td>
<td>1794</td>
<td>2035.84</td>
<td>942.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Others include investigation and small hillschemes as well as Uttarkhand Schemes.
Includes Rs. 118.91 crores for renovation of power stations.
Seventh Plan is approved by the Planning Commission.
rose to 1,77,13,534, connected load to 42,03,919 kW and total sales to 7,432 million kWh in 1976-77. Ten years later, at the end of March 1987 the Board served 29,27,689 consumers with a connected load 74,08,729 kW and sold 13,655 million units.

TABLE: 6.3

<table>
<thead>
<tr>
<th>Period</th>
<th>IC Sustained Demand</th>
<th>Energy Consumption in Uttar Pradesh(MU)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(MW)</td>
<td>(MW)</td>
</tr>
<tr>
<td>1970-71 to 1986-87</td>
<td>7.8</td>
<td>8.4</td>
</tr>
<tr>
<td>1976-77 to 1986-87</td>
<td>7.5</td>
<td>8.4</td>
</tr>
<tr>
<td>1980-81 to 1986-87</td>
<td>5.2</td>
<td>8.5</td>
</tr>
<tr>
<td>1974-75 to 1979-80</td>
<td>12.5</td>
<td>13.2</td>
</tr>
<tr>
<td>1970-71 to 1976-77</td>
<td>9.9</td>
<td>8.6</td>
</tr>
</tbody>
</table>

During the period 1970-71 to 1986-87, the electric system has increased at a fast rate. The sustained peak demand grew at a trend growth rate of 8.4 per cent whereas energy consumption within the state increased at an annual rate of 8.5 per cent. This has become possible due to the installation of new capacities.

Installed capacity has grown at a rate of 7.8 per cent which has kept pace little slow in comparison to peak load as
well as energy demand. Domestic energy demand has increased at an annual rate of 14.76 per cent whereas commercial demand has increased at a rate much faster than this. Agricultural demand grew at a rate of 13.8 per cent per annum against an increase of 5.7 per cent in the industrial sector. These growth rates have been worked out on the basis of actual demand met which automatically gets restricted to availability. Therefore, these growth rates of energy consumption also reflect state's priorities between agricultural and industrial sectors.

Due to differences in relative growth in demands of various consumer classes, there has been a change in the relative share of energy consumption in various sectors. In 1970-71, relative shares of domestic, industrial and agricultural demands were 5.5 per cent, 59.3 per cent and 16.6 per cent which changed to 14.2 per cent, 35.0 per cent and 36.1 per cent in 1986-87 respectively. Table 6.4 gives the pattern of electricity consumption in Uttar Pradesh.

Table 6.4

<table>
<thead>
<tr>
<th>Sector/Category</th>
<th>Share as percentage to total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>5.5</td>
</tr>
<tr>
<td>Commercial</td>
<td>1.5</td>
</tr>
<tr>
<td>Industry</td>
<td>59.3</td>
</tr>
<tr>
<td>Agriculture</td>
<td>16.6</td>
</tr>
<tr>
<td>Others*</td>
<td>17.1</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

*Others include Public lighting, Traction, Public Water Works & Sewage Pumping, Bulk Supply and Miscellaneous.
This indicates that there was tremendous increase in the domestic demand consequent to the improvements in standards of living, increase in household incomes and greater use of electrical appliances. Improvement in the share of agriculture indicates increasing modernisation of agriculture. The fall in the share of industry indicates a relative slow down in industrial growth and demand. The salient features of the Uttar Pradesh Electric power system and changes therein, have been presented in Appendix VI.1.

In spite of the fact that installed capacity as well as actual consumption have gone up significantly during the last few years, they still have not kept pace with the growing requirements of electrical energy in the state. As a result, there has been a shortage of power for the last many years and if present trends are an indication, this position is not likely to improve significantly in the near future.

Load Pattern and Operational Characteristics of U.P. Grid.

The Uttar Pradesh State Electricity Board is a constituent of the Northern Regional Electricity Board (NREB) which was formed in 1964. The Northern Regional Power Grid is the largest power grid in the country. This is constituted of the Power Grids of Union Territories of Chandigarh and Delhi and states of Haryana, Himachal Pradesh, Punjab, Jammu and Kashmir, Rajasthan and Uttar Pradesh. Some of the important central projects like Rajasthan Atomic Power Station, Singrauli Super Thermal Power Station of National Thermal Power Corporation, Baira Siul Hydro Electric Project of National Hydro Power Corporation and Bhakra Beas
Management Board come under the purview of the region. The major objectives of the Northern Regional Electricity Board are to plan and ensure integrated operation of the power system in such a way that at any point of time the total amount of electricity generated and transmitted shall give the maximum possible benefit to the region as a whole. Power and energy are exchanged among the states normally on the returnable basis as and when any state has an overall surplus of energy. For the peaking purpose all the generating stations of the region are operated in an integrated way. Of the total energy of 38,591 MU(net) generated by the various power systems in the region during 1984-85, nearly 15% was exchanged amongst the constituents.

The power system of UPSEB is such that the demand on the system is more than the demand meeting capacity of power generation. Thus there is both an energy and a peak shortage. This shortage is likely to continue for several years to come. Variety of restrictions are imposed by the Board to significantly contain excess demand during peak hours and to generally reduce energy consumption in the State with the minimum possible harmful effect to industry and agriculture. Electricity is being supplied in a phased manner or demand/power cut is applied at peak period or cut is imposed for a given number of hours or quota is allocated as to the number of units an industrial consumer can draw in a day or a week. Because of these cuts, load curves are

3. Northern Regional Electricity Board, Annual Report, 1984-85, op. cit., p.22
suppressed which reflect a supply pattern not strictly in accordance with the natural demand pattern. The main reason for these restrictions is the power shortage that Uttar Pradesh has faced during the last many years.

These restrictions of supply in different categories are operative for different lengths of time during the years of power and energy shortage. The restrictions of supply in different categories during the evening hours continue even at present indicating that the peak hours of the system would generally be in the evening. The peak hours are those hours when the demand on the system is pressing close to capacity. The peak hours are grouped by most writers on electricity economics on a pragmatic basis. As little is known about peak period elasticities, especially in a country like India, it is not possible to know about the peak hours groups that would emerge with changes in electricity tariff.

To analyse the realistic demand pattern, it is necessary to arrive at notional load curves that would prevail in the absence of power and energy restrictions. A notional load curve can be derived by vertically adding, hour by hour, to the actual (restricted) system demand, the demand that is shown to be rostered in that hour. The resultant curve should represent potential system demand for that day in the absence of all restrictions. The shape of the notional load curves, however, would not alter significantly with the assumed removal of all restrictions except that the peak would become steeper. In the absence of exhaustive list of restrictions, their precise duration/extent of each type of
restriction, it is difficult to construct notional load curves to remove the effect of all restrictions.

To be close to the natural demand and supply pattern, as an alternative, 1982-83 financial year has been selected as it can be considered to be more close to normal year. The availability of power at 14,075 MU during that year was about 19 per cent higher than that in the previous year and the overall shortfall between demand and availability at the end of 1982-83 was 3159 MU only as compared with 5248 MU during the previous year. This gap between the availability and the unrestricted demand was the least during the last few years. Estimated unrestricted consumption is given in Table 6.5 and graphV.1. In 1982-83, the major improvement was on account of better flows to the hydel stations, better performance of thermal stations and additional power purchased from neighbouring states.

During 1982-83 power cut on consumption of electricity was reduced in general because of higher availability. Supply was available for more number of hours to agricultural consumers. There were only selected industrial cuts for power consumption. Domestic and Industrial cuts were also less. Details about cuts applied to the supply during this year are given in Table 6.6. The peak demand reached an all time high of 2,754 MW in January 1983.

Load Pattern

As defined earlier load pattern is the time profile of power capacity demanded or supplied in relation to a certain time period. This time period could be a day, a week, a month.
TABLE 6.5

<table>
<thead>
<tr>
<th>Month</th>
<th>Actual consumption</th>
<th>Reduction due to cut, Group Restrictions Load Shedding etc.</th>
<th>Estimated unrestricted consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>April 1982</td>
<td>1124.7</td>
<td>302.7</td>
<td>1427.4</td>
</tr>
<tr>
<td>May</td>
<td>1134.6</td>
<td>345.0</td>
<td>1479.6</td>
</tr>
<tr>
<td>June</td>
<td>1150.8</td>
<td>191.4</td>
<td>1342.2</td>
</tr>
<tr>
<td>July</td>
<td>1191.3</td>
<td>181.7</td>
<td>1373.0</td>
</tr>
<tr>
<td>August</td>
<td>1113.8</td>
<td>119.4</td>
<td>1233.2</td>
</tr>
<tr>
<td>September</td>
<td>1144.5</td>
<td>126.3</td>
<td>1270.8</td>
</tr>
<tr>
<td>October</td>
<td>1225.7</td>
<td>227.9</td>
<td>1453.6</td>
</tr>
<tr>
<td>November</td>
<td>1129.2</td>
<td>303.9</td>
<td>1433.1</td>
</tr>
<tr>
<td>December</td>
<td>1265.1</td>
<td>309.4</td>
<td>1574.5</td>
</tr>
<tr>
<td>January 1983</td>
<td>1233.2</td>
<td>319.0</td>
<td>1552.2</td>
</tr>
<tr>
<td>February</td>
<td>1067.1</td>
<td>346.9</td>
<td>1414.0</td>
</tr>
<tr>
<td>March</td>
<td>1299.0</td>
<td>378.1</td>
<td>1677.1</td>
</tr>
<tr>
<td>Total</td>
<td>14079.0</td>
<td>3151.7</td>
<td>17230.7</td>
</tr>
</tbody>
</table>

Source: UPSEB Grid Control
UPSEB: Monthly Peak Demand (1982-83)

UPSEB: Unrestricted Consumption Estimate: 1982-83

--- Peak Load (MW)

--- Actual --- Unrestricted

MONTHS
## TABLE 6.6

**Power Supply in U.P.**

**SALIENT CUTS/RESTRICTIONS IN FORCE IN 1982-83**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Consumer Category</th>
<th>April'82</th>
<th>May'82 - March'83</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Rural Feeders</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) Agricultural Consumers</td>
<td>Restricted supply for 8 hrs at night and 6 hrs during day on alternate days</td>
<td>Average 7 hrs/day upto 12.5.82 Av. 14 hrs/day Western U.P. 13.5.82 to 14.6.82 Av. 11 hrs/day Eastern U.P. 13.6.82 Av. 7 hrs/day 14.6.82 to 13.7.82 Av. 10 hrs/day 14.7.82 to 17.10.82 (in 4 groups on weekly rotation) Av. 7 hrs/day 18.10.82 to 14.11.82 Av. 10 hrs/day 15.11.82 to 4.3.83 Av. 7 hrs/day 4.3.82 to 31.3.83</td>
</tr>
<tr>
<td>2.</td>
<td>Industrial Feeder</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) All consumers receiving power at 33 KV &amp; above and having own generation equal to or more than 80% of their highest max. demand recorded between Aug'78-July'79</td>
<td>100% cut upto 17.4.82 (i) 50 MW cut on M/s Hindal Co. No cut thereafter 47.5 MW cut thereafter. (ii) 3.5 MW cut on M/s Kanoria Chemicals No cut thereafter Upto 31.8.82</td>
<td>80% of their highest max. demand recorded between Aug'78-July'79 or on the contracted demand, whichever was lower.</td>
</tr>
<tr>
<td></td>
<td>(b) All other Industrial in (a)</td>
<td>20% cut upto 17.4.82 &amp; No cut thereafter on the highest Max. Demand No cut</td>
<td>No cut</td>
</tr>
<tr>
<td></td>
<td>(c) All Industrial consumers &amp; Non-continuous &amp; Textile Mills having loads above 100 BHP/100 KVA/75 KW</td>
<td>100% cut upto 17.4.82 No cut</td>
<td>No cut</td>
</tr>
<tr>
<td></td>
<td>(d) Sugar, Vanaspati, Drug, Fertilizers, Cement, Jute, Rice Mills, BHEL, Rayon &amp; Tex. Spinning</td>
<td>No cut</td>
<td>80% of their highest max. demand recorded between Aug'78-July'79 or on the contracted demand, whichever was lower.</td>
</tr>
<tr>
<td></td>
<td>(e) Industries in Hill districts</td>
<td>No cut</td>
<td>No cut</td>
</tr>
<tr>
<td></td>
<td>(f) Arc/Induction furnaces receiving power at and below 33 KV</td>
<td>Supply 12 hrs/day upto 6.5.82</td>
<td>Supply 12 hrs/day 8/1.2 hrs/day upto 31.5.82</td>
</tr>
<tr>
<td></td>
<td>(g) Rolling &amp; Rerolling Mills</td>
<td>No cut</td>
<td>No cut</td>
</tr>
</tbody>
</table>

contd.
### TABLE 6.6

**Power Supply in U.P.**

<table>
<thead>
<tr>
<th>S1. No.</th>
<th>Consumer Category</th>
<th>April '82</th>
<th>May '82 - March '83</th>
</tr>
</thead>
<tbody>
<tr>
<td>(h) All Non-continuous Industries</td>
<td>Observe one holiday in a week and complete ban on supply during evening peak from 1800-2200 hrs.</td>
<td>Same as in April '82</td>
<td></td>
</tr>
<tr>
<td>(i) Cold storages (with 1 KV independent feeders)</td>
<td>16-18 hrs/day upto Nov '82 At par with Agri. supply if situated in rural areas (Dec '82 - Mar '83)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Domestic &amp; Commercial cuts</td>
<td>Supply as per rural feeder programme In addition two-phase power supplied between 1800-2200 hrs</td>
<td>Same as in April '82 upto Sep '82 Two phase power supply increased for 12 hrs/day from 22.10.82 between 1700 hrs-0500 hrs.</td>
<td></td>
</tr>
<tr>
<td>(a) All category II towns/localities having population more than 10,000 as per '71 census.</td>
<td>Complete ban on use of Air conditioners upto 16.4.82. No cut thereafter.</td>
<td>Complete ban on display of decorative/advertising lights except for one board during normal hours of business.</td>
<td></td>
</tr>
<tr>
<td>(b) Offices incl. Govt. Offices, Hotels &amp; Commercial Establishments (except Cinema Houses)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) (i) KAVAL Towns</td>
<td>No scheduled rostering upto 4.3.83 Rostering introduced w.e.f. 5.3.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ii) Special Class Towns</td>
<td></td>
<td>(a) KAVAL Towns - One hour/day</td>
<td></td>
</tr>
<tr>
<td>(iii) Category I Town</td>
<td></td>
<td>(b) Special class towns - 2 hrs/day</td>
<td></td>
</tr>
<tr>
<td>(d) Hill Districts and Bundelkhand Region</td>
<td></td>
<td>(c) Distt. Towns - 3 hrs/day</td>
<td></td>
</tr>
</tbody>
</table>

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or a year. For evolving a rational price policy, an electric utility has to take into account the differing pattern of peak and off-peak demands of consumers, the aim being to flatten, in due course, the system load curve in the manner achieved by utilities like Electricité De France. It is, therefore, important to examine the pattern of demand for electricity in U.P.

While there is a system load-curve for everyday of the year showing energy consumed in each of the 24 hours, it is considered sufficient for the present analysis to analyse load curves for each season or at the most each month to study the load pattern for electricity in Uttar Pradesh. Ideally such curves should be analysed for every consumer category for which a separate tariff is to be constructed so that each category’s consumption pattern can be taken especially during system peak hours into consideration in suggesting tariff schedules. Since it is not possible to have such consumer-category curves, one has to depend on general knowledge of category-wise demands, based on known/inferred demand characteristics of different groups of consumers.

To determine the load pattern, the monthly peak demand and its time of incidence for the year 1982-83 has been examined. The load pattern over a 24 hours daily cycle for the representative days of each of the season has also been analysed. Table 6.7 below gives monthly peak demand for Uttar Pradesh for the year 1982-83.
TABLE: 6.7

UTTAR PRADESH: Actual Monthly Peak Demand 1982-83

<table>
<thead>
<tr>
<th>Month</th>
<th>UPSEB Peak Demand (MW)</th>
<th>Date</th>
<th>Time (Hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 1982</td>
<td>1929</td>
<td>17.4.82</td>
<td>2000</td>
</tr>
<tr>
<td>May 1982</td>
<td>2016</td>
<td>27.5.82</td>
<td>0600</td>
</tr>
<tr>
<td>June 1982</td>
<td>2051</td>
<td>26.6.82</td>
<td>0500</td>
</tr>
<tr>
<td>July 1982</td>
<td>2174</td>
<td>10.7.82</td>
<td>0600</td>
</tr>
<tr>
<td>August 1982</td>
<td>1946</td>
<td>20.8.82</td>
<td>1900</td>
</tr>
<tr>
<td>September 1982</td>
<td>2198</td>
<td>19.9.82</td>
<td>1900</td>
</tr>
<tr>
<td>October 1982</td>
<td>2099</td>
<td>7.10.82</td>
<td>0600</td>
</tr>
<tr>
<td>November 1982</td>
<td>2082</td>
<td>8.11.82</td>
<td>1900</td>
</tr>
<tr>
<td>December 1982</td>
<td>2256</td>
<td>20.12.82</td>
<td>1800</td>
</tr>
<tr>
<td>January 1983</td>
<td>2754</td>
<td>18.1.83</td>
<td>1900</td>
</tr>
<tr>
<td>February 1983</td>
<td>2129</td>
<td>11.2.83</td>
<td>1900</td>
</tr>
<tr>
<td>March 1983</td>
<td>2310</td>
<td>17.3.83</td>
<td>2300</td>
</tr>
</tbody>
</table>

Source: NREB Monthly Progress Reports, 1982-83

As cut on electricity is imposed in the evening times, it is reasonable to assume that the potentially peak hours are during 6 p.m. to 10 p.m. Except for the four months of May, June, July and October 1982 when the system peak was in the early morning, in all other months in the year the peak period was in the evening mainly from 7 p.m. to 11 p.m. Shifting of peak time has been mainly due to the cuts applied at the peak period and due to high seasonal variations in irrigation demand both for Rabi and Kharif crops. The annual peak was 2754 MW and its incidence was at 1900 hrs on 18.1.1983.

Operational Characteristics:

The Uttar Pradesh power system is in synchronism with the Northern Regional Grid since May 1982. Since then, Bihar is also running in synchronism with Uttar Pradesh. The tie lines between Uttar Pradesh and and Northern Region on which
23.4.82 (FRIDAY)

HOURLY DEMAND CURVE OF THE UTTAR PRADESH SYSTEM

TOTAL GEN (THERMAL+HYDRO ONLY)

THERMAL GEN ONLY

LEGEND

LOAD

GENERATION
HOURLY DEMAND CURVE OF THE U.P. SYSTEM 31-5-82 (MONDAY)

TOTAL GEN. THERMAL + HYDRO

THERMAL GEN. ONLY

HOURS

MW
HOURLY DEMAND CURVE OF THE UTTAR PRADESH SYSTEM ON SECOND SUNDAY

LEGEND:
- LOAD
- GENERATION

(12.9.82)
DEMAND CURVE OF U.P. SYSTEM ON THE PEAK DAY 19-9-82 (SUNDAY)

TOTAL GEN. THERMAL + HYDRO

THERMAL GEN. ONLY

LEGEND
LOAD
GENERATION
HOURLY DEMAND CURVE OF THE U.P. SYSTEM ON 22-11-82 (MONDAY)

LEGEND:

LOAD

GENERATION

THERMAL GEN. ONLY
HOURLY DEMAND CURVE OF THE UTTAR PRADESH SYSTEM

21.12.82

THERMAL + HYDRO GEN. ONLY

THERMAL GEN. ONLY

LEGEND:

LOAD

GENERATION
HOURLY DEMAND CURVE OF THE U.P. SYSTEM ON SECOND SUNDAY THUS
LEGEND:

LOAD

GENERATION

HOURLY DEMAND CURVE OF THE U.P. SYSTEM ON TUESDAY 18-1-83
Hourly Demand Curve of Uttar Pradesh on 7.3.83 (Monday)

![Graph showing electrical demand and generation over 24 hours.](image_url)
HOURLY DEMAND CURVE OF THE U.P. SYSTEM ON SUNDAY 13.3.83

LEGEND

LOAD

GENERATION

2016

2083

2 4 6 8 10 12 14 16 18 20 22 24

HOURS
regular exchange of power takes place are 220 KV Muradnagar-Badarpur and Muradnagar-Patparganj lines and 132 KV Mathura-Bharatpur and Kushal-Giri lines. Uttar Pradesh also has inter-state ties with Bihar and Madhya Pradesh for casual exchange of power depending upon the system conditions.

The present status of load despatch is that the State Load Despatch Centre (SLDC) is located at Lucknow. For control purposes, the Uttar Pradesh power system has been divided in four regions with four Sub-State Load Despatch Centres at Panki, Sahupuri, Moradabad and Roorkee, which are directly responsible to Central Load Despatch Station in Lucknow. The Central Load Despatch station formulates regularly the generation and supply strategy and gives various regions guidelines for carrying out frequency and voltage control, network operations, and the arrangement of shut down. The area load despatch stations control the grid generation, system load voltage condition and the inter-state power flows. Inter-State Load Despatch Centre and Northern Regional Electricity Board (NREB) is located at Delhi of which UPSEB is a constituent unit. Presently the communication system used for all Load Despatch functions consists of DOT lines, Microwave links and Power Line Carrier links. A 60 channels analogue microwave system is also partially in operation. The control and operation philosophy basically is hierarchical in nature. Major generation stations and 400 kv and 220 kv substations in the state report directly to SLDC.

For the smooth operation of such a large integrated
power system, the load despatch stations of various constituents of Northern Regional Electricity Board have to work in close unison and function in a complementary mode with each other. The conventional existing communication system (presently being computerised) are, however, not adequate to optimally run the system and cope with the present load despatch functions. This is so because power system of Uttar Pradesh has increased manifold during last two decades. Modernisation of load despatching activities by introducing computer based Load Despatching System has become essential for coordinated and integrated operation of widely spread and varied generation sources and transmission and distribution network. Accordingly, the communication facilities also need to be upgraded for an effective and reliable system. The Board has planned to provide telemetry facilities to automatically telemeter all the required system operation data within the State which will also transmit to inter-state load despatch centre of NREB selected data such as power flow on EHV lines and transformers, stationwise/unit-wise generation of power etc.

The working of two hydel stations having reservoirs, viz., Obra hydel and Rihand shows that they are used as peaking stations. While irrigation gets the first priority for Obra hydel and releases are regulated primarily for irrigation purposes from November to February/March every year, Rihand is also used for peaking loads only. Even barrages, pondage type capacity mainly, on run-of- river are also used in winter months for some peaking in the evening.
The water in the barrages is stored during snow-melting hours when water discharge is less so as to take maximum generation in the evening. Thermal is mainly used for base and intermediate loads.

Generally speaking hydel stations are used as peaking stations in Uttar Pradesh and thermal stations are used as base load stations. As monsoons are not predictable, utmost care is exercised in use of water resources during dry seasons for hydel generation. Care is also taken that no spilling of water takes place without generation from hydel reservoirs during the flood seasons. The working of steam and hydel power stations is likely to continue in the same manner for the next several years. An analysis of some of the typical daily load curves indicates that generation curve for thermal stations is reasonably flat. Considerably high load factor is achieved by using the hydel stations and by imports from neighboring states.

During the off-peak time first priority is given to close down Rihand, hydro-electric unit, second is to connect all possible loads and let all restrictions go off; third priority is to export to neighbouring states and last of all close down thermal plants for planned maintenance outages.

On the supply side it has been estimated that the peaking capability in the year 2000 is likely to be 11,920 MW taking into account the identified projects in the expansion plan of the Uttar Pradesh State Electricity Board as compared to 3,654 MW at present. The total installed capacity in the state is likely to be 13,099 MW in the same year as against
4,811 MW at the end of March 1987. These figures are computed in accordance with Central Electricity Authority norms, taking peaking availability as 57.3 per cent of the installed capacity for Thermal and Gas units, 85 per cent for the nuclear projects and 87 per cent for the hydel plants. The annual energy availability will be approximately 71,711 million units in the year 2000 as against 19,510 million units in the year 1987-88. On the contrary the Thirteenth Power Survey conducted by the Central Electricity Authority has estimated the figures for the peak load demand as well as Energy requirement for the whole state of Uttar Pradesh at 13,759 MW and 65,308 MU respectively by the turn of the century. The peaking capability of UPSEB is expected to continue to be short of requirement till the year 2000 when the shortage would be approximately 1,839 MW. The State, however, is expected to have surplus energy of 6,403 MU by the year 2000.

Under the 1985-90 system expansion plan, 1507 MW of additional generating capacity and 9484 Kms. of transmission lines are proposed to be added. The additional generating capacity comprises of 72 MW hydro scheme at Khara, 1435 MW thermal with 3 units at Anpara 'A' and 2 units at Unchahar of 210 MW each respectively and 4 units of 110 MW each at Tanda. Besides this, the State's share in the additional Central Sector thermal generation capacity during Seventh Plan is likely to be 1,125 MW out of an addition of 2,470 MW. Because the shortages are likely to persist in future also, it is assumed that the system will work at full capacity in the
coming years as well.

Increase in hydel capacity till 1989-90 is rather small. Under the circumstances the marginal requirement of power in U.P. for the next, at least, 5 years has to be met by new thermal power stations i.e. by raising the base load generation which would be provided by thermal power stations. The peak, however, will have to be met by hydel stations, as is being done at present. Small thermal stations would also require to be run all out during peak hours. If at any time, hydel stations are required to meet any unplanned load, due to break down in thermal stations (or due to any other reason), the same quantity of energy should be banked by large or small thermal stations. Thus marginal power is to be provided by new power station capacities which are mainly thermal. The margin for energy requirement will be met by the most inefficient stations i.e. small thermal stations and Harduaganj. As with all power systems, it is a standard practice with the U.P. power system also to run the power stations in order of their efficiency i.e. the most efficient power station will run most of the time and peaking is done by least efficient power station. Thus the margin for energy requirement will be met by the most inefficient stations i.e. small thermal stations and least efficient Harduaganj.

Assumptions Regarding Parameters

Loss Factors:

Line losses are an important aspect of costing. On its way to the distribution network, there are considerable line
losses in the UPSEB network, especially when electricity is transmitted on lower voltages over long distance. The Uttar Pradesh State Electricity Board, however, does not estimate voltage-wise transmission and distribution losses. Recently an attempt has been made to separately estimate transmission (132 KV and above) E.H.V and Project transmission and distribution (66 KV and below) losses. In the absence of definite data of line-losses at different voltages, some estimates have to be made. The average transmission and distribution losses in UPSEB which were quite high in the range of 21 to 28 per cent during 1970-71 to 1976-77 came down to the range of 18 to 21 per cent in subsequent decade with an exception of 15.8 per cent losses in the year 1980-81 (Table 6.8). There was a sudden increase in the transmission and distribution losses in 1987-88 and 1988-89 to 27 per cent. Based on the data made available by UPSEB for the estimated consumption at various voltage levels in 1983-84, loss factors have been worked out per unit of consumers' demand at various voltages. Line loss factors indicate the extent of loss at any level. Individual line loss factors indicate the loss at a particular level while cumulative line loss factors determine losses up to and including that voltage level. Losses at peak may be assumed 20 per cent higher than the average losses because the ratio of peak demand/average demand for a normal typical day works out to 1.2 in respect of UPSEB system. A departmental study of UPSEB had also assumed this ratio at 1.2. For calculating marginal costs, alternative assumptions of losses at desired levels, as were...
made in the case of Tamil Nadu, are also being made in the case of Uttar Pradesh.

TABLE: 6.8

UPSEB: Transmission & Distribution Loss (Total)

<table>
<thead>
<tr>
<th>Year</th>
<th>Loss</th>
<th>Loss as percentage of total ex-bus energy available</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-71</td>
<td>1321</td>
<td>23.54</td>
</tr>
<tr>
<td>1971-72</td>
<td>1482</td>
<td>24.83</td>
</tr>
<tr>
<td>1972-73</td>
<td>1818</td>
<td>27.45</td>
</tr>
<tr>
<td>1973-74</td>
<td>1695</td>
<td>28.17</td>
</tr>
<tr>
<td>1974-75</td>
<td>1449</td>
<td>22.65</td>
</tr>
<tr>
<td>1975-76</td>
<td>1692</td>
<td>21.32</td>
</tr>
<tr>
<td>1976-77</td>
<td>2316</td>
<td>23.76</td>
</tr>
<tr>
<td>1977-78</td>
<td>1734</td>
<td>19.86</td>
</tr>
<tr>
<td>1978-79</td>
<td>1815</td>
<td>18.44</td>
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<tr>
<td>1979-80</td>
<td>1826</td>
<td>18.78</td>
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<tr>
<td>1980-81</td>
<td>1528</td>
<td>15.8</td>
</tr>
<tr>
<td>1981-82</td>
<td>2013</td>
<td>18.9</td>
</tr>
<tr>
<td>1982-83</td>
<td>2376</td>
<td>18.8</td>
</tr>
<tr>
<td>1983-84</td>
<td>2411</td>
<td>18.2</td>
</tr>
<tr>
<td>1984-85</td>
<td>2936</td>
<td>20.82</td>
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<tr>
<td>1985-86</td>
<td>3079</td>
<td>20.57</td>
</tr>
<tr>
<td>1986-87</td>
<td>3578</td>
<td>20.76</td>
</tr>
<tr>
<td>1987-88</td>
<td>5307</td>
<td>26.82</td>
</tr>
<tr>
<td>1988-89</td>
<td>5785</td>
<td>26.45</td>
</tr>
</tbody>
</table>


Reserve Capacity Margin:

The ratio of the grid maximum demand to the total installed capacity including power purchase for Uttar Pradesh has been analysed as in the case of Tamil Nadu. Table 6.10 gives the required data. This ratio varies from 0.52 in 1981-82 to 0.79 during the last decade or so. As stated above further additions in UPSEB in Seventh and Eighth Five Year Plan would be mainly from thermal stations for which the present trend of plant availability factor is no better than Tamil Nadu at less than 60 per cent. Therefore, 40 per cent
TABLE: 6.9

UPSEB: Loss Factors for calculating Generation Capacity Cost Receipts, Despatches, Deliveries and Losses: 1983-84

(Million Units)

<table>
<thead>
<tr>
<th>Voltage Sector</th>
<th>Units Received</th>
<th>Units Despatched</th>
<th>Billed on Consumers</th>
<th>Loss</th>
<th>Loss Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Units</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>1. EHV (230/110/66 kv)</td>
<td>13226</td>
<td>10591</td>
<td>2002</td>
<td>633</td>
<td>4.79</td>
</tr>
<tr>
<td>2. HV (33/22/11 kv)</td>
<td>10591</td>
<td>8112</td>
<td>1535</td>
<td>944</td>
<td>8.91</td>
</tr>
<tr>
<td>3. LT (400 volts &amp; below)</td>
<td>8112</td>
<td>-</td>
<td>7291</td>
<td>821</td>
<td>10.12</td>
</tr>
<tr>
<td>Total</td>
<td>13226</td>
<td>-</td>
<td>10828</td>
<td>2398</td>
<td>18.13</td>
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</table>

Loss Factors

<table>
<thead>
<tr>
<th>Voltage Sector</th>
<th>Individual Level</th>
<th>Cumulative Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. EHV</td>
<td>13226/12593</td>
<td>1.05</td>
</tr>
<tr>
<td>2. HV</td>
<td>10591/9647</td>
<td>1.10</td>
</tr>
<tr>
<td>3. LT</td>
<td>8112/7291</td>
<td>1.11</td>
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Loss Factors at Peak Load

Assuming 20% higher losses

<table>
<thead>
<tr>
<th>Voltage Sector</th>
<th>Individual Level</th>
<th>Cumulative Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>1. EHV</td>
<td>13226/12466</td>
<td>1.06</td>
</tr>
<tr>
<td>2. HV</td>
<td>10591/9458</td>
<td>1.12</td>
</tr>
<tr>
<td>3. LT</td>
<td>8112/7127</td>
<td>1.14</td>
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</tbody>
</table>

Note: Loss Factor = 1/(1-% Loss)

Cumulative Loss Factor = Loss factor at specified voltage sector multiplied by the loss factors at higher voltage.
### Table 6.10

**UPSEB: Ratio of Peak Demand to Installed Capacity**

<table>
<thead>
<tr>
<th>Year</th>
<th>Installed Capacity (MW)</th>
<th>Peak Demand (MW)</th>
<th>Ratio of Peak Demand to Installed Capacity</th>
<th>Energy Generation (Net incl. power purchase Ex-Bus) (MU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-71</td>
<td>1434</td>
<td>1281</td>
<td>0.8933</td>
<td>5612</td>
</tr>
<tr>
<td>1971-72</td>
<td>1572</td>
<td>1267</td>
<td>0.8060</td>
<td>5968</td>
</tr>
<tr>
<td>1972-73</td>
<td>1580</td>
<td>1281</td>
<td>0.8108</td>
<td>6622</td>
</tr>
<tr>
<td>1973-74</td>
<td>1674</td>
<td>1262</td>
<td>0.7539</td>
<td>6017</td>
</tr>
<tr>
<td>1974-75</td>
<td>1957</td>
<td>1217</td>
<td>0.6219</td>
<td>6398</td>
</tr>
<tr>
<td>1975-76</td>
<td>2203</td>
<td>1744</td>
<td>0.7916</td>
<td>7938</td>
</tr>
<tr>
<td>1976-77</td>
<td>2615</td>
<td>1911</td>
<td>0.7308</td>
<td>9748</td>
</tr>
<tr>
<td>1977-78</td>
<td>2982</td>
<td>1795</td>
<td>0.6019</td>
<td>8729</td>
</tr>
<tr>
<td>1978-79</td>
<td>3187</td>
<td>2256</td>
<td>0.7078</td>
<td>9844</td>
</tr>
<tr>
<td>1979-80</td>
<td>3379</td>
<td>2324</td>
<td>0.6878</td>
<td>9721</td>
</tr>
<tr>
<td>1980-81</td>
<td>3713</td>
<td>2485</td>
<td>0.6693</td>
<td>9660</td>
</tr>
<tr>
<td>1981-82</td>
<td>3957</td>
<td>2061</td>
<td>0.5208</td>
<td>10650</td>
</tr>
<tr>
<td>1982-83</td>
<td>3957</td>
<td>2754</td>
<td>0.6960</td>
<td>12648</td>
</tr>
<tr>
<td>1983-84</td>
<td>4194</td>
<td>1775</td>
<td>0.4232</td>
<td>13239</td>
</tr>
<tr>
<td>1984-85</td>
<td>3939@</td>
<td>2293</td>
<td>0.5821</td>
<td>14095</td>
</tr>
<tr>
<td>1985-86</td>
<td>4136@</td>
<td>2962</td>
<td>0.7162</td>
<td>14960</td>
</tr>
<tr>
<td>1986-87</td>
<td>4541@</td>
<td>3360</td>
<td>0.7399</td>
<td>14730</td>
</tr>
</tbody>
</table>

* Includes Renusagar and Licensees.
@ Excludes Renusagar and Licensees.
capacity margin for calculating marginal capacity costs has been similarly assumed. It is significant to mention that in actual practice UPSEB, in their generation capacity expansion plan, has not considered it important to provide an allowance for annual overhaul in the case of new machines which implies that no allowance for spinning reserve is provided keeping in view the shortage of power in the state. There is a strong justification for a reserve margin of 40 per cent keeping in view the past trend of forced outages and plant maintenance. Marginal capacity cost calculations have, however, been made with 40 per cent reserve capacity margin as well as with the alternative assumption of 25 per cent desired normative level of reserve capacity margin.

**Auxiliary Consumption Factor**

Table 6.11 furnishes the auxiliary consumption for the thermal, hydro and total generation of UPSEB for the past many years. It would be seen that the auxiliary consumption in thermal plants has been varying generally between 10 to 13.5 per cent with the exception of one or two years. In the generation capacity expansion programme in U.P., the component of thermal power capacity is as high as in the case of Tamil Nadu. It has, therefore, been assumed that in Uttar Pradesh the weighted average auxiliary consumption of the additional capacity being installed in 1985-90, will be 0.1 (10 per cent) for future years.

**Assumptions about Other parameters**

Assumptions regarding life of the plant equipments and rate of discount are the same as discussed in the previous
<table>
<thead>
<tr>
<th>Year</th>
<th>Gross Generation (MU)</th>
<th>Aux. Consumption (MU)</th>
<th>ACF (3) as % of (2)</th>
<th>Gross Gen. (MU)</th>
<th>Aux. Consumption (MU)</th>
<th>ACF (7) as % of (6)</th>
<th>Gross Gen. (MU)</th>
<th>Aux. Consumption (MU)</th>
<th>ACF (11) as % of (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971-72</td>
<td>2278</td>
<td>3708</td>
<td>0.969</td>
<td>5986</td>
<td>354</td>
<td>0.941</td>
<td>5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1972-73</td>
<td>2709</td>
<td>3852</td>
<td>0.984</td>
<td>6561</td>
<td>355</td>
<td>0.945</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1973-74</td>
<td>1974</td>
<td>3759</td>
<td>0.987</td>
<td>5733</td>
<td>359</td>
<td>0.937</td>
<td>6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974-75</td>
<td>1579</td>
<td>4575</td>
<td>0.987</td>
<td>6154</td>
<td>465</td>
<td>0.925</td>
<td>7.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1975-76</td>
<td>2655</td>
<td>5358</td>
<td>0.989</td>
<td>8013</td>
<td>541</td>
<td>0.933</td>
<td>6.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976-77</td>
<td>3932</td>
<td>117</td>
<td>0.977</td>
<td>5799</td>
<td>490</td>
<td>0.916</td>
<td>8.4</td>
<td>9630</td>
<td>607</td>
</tr>
<tr>
<td>1977-78</td>
<td>3175</td>
<td>50</td>
<td>0.984</td>
<td>6114</td>
<td>628</td>
<td>0.897</td>
<td>10.3</td>
<td>9289</td>
<td>678</td>
</tr>
<tr>
<td>1978-79</td>
<td>3683</td>
<td>49</td>
<td>0.987</td>
<td>6447</td>
<td>712</td>
<td>0.890</td>
<td>11.0</td>
<td>10130</td>
<td>761</td>
</tr>
<tr>
<td>1979-80</td>
<td>3266</td>
<td>37</td>
<td>0.989</td>
<td>6859</td>
<td>768</td>
<td>0.888</td>
<td>11.2</td>
<td>10124</td>
<td>805</td>
</tr>
<tr>
<td>1980-81</td>
<td>3456</td>
<td>11</td>
<td>0.977</td>
<td>6737</td>
<td>866</td>
<td>0.871</td>
<td>12.9</td>
<td>10190</td>
<td>877</td>
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<tr>
<td>1981-82</td>
<td>3836</td>
<td>11</td>
<td>0.977</td>
<td>7512</td>
<td>948</td>
<td>0.874</td>
<td>12.6</td>
<td>11348</td>
<td>959</td>
</tr>
<tr>
<td>1982-83</td>
<td>4175</td>
<td>17</td>
<td>0.996</td>
<td>8420</td>
<td>1071</td>
<td>0.873</td>
<td>12.7</td>
<td>12595</td>
<td>1088</td>
</tr>
<tr>
<td>1983-84</td>
<td>4020</td>
<td>11</td>
<td>0.997</td>
<td>7663</td>
<td>1004</td>
<td>0.869</td>
<td>13.1</td>
<td>11683</td>
<td>1015</td>
</tr>
<tr>
<td>1984-85</td>
<td>4553</td>
<td>12</td>
<td>0.977</td>
<td>6759</td>
<td>898</td>
<td>0.867</td>
<td>13.3</td>
<td>11312</td>
<td>910</td>
</tr>
<tr>
<td>1985-86</td>
<td>4584</td>
<td>14</td>
<td>0.977</td>
<td>7629</td>
<td>1030</td>
<td>0.865</td>
<td>13.5</td>
<td>12213</td>
<td>1054</td>
</tr>
<tr>
<td>1986-87</td>
<td>4716</td>
<td>24</td>
<td>0.995</td>
<td>9516</td>
<td>1084</td>
<td>11.39</td>
<td>17338</td>
<td>1074</td>
<td>0.938</td>
</tr>
</tbody>
</table>

Auxiliary Consumption factor (ACF) = (Gross generation - Auxiliary Consumption)/Gross generation
chapter for Tamil Nadu. There is a complete absence of data regarding coincident demand and diversity factors for the U.P. power system. Diversity factors are, therefore, assumed to be the same as in the case of Tamil Nadu although this assumption may be less realistic without taking into account the trend in increase in load factor of various categories of consumers.

**Marginal Energy Cost**

To determine marginal energy cost, it should be examined how the system is likely to be operated to meet demand in the period 1985-90. It has been discussed before that in a hydro-thermal mixed system, it is the thermal plant that turns out to be the marginal plant. In the UPSEB system also the marginal energy cost is always equal to the fuel cost of generating extra units in the thermal stations. The reason for this is that the quantum of energy available from the hydel stations is always fixed by the weather and the experience in U.P. has been that there is no spillage of water from the reservoirs even during the wet season. Any extra energy supplied/saved by hydro at any time means extra generation by thermal plant. In other words, the hydel energy represents a fixed amount of energy which can be (and is) used during the year so that the reservoirs can be replenished during the wet season. In this sense, the marginal energy is always that of the thermal stations.

Base loads are met with supplies partly from central sector Singrauli Thermal Power Station and partly from non-irrigation tied hydel projects and the balance from the
various Obra thermal power stations. Intermediate loads are met out of the remaining thermal supplies. For peaking purposes reservoir type hydro stations of the system are used besides availing relief from Rajasthan Atomic Power Station, National Hydel Power Corporation (Baira Siul), Bhakra Beas Management Board and from Madhya Pradesh and Bihar power systems. In the Uttar Pradesh power system most of the main extensions are thermal and new plant being more efficient will add to the base load. The operation of the power stations would be such that less efficient will generate in order of their dropping efficiency. The table 6.12 indicates since 1980-81 the relative fuel cost of the different thermal plants in existence at the end of Sixth Plan and Parichha, Anpara 'A' and Tanda' commissioned in first, second and third year of Seventh Plan.

In the table information is also furnished regarding the average energy cost of small thermal power stations. These stations have thirty three generating units of 5 MW or less located in thirteen places in Uttar Pradesh. The question is which stations can be regarded as providing marginal energy requirements? If the very inefficient small thermal stations (most of which are more than 30 years old; a few are more than 40 years old) are taken it appears to be a distorted sample, giving an unrealistically inflated marginal energy cost. Apart from this, many of these stations are progressively being retired from service. Marginal energy cost is a forward-looking concept, and the approach has to be oriented towards those stations which will
<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Generation</td>
<td>Cost/Unit (Rs. lakhs)</td>
<td>Cost/Unit (P/kWh)</td>
<td>Cost/Unit (Rs. lakhs)</td>
<td>Cost/Unit (P/kWh)</td>
</tr>
<tr>
<td>1</td>
<td>Obra</td>
<td>990.2</td>
<td>1164</td>
<td>11.68</td>
<td>2036</td>
</tr>
<tr>
<td>2</td>
<td>Obra Extn. I</td>
<td>1049.4</td>
<td>1560</td>
<td>14.87</td>
<td>1099</td>
</tr>
<tr>
<td>3</td>
<td>Obra Extn. II &amp; III</td>
<td>1976.2</td>
<td>3030</td>
<td>15.32</td>
<td>2402</td>
</tr>
<tr>
<td>4</td>
<td>Panki Old</td>
<td>291.7</td>
<td>479</td>
<td>16.42</td>
<td>224</td>
</tr>
<tr>
<td>5</td>
<td>Panki Extn.</td>
<td>909.6</td>
<td>1603</td>
<td>17.62</td>
<td>918</td>
</tr>
<tr>
<td>6</td>
<td>Harduaganj 'A'</td>
<td>18.5</td>
<td>36</td>
<td>19.44</td>
<td>122</td>
</tr>
<tr>
<td>7</td>
<td>Harduaganj 'B'</td>
<td>630.5</td>
<td>1409</td>
<td>22.35</td>
<td>700</td>
</tr>
<tr>
<td>8</td>
<td>Harduaganj 'C'</td>
<td>495.0</td>
<td>879</td>
<td>17.76</td>
<td>832</td>
</tr>
<tr>
<td>9</td>
<td>R.P.H. Kanpur</td>
<td>135.5</td>
<td>393</td>
<td>29.01</td>
<td>137</td>
</tr>
<tr>
<td>10</td>
<td>Small TPH (Average)</td>
<td>231.7</td>
<td>772</td>
<td>33.23</td>
<td>141</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>6734.0</td>
<td>11325</td>
<td>16.82</td>
<td>7512</td>
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<tr>
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<td>---------</td>
<td>---------</td>
<td>-----------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(MU)</td>
<td>Cost/Unit (Rs lakhs)</td>
<td>Cost/Unit (P/kWh)</td>
<td>Cost/Unit (Rs lakhs)</td>
</tr>
<tr>
<td>1.</td>
<td>Obra</td>
<td>918</td>
<td>2238</td>
<td>24.38</td>
<td>28.00</td>
</tr>
<tr>
<td>2.</td>
<td>Obra Extn. I</td>
<td>678</td>
<td>1622</td>
<td>23.92</td>
<td>25.33</td>
</tr>
<tr>
<td>4.</td>
<td>Panki Old</td>
<td>191</td>
<td>669</td>
<td>35.03</td>
<td>37.52</td>
</tr>
<tr>
<td>5.</td>
<td>Panki Extn.</td>
<td>907</td>
<td>3205</td>
<td>35.34</td>
<td>36.37</td>
</tr>
<tr>
<td>7.</td>
<td>Harduaganj 'B'</td>
<td>659</td>
<td>2994</td>
<td>45.43</td>
<td>45.42</td>
</tr>
<tr>
<td>8.</td>
<td>Harduaganj 'C'</td>
<td>506</td>
<td>2127</td>
<td>42.04</td>
<td>43.87</td>
</tr>
<tr>
<td>9.</td>
<td>R.P.H. Kanpur</td>
<td>141</td>
<td>872</td>
<td>61.84</td>
<td>81.08</td>
</tr>
<tr>
<td>10.</td>
<td>Small TPH (Average)</td>
<td>69</td>
<td>570</td>
<td>82.61</td>
<td>76.72</td>
</tr>
<tr>
<td>11.</td>
<td>Parichha</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Anpara 'A'</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Tanda</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>6759</td>
<td>21902</td>
<td>32.40</td>
<td>33.41</td>
</tr>
</tbody>
</table>

**TABLE 6.12**

UPSEB: Station wise Fuel Cost
provide marginal energy in the coming years. The fuel consumption per unit of different thermal stations has also been analysed. This has substantially varied over time and has been much higher compared to the norms for many thermal plants like Obra, Harduaganj and Kanpur (Table 6.13). Considering the thermal efficiency and other facts stated above, a weighted average of the energy cost of Harduaganj A, B and C and RPH Kanpur (weighted by the energy produced in 1984-85) has been taken for the purpose of this study. This comes to 47.89 paise per unit. This average fuel cost includes the cost of coal as well as oil used as support fuel for flame stabilisation and represents the energy cost of the marginal plant. This energy cost of marginal plant is higher than the average fuel cost for the total thermal generation of UPSEB given in table 6.12.

Energy Cost at Various Voltage Levels:

The weighted average of fuel cost of marginal power stations has to be modified by auxiliary consumption factors and the average cumulative loss factors so that we are able to take into account the increase in the cost of supplying electricity due to auxiliary consumption and transmission and distribution losses. It has been assumed that the auxiliary consumption is 10 per cent of the total generation. Cumulative loss factors at various voltage levels have already been worked out and are given in Table 6.9. The cost of energy supplied at various voltage ends has been computed by applying suitably the auxiliary consumption factors and cumulative loss factors and are given in the table 6.14.
### TABLE 6.13

**UPSEB: Rate of Fuel Consumption of Uttar Pradesh Thermal Stations 1980-81 to 1987-88**

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Coal Consumption (kg)</th>
<th>Fuel Oil Consumption (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Obra</td>
<td>0.87</td>
<td>19.07</td>
</tr>
<tr>
<td>2. Obra Extn. I</td>
<td>0.80</td>
<td>23.90</td>
</tr>
<tr>
<td>3. Obra Extn. II &amp; III</td>
<td>0.66</td>
<td>35.09</td>
</tr>
<tr>
<td>4. Panki Old</td>
<td>0.62</td>
<td>18.42</td>
</tr>
<tr>
<td>5. Panki Extn.</td>
<td>0.76</td>
<td>11.61</td>
</tr>
<tr>
<td>6. Harduaganj 'A'</td>
<td>0.85</td>
<td>8.05</td>
</tr>
<tr>
<td>7. Harduaganj 'B'</td>
<td>0.68</td>
<td>40.12</td>
</tr>
<tr>
<td>8. Harduaganj 'C'</td>
<td>0.88</td>
<td>17.80</td>
</tr>
<tr>
<td>9. R.P.H. Kanpur</td>
<td>1.15</td>
<td>4.56</td>
</tr>
<tr>
<td>10. Small TPH (Average)</td>
<td>1.49</td>
<td>1.58</td>
</tr>
<tr>
<td>11. Parichha</td>
<td>0.75</td>
<td>21.7</td>
</tr>
<tr>
<td>12. Anpara 'A'</td>
<td>0.70</td>
<td>12</td>
</tr>
<tr>
<td>13. Tanda</td>
<td>0.75</td>
<td>12</td>
</tr>
</tbody>
</table>
bellow.

**TABLE 6.14.1**

Voltage-wise Energy Costs

**Scenario I**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Supply end.</th>
<th>ACF/cumulative loss factors (As in Table 6.9)</th>
<th>Energy cost (P/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Generation</td>
<td>-</td>
<td>47.89</td>
</tr>
<tr>
<td>2.</td>
<td>At the busbar</td>
<td>0.9</td>
<td>(0.9x47.89) = 53.21</td>
</tr>
<tr>
<td>3.</td>
<td>At EHV end</td>
<td>1.05</td>
<td>(1.05x53.21) = 55.87</td>
</tr>
<tr>
<td></td>
<td>(400/220/132/66 Kv)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>At HV end</td>
<td>1.155</td>
<td>(1.155x53.21) = 61.46</td>
</tr>
<tr>
<td></td>
<td>(33/22/11 Kv)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>At LT end</td>
<td>1.282</td>
<td>(1.282x53.21) = 68.22</td>
</tr>
<tr>
<td></td>
<td>(0.4 kv/230v)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: To arrive at energy cost at every level, multiplication by cumulative loss factors is necessary to take account of transformation and line losses. To supply one unit at EHV really means that 1.05 units will have to be supplied at the busbar by the generating station, and similarly, at every voltage level.

With the alternative assumptions of system energy losses energy cost at various voltage levels would be as given in Table 6.14.2.

**TABLE 6.14.2**

Voltage wise Energy Costs

**Scenario II**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Supply end.</th>
<th>System energy losses (As in Table 5.11.2)</th>
<th>Energy Cost (Paise/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Generation</td>
<td></td>
<td>47.89</td>
</tr>
<tr>
<td>2.</td>
<td>At Busbar</td>
<td>10% (47.89/(1-0.1))</td>
<td>53.21</td>
</tr>
<tr>
<td>3.</td>
<td>At EHV end</td>
<td>3%  (53.21/(1-0.03))</td>
<td>54.86</td>
</tr>
<tr>
<td>4.</td>
<td>HV - end</td>
<td>6%  (54.86/(1-0.06))</td>
<td>58.35</td>
</tr>
<tr>
<td>5.</td>
<td>LT - end</td>
<td>6%  (58.35/(1-0.06))</td>
<td>62.08</td>
</tr>
</tbody>
</table>

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If energy cost is to be charged separately for peak load hours, the same can be worked out by multiplying the above energy costs, by the ratio of Peak Demand/Average Demand obtained for a normal typical day. This ratio has been assumed 1.2 in respect of UPSEB system on the basis of trend observed in the past.

**Marginal Generation Capacity Cost**

**The Investment Plan for Generation System:**

The installed generation capacity of the UPSEB at the beginning of the Seventh Five Year Plan was 4391 MW. The details of various plants and their rated capacities at the end of March 1987 are given in Table 6.1. UPSEB has made projections for the installed capacity, peak capacity availability, energy availability as well as capacity and energy needed over the next fifteen years. The forecast made by Thirteenth Annual Power Survey conducted by Central Electricity Authority for the years 1984-85 to 1999-2000 shows that both energy and peak demand in Uttar Pradesh are expected to increase at a compound rate of 10.0 per cent during this period. Thirteenth Annual Power Survey has also estimated capacity as well as energy availability for the same period. There are differences in the capacity and energy availability estimates of UPSEB & Thirteenth Annual Power Survey which are mainly due to the differences in the dates of commissioning assumed for ongoing projects. However, there is a common inference from both these estimates that the State will remain in deficit in power as well as energy availability for quite some time.
Some of the Uttar Pradesh's ongoing projects are expected to become operational by the end of Seventh Plan and are expected to add 1,507 MW to the UPSEB's existing installed capacity. The State will get a share of 1,713 MW out of the Central Power Projects likely to be completed by the end of the Seventh Plan period. Table 6.15 gives the anticipated power position in Uttar Pradesh upto 1999-2000.

To bridge the gap between the availability and requirement of energy and generation capacity, some schemes are already under implementation or have been proposed for approval. These shall give benefits during eighth or ninth plan. Several of the schemes in the Central sectors will also be commissioned before the end of eighth plan in which the State Government has a share which will further increase its peaking capability as well as its capacity to supply more energy. The Central sector projects include Thermal, Nuclear Gas power and hydro projects. Table 6.17 gives details of these Central Sector Projects, UP's percentage share in capacity and time schedule of availability and addition of this capacity to Uttar Pradesh Generation system on commissioning of these projects. However, even if all schemes ongoing, newly approved or proposed for sanction are executed a gap in the availability and requirement of peaking capacity will still remain. The projects which will become operational upto the end of eighth plan with yearly additions to the generation capacity have been given in Table 6.16. These include hydro, thermal and gas power stations. Khara hydro project will have for a few years peaking capability of
## Table 6.15

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1984-85</td>
<td>2313</td>
<td>3818</td>
<td>-</td>
<td>17829</td>
<td>19397</td>
<td>(1568)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985-86</td>
<td>2588*</td>
<td>4206</td>
<td>-</td>
<td>18983</td>
<td>21369</td>
<td>(2386)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987-88</td>
<td>1186</td>
<td>2802</td>
<td>-</td>
<td>712</td>
<td>4700</td>
<td>3046</td>
<td>5072</td>
<td>2026</td>
<td>24694</td>
<td>25772</td>
<td>(1078)</td>
</tr>
<tr>
<td>1988-89</td>
<td>1186</td>
<td>3387</td>
<td>-</td>
<td>1313</td>
<td>5866</td>
<td>3754</td>
<td>5545</td>
<td>1791</td>
<td>27952</td>
<td>28174</td>
<td>(222)</td>
</tr>
<tr>
<td>1989-90</td>
<td>1208</td>
<td>3657</td>
<td>61</td>
<td>1672</td>
<td>6598</td>
<td>4216</td>
<td>6052</td>
<td>1836</td>
<td>31265</td>
<td>30749</td>
<td>(516)</td>
</tr>
<tr>
<td>1990-91</td>
<td>1208</td>
<td>4172</td>
<td>183</td>
<td>1837</td>
<td>7400</td>
<td>4712</td>
<td>6636</td>
<td>1924</td>
<td>35658</td>
<td>33717</td>
<td>(1941)</td>
</tr>
<tr>
<td>1991-92</td>
<td>1268</td>
<td>4422</td>
<td>281</td>
<td>1926</td>
<td>7897</td>
<td>5043</td>
<td>7277</td>
<td>2234</td>
<td>37609</td>
<td>36972</td>
<td>(637)</td>
</tr>
<tr>
<td>1992-93</td>
<td>1948</td>
<td>5277</td>
<td>451</td>
<td>1937</td>
<td>9613</td>
<td>6280</td>
<td>7979</td>
<td>1699</td>
<td>41061</td>
<td>40540</td>
<td>(521)</td>
</tr>
<tr>
<td>1993-94</td>
<td>2098</td>
<td>5592</td>
<td>618</td>
<td>1979</td>
<td>10287</td>
<td>6760</td>
<td>8749</td>
<td>1989</td>
<td>45389</td>
<td>44454</td>
<td>(935)</td>
</tr>
<tr>
<td>1994-95</td>
<td>2848</td>
<td>5802</td>
<td>788</td>
<td>2315</td>
<td>11753</td>
<td>7896</td>
<td>9594</td>
<td>1698</td>
<td>49097</td>
<td>48745</td>
<td>(352)</td>
</tr>
<tr>
<td>1995-96</td>
<td>3452</td>
<td>5802</td>
<td>958</td>
<td>2670</td>
<td>12882</td>
<td>8795</td>
<td>10520</td>
<td>1725</td>
<td>53245</td>
<td>53450</td>
<td>(205)</td>
</tr>
<tr>
<td>1996-97</td>
<td>3752</td>
<td>5907</td>
<td>1117</td>
<td>2720</td>
<td>13496</td>
<td>9283</td>
<td>11535</td>
<td>2252</td>
<td>57185</td>
<td>58609</td>
<td>(1424)</td>
</tr>
<tr>
<td>1997-98</td>
<td>4112</td>
<td>6117</td>
<td>1290</td>
<td>2943</td>
<td>14462</td>
<td>9994</td>
<td>12649</td>
<td>2655</td>
<td>62123</td>
<td>64267</td>
<td>(2144)</td>
</tr>
<tr>
<td>1998-99</td>
<td>4512</td>
<td>6222</td>
<td>1409</td>
<td>3166</td>
<td>15309</td>
<td>10634</td>
<td>13870</td>
<td>3236</td>
<td>67424</td>
<td>70470</td>
<td>(3046)</td>
</tr>
<tr>
<td>1999-2000</td>
<td>5012</td>
<td>6222</td>
<td>1511</td>
<td>3389</td>
<td>16134</td>
<td>11285</td>
<td>15209</td>
<td>3924</td>
<td>71711</td>
<td>77272</td>
<td>(5561)</td>
</tr>
</tbody>
</table>

*Restricted to Actual.

Note: 1. Peak Demand is as per XII Annual Power Survey and is estimated with the help of average yearly load factor.
2. Peaking capability has been worked out as per CEA Norms: Hydro 087% Thermal 057.3% and Nuclear 085%

Data Source: UPSEB statements on XII APS Estimates of Anticipated Availability of Peaking capability (January 1987)
### TABLE 6.16

H - Hydro  G - Gas  
T - Thermal  N - Nuclear

**UPSEB: Generation Capacity Expansion Schedule I - State Sector Projects (MW)**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Station - No. of Units x MW Rating</th>
<th>Capacity</th>
<th>Commissioning Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ongoing &amp; Sanctioned Schemes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Hydel Khara 3x24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Lakhwar Vyasi 3x100+2x60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Srinagar 6x53.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Tehri - I 4x250</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(U.P. - Central share 60:40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Maneri Bhali - II 4x76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Thermal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Anpara 'A' 3x210</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Unchahar 2x210</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Tanda 4x110</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Anpara 'B' 2x500</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Unchahar Extn.* 3x210</td>
<td>105</td>
<td></td>
</tr>
</tbody>
</table>

*Project of Uttar Pradesh Rajya Vidyut Utpadan Nigam.*
TABLE 6.17

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Station (No. of Units x MW rating)</th>
<th>UP's % share in capacity (MW)</th>
<th>Capacity availability to U.P. on commissioning year of</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Singrauli (3x200)</td>
<td>150 @ 25%</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>Singrauli Extn. (2x200)</td>
<td>200 @ 50%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Rihand S.T. (2x500)</td>
<td>500 @ 50%</td>
<td>250 250</td>
</tr>
<tr>
<td>3</td>
<td>Rihand Extn. (2x500)</td>
<td>446 @ 44.64%</td>
<td>112 223 111</td>
</tr>
<tr>
<td>4</td>
<td>Auraiua (GT) (6x100)</td>
<td>270 @ 44.64%</td>
<td>23 90 90 67</td>
</tr>
<tr>
<td>5</td>
<td>Anta (GT) (3x100)</td>
<td>150 @ 34.64%</td>
<td>53 75 22</td>
</tr>
<tr>
<td>6</td>
<td>Muradnagar (Dodri) (4x210)</td>
<td>84 @ 10%</td>
<td>11 42 31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Narora (2x235)</td>
<td>210 @ 44.64%</td>
<td>105 105</td>
</tr>
<tr>
<td>8</td>
<td>RAPP Extn. (2x235)</td>
<td>164 @ 34.64%</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chamara (H.P) (3x180)</td>
<td>183 @ 45%</td>
<td>61 122</td>
</tr>
<tr>
<td>10</td>
<td>Tanakpur (U.P.) (3x40)</td>
<td>54 @ 45%</td>
<td>54</td>
</tr>
<tr>
<td>11</td>
<td>Dulhasti (J&amp;K) (3x130)</td>
<td>132 @ 34%</td>
<td>44 88</td>
</tr>
<tr>
<td>12</td>
<td>Uri (J&amp;K) (4x120)</td>
<td>164 @ 34%</td>
<td>82 82</td>
</tr>
<tr>
<td>13</td>
<td>Nathpa Jhakri (6x250)</td>
<td>510 @ 34%</td>
<td>85 170</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>350 362 601 420 287 187 181 209 506</td>
<td></td>
</tr>
</tbody>
</table>

- H - Hydro  G - Gas  T - Thermal  N - Nuclear

UPSEB: Generation Capacity Expansion Schedule II - Central Sector Projects
22 MW as against installed capacity of single unit of 24 MW due to some restraint in availability of water. After a few years Khara Project will attain its full capacity of 3x24 MW. In Tehri project State share is only sixty per cent. The commissioning of Unchachar Extension project of 3x210 MW has been entrusted to newly set up UP Rajya Vidyut Utpadan Nigam. Total generation from this project will be sold to UPSEB for further distribution to consumers. The total addition to the generation capacity of Uttar Pradesh system will be 7,869 MW including U.P.'s share in Central Sector Projects.

To estimate marginal capacity cost of generation, schedule of yearly investments on each of the schemes is given in Table 6.18. Only those schemes have been included which will become operational in the period 1985-95. The yearly investment upto the year 1986-87 are actual, for the year 1987-88 proposed outlay and for 1988-89 and 1989-90 are as per State Plan estimates. The total cost of the project has been estimated with reference to 1985-86. Since the total estimated expenditure is known, the balance of the investment expenditure has been phased out in consultation with UPSEB planners over the rest of the time period of the projects to become operational.

The perspective plan of Uttar Pradesh includes several new hydel and thermal schemes to substantially improve the availability of the state's power system in the coming years. Some of these have been newly started and are under generation and would yield benefits only in the ninth or tenth five year plan. There are, however, five hydel and
<table>
<thead>
<tr>
<th>Year of Commisioning</th>
<th>Khara Lakhwar Srinagar Tenri-I</th>
<th>Maneri Anpara Unchahar Tanda Anpara 'B' Extn.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>162.00</td>
<td>254.00</td>
<td>370.23</td>
</tr>
<tr>
<td>1979-80</td>
<td>4.97</td>
<td>6.45</td>
<td></td>
</tr>
<tr>
<td>1980-81</td>
<td>5.26</td>
<td>7.44</td>
<td></td>
</tr>
<tr>
<td>1981-82</td>
<td>5.26</td>
<td>1.66</td>
<td></td>
</tr>
<tr>
<td>1982-83</td>
<td>5.25</td>
<td>1.86</td>
<td></td>
</tr>
<tr>
<td>1983-84</td>
<td>10.64</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>1984-85</td>
<td>13.83</td>
<td>4.22</td>
<td></td>
</tr>
<tr>
<td>1985-86</td>
<td>16.15</td>
<td>4.25</td>
<td></td>
</tr>
<tr>
<td>1986-87</td>
<td>25.07</td>
<td>6.34</td>
<td>2.27</td>
</tr>
<tr>
<td>1987-88</td>
<td>35.00</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>1988-89</td>
<td>30.00</td>
<td>20.00</td>
<td>25.00</td>
</tr>
<tr>
<td>1989-90</td>
<td>10.57</td>
<td>40.00</td>
<td>50.00</td>
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<td>1990-91</td>
<td>50.00</td>
<td>100.00</td>
<td>25.00</td>
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<td>50.00</td>
<td>100.00</td>
<td>25.00</td>
</tr>
<tr>
<td>1992-93</td>
<td>49.50</td>
<td>82.96</td>
<td>25.00</td>
</tr>
<tr>
<td>1993-94</td>
<td>25.00</td>
<td></td>
<td>75.00</td>
</tr>
<tr>
<td>1994-95</td>
<td>24.79</td>
<td></td>
<td>74.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4459.80</td>
</tr>
</tbody>
</table>
five thermal station projects which are scheduled to get completed by the end of eighth plan. The hydel stations are Khara, Lakhwar Vyasi, Srinagar, Tehri-I and Maneri Bhali II. Of these Lakhwar Vyasi and Tehri are multi-purpose projects, inter alia, covering building of reservoirs for irrigation sector. Srinagar is a run-of-river composite hydro-electric project in the Alaknanda valley in Garhwal Himalayas to provide peaking capacity of 320 MW and 1168 MU annual energy. This composite project has a complementary thermal project that includes installation of additional coal handling plant at Obra 'B' power station and replacement of boilers at Harduaganj 'A' alongwith a project for associated transmission system. While the total cost of the composite project is Rs.601.59 crores, Srinagar hydro project alone will cost Rs.370.23 crores and only the later component has been taken into account. Maneri Bhali II involves construction of a barrage near Uttarkashi town on river Bhagirathi. Khara power station is on river Yamuna. Among the thermal projects Anpara stations are located near village Anpara on the left bank of Rihand reservoir near Renusagar Thermal Power Station; Tanda is on the west of Mehripur pumping station and Unchahar is in district Rae Bareili.

It is important to note that some of the projects were approved long before but the commissioning schedule of these projects had slipped due to non-availability of requisite funds to the project and other problems resulting in cost escalation and delay in power capacity availability. Projects like Anpara 'A', Tanda, Unchahar were sanctioned in
79-80. Tehri was sanctioned as early as 1972. These projects could not progress at scheduled pace on account of constraint of resources and delay in environmental clearances. The projects that are submitted for bilateral assistance also have a slow start. These factors disturb the optimal capacity expansion plan. However, given yearly investments on different schemes, total yearly investments have been computed on the generation system as given in Table 6.18.

**Estimates of Marginal Generation Capacity Cost**

Given the investment schedule and corresponding additions to the capacity in Table 6.19 Average Incremental Cost (AIC) method has been used to estimate the marginal generation capacity cost. Streams of investment and capacity addition in different years have been discounted at 12 per cent. All the estimates are made at 1985-86 prices. Average cost per KW addition to capacity, based on the present value of total investments and additions to the capacity comes to Rs.14800.48 per KW.

As in the case of Tamil Nadu, the operation and maintenance costs associated with investment are assumed 2.5 per cent of the capital investment. For annuitisation of cost, the life of the generating equipment is assumed to be 30 years and the rate of discount 12 per cent. Overall auxiliary consumption has been assumed to be 10 per cent and reserve capacity margin needed for reliable functioning of the system has been assumed at 40 per cent.

With these assumptions, the marginal generation capacity

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TABLE 6.19

UPSEB: Marginal Generation Capacity Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Investment (Rs. Crores)</th>
<th>Discount Factor (12%)</th>
<th>Present Worth of Investment (Rs. crores)</th>
<th>Addition to capacity (MW)</th>
<th>Present Worth of capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1979-80</td>
<td>85.90</td>
<td>1.973823</td>
<td>169.55</td>
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<tr>
<td>1980-81</td>
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<td>1.762342</td>
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<td>1981-82</td>
<td>140.95</td>
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<td>221.79</td>
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<td>1.404928</td>
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<tr>
<td>1984-85</td>
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<td>1986-87</td>
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<td>475</td>
<td>378.67</td>
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<td>1988-89</td>
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<td>450.20</td>
<td>585</td>
<td>416.39</td>
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<td>0.635518</td>
<td>359.64</td>
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<td>1990-91</td>
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<td>203.71</td>
<td>55</td>
<td>31.21</td>
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<td>1991-92</td>
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<td>0.506631</td>
<td>150.72</td>
<td>614</td>
<td>311.07</td>
</tr>
<tr>
<td>1992-93</td>
<td>232.46</td>
<td>0.452349</td>
<td>105.15</td>
<td>1535</td>
<td>694.36</td>
</tr>
<tr>
<td>1993-94</td>
<td>100.00</td>
<td>0.403883</td>
<td>40.39</td>
<td>465</td>
<td>187.81</td>
</tr>
<tr>
<td>1994-95</td>
<td>99.10</td>
<td>0.360610</td>
<td>35.74</td>
<td>660</td>
<td>238.00</td>
</tr>
</tbody>
</table>

Total 4459.80 3753.15 4786 2535.83

Capital Cost per kW = (3753.15x10^5)/(2535.83x10^3) = 14800.48
cost per KW per month has been calculated as below:

\[ C_{gbb} = \frac{1}{12}[A.C_k (1+Q)+O&M_t] LfA \]

where:

\( C_{gbb} \) = Marginal generation capacity cost per KW demanded at the busbar of the generating station per month.

\( A \) = Annuitizing factor

\( C_k \) = Marginal generation capacity cost per kw of capacity

\( Q \) = Reserve capacity Margin

\( LfA \) = Loss factor due to auxiliary consumption

In our case:

\[ C_{gbb} = \frac{1}{12}[0.12415 \times 14800.48(1+0.4)+0.025 \times 14800.48(1+0.4)] \frac{1}{0.9} \]

= 286.16

To compute marginal generation capacity cost at various voltages of supply, correction for peak period transmission and distribution losses has been applied. Using peak period loss factors, marginal costs at different voltages are as follows:

\[ C_{g EHV} = \frac{1}{305.15} \frac{1}{1-0.06223} = 305.15 \]

\[ C_{g HV} = \frac{1}{345.13} \frac{1}{1-0.115853} = 345.13 \]

\[ C_{g LT} = \frac{1}{397.39} \frac{1}{1-0.1315} = 397.39 \]

Taking alternative assumptions of reserve margin and system losses, the marginal generation capacity cost per
kw per month would be as under.

\[
C_{gbb} = \frac{1}{12} \left[ 0.124144 \times 14800.48 (1+0.25) + 0.025 \times 14800.48 (1+0.25) \right] = 216.94
\]

Marginal generation capacity costs at various voltages at alternative assumptions of system losses work out as under:

\[
C_{gEHV} = \frac{216.94}{1-0.033} = 224.35
\]

\[
C_{gHV} = \frac{224.35}{1-0.066} = 240.20
\]

\[
C_{gL} = \frac{240.20}{1-0.066} = 257.18
\]

The marginal capacity costs at various voltages have been presented in the Table below:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Voltage of Supply</th>
<th>Cost per kW demand at peak period per month (Rs/kW)</th>
<th>Scenario I</th>
<th>Scenerio II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>At busbar</td>
<td>286.16</td>
<td>216.94</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>At EHV end</td>
<td>305.15</td>
<td>224.35</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>At HV end</td>
<td>345.13</td>
<td>240.20</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>At LT end.</td>
<td>397.39</td>
<td>257.18</td>
<td></td>
</tr>
</tbody>
</table>

Marginal Transmission Capacity Cost

**Investment Plan for Transmission System**

As stated earlier, with the increase in demand at the
peak period associated transmission and transformation capacities also need to be expanded along with the addition to generation capacities. In Uttar Pradesh due to fast development of load both in urban and rural areas, the transmission and transformation system, particularly the secondary distribution system, is already over-burdened. Also due to inadequacy of the generating capacity vis-a-vis the peak demand, only limited hour supply is being given in rural areas. The rural distribution system is being used to feed the entire connected load simultaneously. The diversity of the system has disappeared. Thus the power demanded is more than the available supply in the state. So the transmission network expansion programme is based on the electric power supply availability rather than power demanded by the consumers.

In the case of transmission, investment in EHV system is generally lumpy and once it is made in the EHV system, it tapers off for sometime after the heavy expenditure during a period of five years or so. In the past, Transmission and Distribution System in the State has grown to cope with the increase in demand for energy. It has, therefore, been assumed that the transmission system on which investment is made and the available supply of energy are optimally adjusted for the period under consideration.

With increasing concentration of power generating capacity, both of State Electricity Board and National Thermal Power Corporation in the eastern Uttar Pradesh, bulk power has to be transmitted over long distance to the Western
part of the State having major load centres. The 400 KV system developed some years ago in the primary network for transmission of this power is now proving inadequate and will not be able to cater to the large bulk of power which would need transmission by the year 2000. A major 1500 MW High Voltage Direct Current (HVDC) transmission system is already being constructed by National Thermal Power Corporation from East to West. The State Electricity Board has decided to develop higher A.C. transmission voltage system of 765 KV in 800 range for Uttar Pradesh. As in the case of 400 KV system, Uttar Pradesh is the first State to develop 765 KV system. A single circuit 765 KV line will transmit as much power as would be transmitted by 4 circuits of 400 KV. The cost of construction of single circuit 765 line is expected to be Rs.18.23 lakh per kilometer against Rs.19.0 lakhs per kilometer for 400 KV double circuit transmission line and the operating expenses for 1000 MVA at 765 KV compared to 400 KV are nearly 35 per cent less. In the first stage 765 KV line is planned during Eighth plan from Anpara Power Station to Unnao in Central UP followed by another such line from Tehri Project to Mowana near Meerut.

The Board's transmission plan for the year 1985-2000 has proposed construction of 900 ckt.km. 765 kv lines, 10278 ckt.km 400 kv lines, 7265 ckt.km. 220 kv and 5600 ckt km 132 kv transmission lines. It also envisages construction of 3600 sub-stations for 800 kv, 8815 sub-stations for 400 kv, 11460 sub-stations for 220 kv and 9350 sub-stations for 132 kv.

The Uttar Pradesh State Electricity Board, however, has
a firm plan for the expansion of transmission network for the period 1985-90 that is for the Seventh Five Year Plan only. Projections of proposed expenditure worked out by the Board for the years beyond 1990 are based on projected requirements and are not the firm investment plan outlays. The UPSEB has scheduled investment programme for EHV projects and sub-transmission and distribution system for Seventh Plan as given in Table 6.21. The investment plan covers both lines and sub-stations for suitably expanding the transmission and distribution system so as to evacuate extra power generation and to provide additional transformation capacity commensurate with the load likely to come up on the system.

**TABLE 6.21**

<table>
<thead>
<tr>
<th>Year</th>
<th>EHV (400/220/132)</th>
<th>HV (33/11)</th>
<th>LT (400v &amp; below)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>49.81</td>
<td>48.87</td>
<td>10.42</td>
<td>109.10</td>
</tr>
<tr>
<td>1986-87</td>
<td>67.03</td>
<td>48.90</td>
<td>10.43</td>
<td>126.36</td>
</tr>
<tr>
<td>1987-88</td>
<td>110.00</td>
<td>65.11</td>
<td>13.89</td>
<td>189.00</td>
</tr>
<tr>
<td>1988-89</td>
<td>120.00</td>
<td>70.00</td>
<td>15.00</td>
<td>205.00</td>
</tr>
<tr>
<td>1989-90</td>
<td>140.00</td>
<td>82.42</td>
<td>17.58</td>
<td>240.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>486.84</strong></td>
<td><strong>315.30</strong></td>
<td><strong>67.32</strong></td>
<td><strong>869.46</strong></td>
</tr>
</tbody>
</table>

Estimating Marginal Transmission Capacity Cost:

The additional capacity which will generate energy to be carried by the corresponding additional voltage-wise transmission and distribution capacity being created by the investment over the period 1985-90 has been estimated. As
already stated above the demand estimates are much higher than the electric power availability so that it will be a correct presumption that the whole of available capacity will be fully utilized at the peak period and will equal demand which will be met at various voltage levels. Thus the expansion of transmission and distribution network is a function of the likely availability of electric power rather than anticipated demand for power by the consumers. It is assumed that the yearly investments made and additions to the capacity are fully utilized in the corresponding years. The power carried will be equal to the peak availability at various voltage levels. The peak availability of power at various voltage levels has been estimated in Table 6.22. Given the investment plan and corresponding additions to the power availability, applying average incremental cost method, marginal cost per kW is estimated in Table 6.23. The estimated marginal capacity cost per kW at EHV is Rs.3003.32 whereas at HV it is estimated to be Rs.2616.65.

To estimate marginal transmission capacity cost per kW per month, the life of the EHV (400/220/132 kv) system has been assumed to be 35 years and that of HV system 30 years. The operation and maintenance costs for the EHV system are assumed to be 1.5 per cent and that of HV system 2 per cent of the marginal transmission capacity costs. The costs are annuitized at 12 per cent of discount and the marginal capacity cost per kW per month for the EHV system and the HV system computed as follows.

\[ CTV = \frac{1}{12}(A.Ctv+O&M)L.F. \]
TABLE 6.22

UPSEB: Additional Capacity Available at Different Voltages 1985-90

<table>
<thead>
<tr>
<th>Year</th>
<th>UPSEB System share in 2 + 3 to peak 5 x 0.9 (MW)</th>
<th>UPSEB's Central Sector (MW) capacity ACF</th>
<th>Total Addition at Busbar Losses at EHV (6)-(7) (MW)</th>
<th>Capacity Addition at EHV (6) (MW)</th>
<th>Trans. Loss at mission loss at EHV (6) (Mil)</th>
<th>Consp.-Trans. Line Consump. at EHV end to HT (6) (Mil)</th>
<th>Trans. Line Consump. at HT end to LT (6) (Mil)</th>
<th>Line Consump. at LT end (6) (Mil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>350</td>
<td>300</td>
<td>210</td>
<td>189</td>
<td>9.07</td>
<td>179.93</td>
<td>29.48</td>
<td>150.45</td>
</tr>
<tr>
<td>1986-87</td>
<td>105</td>
<td>-</td>
<td>63</td>
<td>56.7</td>
<td>2.72</td>
<td>53.98</td>
<td>8.85</td>
<td>45.13</td>
</tr>
<tr>
<td>1987-88</td>
<td>475</td>
<td>362</td>
<td>837</td>
<td>502.2</td>
<td>21.70</td>
<td>430.28</td>
<td>70.51</td>
<td>359.77</td>
</tr>
<tr>
<td>1988-89</td>
<td>585</td>
<td>601</td>
<td>1186</td>
<td>711.6</td>
<td>30.74</td>
<td>609.7</td>
<td>99.91</td>
<td>509.79</td>
</tr>
<tr>
<td>1989-90</td>
<td>292</td>
<td>420</td>
<td>712</td>
<td>384.48</td>
<td>18.46</td>
<td>366.02</td>
<td>59.98</td>
<td>306.04</td>
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</table>

Scenario II

<table>
<thead>
<tr>
<th>Year</th>
<th>75% of 4 (MW)</th>
<th>3% of (6) (MW)</th>
<th>17% of (6) (MW)</th>
<th>6% of (6) (MW)</th>
<th>14% of (6) (MW)</th>
<th>6% of (6) (MW)</th>
<th>54% of (6) (MW)</th>
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</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>350</td>
<td>262.5</td>
<td>236.25</td>
<td>7.09</td>
<td>40.16</td>
<td>189</td>
<td>14.18</td>
</tr>
<tr>
<td>1986-87</td>
<td>105</td>
<td>78.75</td>
<td>70.88</td>
<td>2.13</td>
<td>12.04</td>
<td>56.71</td>
<td>4.25</td>
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<td>1987-88</td>
<td>475</td>
<td>627.75</td>
<td>564.98</td>
<td>16.95</td>
<td>548.03</td>
<td>451.98</td>
<td>33.90</td>
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<td>1988-89</td>
<td>585</td>
<td>889.5</td>
<td>800.55</td>
<td>24.02</td>
<td>776.53</td>
<td>640.44</td>
<td>48.03</td>
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<tr>
<td>1989-90</td>
<td>292</td>
<td>712</td>
<td>534</td>
<td>480.6</td>
<td>466.18</td>
<td>384.48</td>
<td>28.84</td>
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**Assumptions** (per cent)

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<th>Scenario I</th>
<th>Scenario II</th>
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<tr>
<td>Reserve Capacity Margin</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>Auxiliary Consumption</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>T &amp; D Losses (of supply at bus)</td>
<td>EHV 4.8</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>HV 7.1</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>LT 6.2</td>
<td>6.0</td>
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</table>

323
<table>
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<tr>
<th>Year</th>
<th>Investment (Rs crores)</th>
<th>Capacity Available (MW)</th>
<th>Discount Factor (At 12%)</th>
<th>Present value of Investment (Rs.crores)</th>
<th>Present value of capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>49.81</td>
<td>179.93</td>
<td>1.000000</td>
<td>49.81</td>
<td>179.93</td>
</tr>
<tr>
<td>1986-87</td>
<td>67.03</td>
<td>53.98</td>
<td>0.892857</td>
<td>59.85</td>
<td>48.20</td>
</tr>
<tr>
<td>1987-88</td>
<td>110.00</td>
<td>430.28</td>
<td>0.797194</td>
<td>87.69</td>
<td>343.02</td>
</tr>
<tr>
<td>1988-89</td>
<td>120.00</td>
<td>609.07</td>
<td>0.711780</td>
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<td>433.97</td>
</tr>
<tr>
<td>1989-90</td>
<td>140.00</td>
<td>366.02</td>
<td>0.635518</td>
<td>88.97</td>
<td>232.61</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>486.84</strong></td>
<td><strong>1633.91</strong></td>
<td></td>
<td><strong>371.73</strong></td>
<td><strong>1237.73</strong></td>
</tr>
</tbody>
</table>

Capital Cost per kW = \( \frac{37173 \times 10^5}{1237.73 \times 10^6} \) = 3003.32

**Scenario II**

<table>
<thead>
<tr>
<th>Year</th>
<th>Investment (Rs crores)</th>
<th>Capacity Available (MW)</th>
<th>Discount Factor (At 12%)</th>
<th>Present value of Investment (Rs.crores)</th>
<th>Present value of capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>49.81</td>
<td>229.16</td>
<td>1.000000</td>
<td>49.81</td>
<td>229.16</td>
</tr>
<tr>
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<td>67.03</td>
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<td>59.85</td>
<td>61.84</td>
</tr>
<tr>
<td>1987-88</td>
<td>110.00</td>
<td>548.03</td>
<td>0.797194</td>
<td>87.69</td>
<td>436.89</td>
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<td>0.711780</td>
<td>85.41</td>
<td>552.72</td>
</tr>
<tr>
<td>1989-90</td>
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<td>466.18</td>
<td>0.635518</td>
<td>88.97</td>
<td>296.27</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>486.84</strong></td>
<td><strong>2088.65</strong></td>
<td></td>
<td><strong>371.73</strong></td>
<td><strong>1576.88</strong></td>
</tr>
</tbody>
</table>

Capital cost per kW = \( \frac{(37173 \div 1576.88) \times 100}{100} \) = 2357.38
where

\[
\text{CTV} = \text{the marginal transmission capacity cost per kW demand per month at the supplying end of the transmission line at a voltage 'V'}
\]

\[
A = \text{Annuity factor (assuming 35/30 years life of lines & sub-stations)}
\]

\[
\text{Ctv} = \text{The marginal transmission capacity cost per kW}
\]

\[
\text{O&M} = \text{Operations & Maintenance Cost}
\]

\[
\text{L.F.} = \text{Loss factor due to transmission losses at a given voltage.}
\]

In the case of Uttar Pradesh:

\[
\frac{1}{12} \left[ 0.122317 \times 3003.32 + 0.015 \times 3003.32 \right] \frac{1}{1-0.06223} = 36.65
\]

\[
\frac{1}{12} \left[ 0.124144 \times 2616.65 + 0.02 \times 2616.65 \right] \frac{1}{1-0.115853} = 35.55
\]

Thus the marginal transmission capacity cost per kW per month for EHV system works out to be Rs. 36.65 per kW and for HV system Rs. 35.55/kW.

The transmission capacity cost per kW demand at the peak period per month at various voltages, on alternative assumptions of system losses work out as under:

\[
\frac{1}{12} \left[ 0.122317 \times 2357.38 + 0.025 \times 2357.38 \right] \frac{1}{0.967} = 27.90
\]

\[
\frac{1}{12} \left[ 0.124144 \times 2050.82 + 0.02 \times 2050.82 \right] \frac{1}{0.934} = 26.38
\]

The Marginal Distribution Capacity Cost (LT level)

Normally distribution system consists of that component
### TABLE 6.24

<table>
<thead>
<tr>
<th>Year</th>
<th>Investment</th>
<th>Scenario I Capacity (MW)</th>
<th>Discount Factor</th>
<th>Scenario I Present Value of Investment (Rs. Crores)</th>
<th>Scenario II Capacity (MW)</th>
<th>Present Value of Capacity (Rs. Crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>48.87</td>
<td>137.03</td>
<td>1.000000</td>
<td>48.87</td>
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<td>174.82</td>
</tr>
<tr>
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<td>0.892857</td>
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<td>36.70</td>
<td>52.46</td>
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<td>1987-88</td>
<td>65.11</td>
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<td>261.22</td>
<td>418.08</td>
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<td>1988-89</td>
<td>70.00</td>
<td>464.32</td>
<td>0.711786</td>
<td>49.82</td>
<td>300.49</td>
<td>592.41</td>
</tr>
<tr>
<td>1989-90</td>
<td>82.42</td>
<td>278.74</td>
<td>0.635518</td>
<td>52.38</td>
<td>177.14</td>
<td>355.64</td>
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<tr>
<td>Total</td>
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<td>1248.87</td>
<td></td>
<td>246.64</td>
<td>942.58</td>
<td>1593.41</td>
</tr>
</tbody>
</table>

**Scenario I Capital Cost per kW** = \( \frac{(246.64 \times 10^5)}{(942.58 \times 10^3)} \) = 2616.65

**Scenario II Capital Cost per kW** = \( \frac{(246.64 \times 10^5)}{(1202.64 \times 10^3)} \) = 2050.82

### TABLE 6.25

<table>
<thead>
<tr>
<th>Year</th>
<th>Investment</th>
<th>Scenario I Capacity (MW)</th>
<th>Discount Factor</th>
<th>Scenario I Present Value of Investment (Rs. Crores)</th>
<th>Scenario II Capacity (MW)</th>
<th>Present Value of Capacity (Rs. Crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985-86</td>
<td>10.42</td>
<td>103.57</td>
<td>1.000000</td>
<td>10.42</td>
<td>103.57</td>
<td>127.58</td>
</tr>
<tr>
<td>1986-87</td>
<td>10.43</td>
<td>31.07</td>
<td>0.892857</td>
<td>9.31</td>
<td>27.74</td>
<td>38.31</td>
</tr>
<tr>
<td>1987-88</td>
<td>13.89</td>
<td>247.69</td>
<td>0.797194</td>
<td>11.07</td>
<td>197.46</td>
<td>305.09</td>
</tr>
<tr>
<td>1988-89</td>
<td>15.00</td>
<td>350.96</td>
<td>0.711786</td>
<td>10.68</td>
<td>249.81</td>
<td>432.30</td>
</tr>
<tr>
<td>1989-90</td>
<td>17.58</td>
<td>210.75</td>
<td>0.635518</td>
<td>11.17</td>
<td>133.90</td>
<td>259.52</td>
</tr>
<tr>
<td>Total</td>
<td>67.32</td>
<td>943.99</td>
<td></td>
<td>52.65</td>
<td>712.48</td>
<td>1162.80</td>
</tr>
</tbody>
</table>

**Scenario I Capital Cost per kW** = \( \frac{(52.65 \times 10^5)}{(712.48 \times 10^3)} \) = 738.97

**Scenario II Capital Cost per kW** = \( \frac{(52.65 \times 10^5)}{(877.64 \times 10^3)} \) = 599.90
of transformation sub-stations which transform power from higher voltages to 11 KV, 11 KV lines and cables and LT lines and distribution transformers. In the case of Uttar Pradesh a substantial amount of power is supplied to industrial and commercial sector at EHV and HV levels. Therefore, the formulation of the distribution plan in Uttar Pradesh is based on the consideration of load development in the State on 33 kv and below. The design of network of 33 kv and below which may make optimum distribution of load on the system can help reducing the line losses which are quite high in Uttar Pradesh. The State Electricity Board has projected load development for Seventh, Eighth and Ninth Plans on the basis of past load connections in four different categories viz. (a) Domestic and Commercial (b) Industrial load (c) Private tube-wells (d) State tubewells/pumps. The total anticipated load growth for Seventh plan comes to 2922 MVA and for Eighth and Ninth plan together, it is estimated at 7000 MVA. The distribution plan of UPSEB for the years 1985-2000 takes into consideration a total load development of 10,300 MVA including the past backlog. The load development is to be augmented by constructing new 33/11 KV sub-stations. The average step down transformation capacity of this new sub-station is estimated at 4 MVA. This will require construction of 957 new 33/11 KV sub-stations and increase in capacity of 6410 existing 33/11 KV sub-stations. The actual requirement of 33 KV lines during the three plans works out to 10,360 ckt kms. The distribution plan is also based on the target to electrify all villages by 1995 as per Central Electricity
Authority's definition; and by laying LT mains by the year 2005. Financial implications for the distribution plan can be worked out on the basis of projected physical requirements of various components of Uttar Pradesh's distribution system. However, in the absence of firm distribution system expansion plan beyond 1990, marginal capacity cost has been estimated for low tension power supplies and distribution on the basis of annual investment on LT lines/cables and distribution transformers for the years 1985-86 to 1989-90 as given in Table 6.25.

Given the investment plan and corresponding increases in power availability for the period 1985-90, present value of investment schedule as well as the increments in the power distribution capacity have been computed. LT distribution capacity cost per kW has been estimated in Table 6.25 by applying Average Incremental Cost method. This works out to Rs.738.97 per kW.

To compute marginal distribution capacity cost per kW per month, it is assumed that the operation and maintenance cost associated with the LT system is 5 per cent of the marginal capacity costs. As life of the capital has been assumed to be 30 years, annuity factor is 0.124144. Peak period loss factor is 1/(1-0.1315)

On the basis of these assumptions, marginal distribution capacity cost per kW per month for LT system is as given below:-

\[ CTV = \frac{1}{12}(A.Ctu + O&Mt) \times L.F. \]

Notations have been already explained above.
The marginal distribution capacity cost per KW per month on alternative assumptions of system losses work out to be Rs. 9.32 per kW as given below:

\[
CT(LT) = \frac{1}{12} \left( 0.124144 \times 738.97 + 0.05 \times 738.97 \right) \frac{1}{1-0.1315} \\
= 12.35
\]

\[
CT(LT) = \frac{1}{12} \left( 0.124144 \times 599.90 + 0.05 \times 599.90 \right) \frac{1}{1-0.066} \\
= 9.32
\]

It may be mentioned here that each part of the distribution system is specific to that area. Therefore, the marginal cost of distribution varies significantly with the load density in any particular area. In view of the lumpiness of distribution investment, marginal cost varies in the short-run from area to area and from load increment to load increment. However, lumpiness is basically a short-run concept, and one is essentially interested in the long run marginal cost. As Turvey points out, the concept of marginal cost can never be meaningful in isolation, but has always to be regarded in relation to a specified load increment. To get a good estimate of LRMC, the load increment has to be sufficiently large. So, therefore, the presumption would be reasonable that additional distribution capacity will be optimal to meet the load increment.

Consumer Costs:

Consumer related costs consist of metering, meter reading, raising bills and collection of bills. The consumer
costs increase with the increase in connections or consumers. The Marginal consumer costs may be computed by taking increments in the indexed consumer costs as well as in the number of connections over a period. In the absence of data availability on the number of consumers and the related increase in consumer costs, which are predominantly wage bills, it is not possible to work out marginal consumer cost. However, consumer cost has been analyzed on the basis of average expenditure in obtaining meter reading and the cost of bill preparation (Appendix.V1.3) It comes to Rs.5.26 per consumer per month for consumers billed on monthly basis. It has been presumed that these costs will remain constant during the period 1985-90 and the average is equal to the marginal cost. The consumer costs for each consumer category may be different but for the purpose of the study these costs are assumed to be the same.

The Marginal Distribution Capacity Cost for Agricultural Sets

The State of Uttar Pradesh lags behind in the field of rural electrification. Rural electrification programme of the state has two main components (a) electrification of villages by providing access to domestic/street light connections in the villages and Harijan bastis and (b) additional energisation of private tube-wells/pump sets. It has been estimated that the demand of private tubewells constitutes a little over 80 per cent of the 0.4 KV rural distribution peak. However, no authentic information is available as no separate figures of maximum demand are available for rural feeders: more important the precise time-pattern of demand is
not known and can only be estimated.

For additional energisation of an agricultural pump set, more distribution capacity is required in terms of transformer capacity as well as 11/0.4 KV lines to meet one kW of demand. Therefore, the marginal distribution capacity cost will be much higher. Besides additional distribution capacity, the load density in the rural areas is much lower than urban areas. Poor load density and long distribution lines result in higher loss factors. These factors add to the costs of agricultural sets.

Rural Electrification Corporation has estimated that the average cost of energising one irrigation pump set is Rs.11,000. These costs consist of additional 11 KV and L.T. lines and transformation capacity cost. As already worked out in the case of Tamil Nadu, the annuitized cost per pump set per month is Rs. 113.80. Considering the average connected load per pump set to be 3.7 kW, this cost works out to be Rs.30.75 per kW. This is in addition to the marginal cost upto LT end. The total capital cost of supplying per kW of power to a tubewell comes out to be Rs.528.51 as given in Table 6.26.1

Marginal Cost of Supplying Power at various Voltage levels: Scenario I

In the previous section, voltage-wise cost of supplying power has been computed. The marginal generation capacity cost at different voltage levels has been presented in Table 6.20. As per scenario I assumptions the marginal costs of transmission and distribution for different components of the
system are: EHV Rs. 36.65 per kW, HV Rs. 35.55 per kW and LT distribution system Rs. 12.35 per kW. To calculate marginal cost of supply at various voltage levels, these costs have to take into account the cost increases due to peak period losses involved. These costs are corrected for transmission and distribution losses and added to get the total marginal cost of supplying power at various voltages. The peak period transmission and distribution losses are assumed to be: EHV system 6.2 per cent, HV system 11.6 per cent, and LT distribution system 13.2 per cent. The results are presented in Table 6.26.1 given below.

Table 6.26.1
Marginal Cost of Supply at various voltage levels

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Voltage of Supply</th>
<th>Marginal Capacity Cost (Rs. per kW per month)</th>
<th>Marginal Energy Cost (P/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Generation EHV</td>
<td>HV</td>
</tr>
<tr>
<td>1</td>
<td>Generation</td>
<td>286.16</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(at Busbar)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>EHV end</td>
<td>305.15</td>
<td>36.65</td>
</tr>
<tr>
<td>3</td>
<td>HV end</td>
<td>345.13</td>
<td>41.45</td>
</tr>
<tr>
<td>4</td>
<td>LT end</td>
<td>397.39</td>
<td>47.73</td>
</tr>
<tr>
<td>5</td>
<td>Tubewell</td>
<td>397.39</td>
<td>47.73</td>
</tr>
</tbody>
</table>

Consumer Connection per month = Rs. 5.26

Marginal cost of supplying power at various voltage levels on alternative assumptions of desired level of reserve capacity margin and system losses as separately worked out above are given in Table 6.26.2.
TABLE 6.26.2.

UPSEB: Marginal Cost of Supply at Various Voltage levels

Scenario-II

<table>
<thead>
<tr>
<th>Sl. Supply No.</th>
<th>Voltage</th>
<th>Marginal Capacity Cost per month (Rs/kw)</th>
<th>Marginal Energy Cost (P/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Generation EHV HV LT Total</td>
<td></td>
</tr>
<tr>
<td>1. At Busbar</td>
<td></td>
<td>216.94 -- -- -- 216.94 53.21</td>
<td></td>
</tr>
<tr>
<td>2. EHV end</td>
<td></td>
<td>224.35 27.90 -- -- 252.25 55.87</td>
<td></td>
</tr>
<tr>
<td>3. HV end</td>
<td></td>
<td>240.20 29.87 26.38 -- 296.45 61.46</td>
<td></td>
</tr>
<tr>
<td>4. LT end</td>
<td></td>
<td>257.18 31.98 28.24 9.32 326.72 68.22</td>
<td></td>
</tr>
<tr>
<td>5. Agricultural Pump sets</td>
<td></td>
<td>257.18 31.98 28.24 40.07* 357.47 68.22</td>
<td></td>
</tr>
</tbody>
</table>

*LT-end cost plus Agricultural pump set cost per kW. Consumer cost per connection per month of Rs.5.26 to be added.

In the Table 6.26.1 and 6.26.2 marginal capacity costs of generation, transmission and distribution have been added taking simultaneity factors equal to 1 for the same reasons as stated in the case of Tamil Nadu Electric power system (See Section V.4)

The Tariff Structure Based on Marginal Costs:

If price is to be made equal to the marginal cost of supply, at the peak period, price from the low tension consumers (400 volts/230 volts) should be equal to Rs.497.71 per kW per month plus 68.22 paise per unit for the energy consumption and at the off-peak period, price should be equal to 68.22 paise per unit of the energy consumed. From HV consumers, price at peak period should be Rs.422.13 per kW demanded per month plus 61.46 paise per unit for the total energy consumption and at off-peak period only energy cost 61.46 paise per unit should be charged. As Uttar Pradesh is
also facing an acute shortage of power as well as energy, it is recommended that full marginal cost based prices should be charged at peak as well as off-peak consumption from all the categories of consumers.

For the small consumers, two part tariff is costly because of higher metering costs. Therefore, price at a flat rate should be charged. The price at a flat rate has been calculated for L.T. and HV consumers as follow:

\[ p = \frac{f}{h \cdot l} + v \]

where:
- \( p \) = price per unit of energy
- \( f \) = marginal capital cost per kW
- \( h \) = number of hours for which energy is supplied in a month
- \( l \) = Load factor
- \( v \) = marginal energy cost

In this case

\[ p_{LT} = \frac{497.71 \times 100}{730 \times 1} + 68.22 = 136.40 \]

\[ p_{HV} = \frac{422.13 \times 100}{730} + 61.46 = 119.29 \]

Thus price for HV consumers should be 119.29 paise per unit and L.T. consumers 136.40 paise per unit.

Cost of supply at LT end on alternative assumptions of

Scenario II would be

\[ p_{LT} = \frac{326.72 \times 100}{730 \times 1} + 68.22 = 112.98 \]

and at HV end

\[ p_{HV} = \frac{296.45 \times 100}{730 \times 1} + 61.46 = 102.07 \]

It is pertinent here to mention that Tariff
Rationalisation Committee set up by the Government of Uttar Pradesh in 1986 made an attempt to work out incremental costs (capacity and energy cost) of new generating capacity proposed to be added during 1985-90 as a good approximation to LRMC. The incremental cost based on new thermal capacity coming up during 1985-90, together with transmission and distribution costs as worked out by the Committee are given in Appendix VI.4. The average price per unit on this basis comes to approximately 118 paise per unit which is quite close to the estimate of LRMC in the present study.

The comparison of marginal cost based prices with the existing tariff structure (introduced w.e.f. 01-06-86, Appendix VI.6) shows that all the consumers are paying less than the marginal cost of supplying power. As the cost is increasing, it is recommended that marginal cost based prices be introduced in phased manner.

4. Long run marginal cost (LRMC) calculations taking different load factors on the basis of assumptions of diversity factors are summarised in Appendices VI.5.1 and VI.5.2.