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PROBLEMS OF PLANT AND SYSTEM DEVELOPMENT

by

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NOTE: This text is subject to technical and editorial revision.

PROBLEMS OF PLANT AND SYSTEM DEVELOPMENT

This paper outlines general considerations to be taken into account before deciding on plant and system development.

At the beginning, a summary is given of the most important information that should be on hand before attempting to determine what is the approoriate solution.

As suggested to authors, the first section reviews different types of generating stations indicating features which make some selection particularly obvious for a given set of conditions.

In section II, advantages and disadvantages to be derived from interconnections are listed and commented on briefly.

Section III describes particular features of thermal and hydro generating stations. It also suggests how to obtain maximum benefit from their combined use and lists type of information that should be readily available to load dispatchers.

Section IV outlines considerations particular to a new are where existing facilities are very limited.

Section V brings out different criteria for the determination of priorities in electricity development emphasizing difference between government owned and privately-owned utilities.

/PROBLEMS OF

PROBLEMS OF PLANT AND SYSTEM DEVELOPMENT

Before dealing explicitly with problems of plant and system development, we would like to review the information which must be available to those having the responsibility for taking decisions in this respect. We understand that such considerations have been dicussed under parts I and II of this seminar, but to substantiate our thinking, we would assume that details have been obtained on the following:

1. Load forecast for nest decade or so, and characteristics of load with regard to seasonal, weekly and daily fluctuations, both in demand and energy.
2. Approximate geographical distribution of important loads.
3. Type of load with regard to necessity of continuity of service; whether, for instance, it is for local industrial mills or for public distribution in urban areas.
4. Possibilities of revenues from sale of off-peak or secondary energy.
5. Thorough survey of hydroelectric possibilities of rivers within economic transmission distance.
6. Determination of unusual hazards that may imperil plant or line construction (earthquakes, landslides, tornadoes, sleet storms, forest fires, local floods, etc.).
7. Availability and cost of fuel for thermal generation.

One of the first answers to be obtained is the optimum capacity factor for the expected load factor of the system. To that end, a curve may be drawn showing the forecasted annual peak load and energy consumption. An indication is so obtained of the future trend in load factor, whether increasing or decreasing.

By comparing such trend with the actual performance of the system, both as to peak load and annual energy, the desirable capacity factor of future installations can be derived.

/It is

It is also useful at this early stage to analyse carefully the characteristics of the load curve and determine the energy content in the higher blocks of the demand duration curve. If such energy content is very low for an important block, this will point out the advisability of considering peak-shaving plant, consisting of low-cost thermal installation.

I. TYPE OF GENERATING STATIONS

Hydro or Thermal

The choice is generally dictated by the availability of natural resources within acceptable distances and by the characteristics of load. Generally speaking, hydro power is considered to be a cheaper source of power with a load factor in excess of a given minimum. Factors which may contribute to swing the balance in favor of thermal power are:

a) Remoteness of adequate hydraulic sites;
b) Lack of storage facilities and occurrence of very low run-off periods;
c) Proximity to low cost fuel supply and/or market for steam in industrial processes;
d) Load factor inferior to 15 or 20 per cent.

Where capital initially available is very limited and money cannot be borrowed easily, thermal power will be preferred since a larger installation can be built for a given cost. However, as mentioned before, annual operating costs will generally be higher.

Size

An important consideration is the ability to match generating capacity with expected load curve, thus avoiding investing money for which no immediate return is to be expected. For a small system, this may eliminate consideration of good hydro sites on large rivers, where civil engineering works would make the unit cost of power prohibitive until full development has been reached.

Bulkhead or tunnel

As mentioned previously, unless large storage reservoirs are possible, the annual energy capacity of a hydro site is generally fixed by nature within rather narrow limits. However, with vastly improved methods of

/tunnelling, special

tunnelling, special investigation of the possibility of concentrating a high head at a given point will often permit very noticeable savings, and the more so, when rock conditions are favorable. That was particularly the case with our Bersimis river plants, where preliminary mass inventory of provincial hydro resources had indicated a probable total installation of about 250,000 H.P. and where detailed aerial surveys and field explorations have permitted us to install 2,000,000 H.P. Though the use of tunnels, one 13,500 meters long and the other one, 750 meters long, it was possible to concentrate at two sites a total drop of 377 meters over a 29-kilometer stretch.

Where river flows are considerable, in the order of 700 cubic meters per second or more, the cost of a tunnel and the head loss rapidly assume major importance. In the case of another site it was concluded that with a 15-meter concrete-lined power tunnel, it would be necessary for the river profile to fall an average of 8.5 meters per kilometer between the dam site and the powerhouse site, in order that the use of such a tunnel be economic.

Underground construction

Underground powerhouses have become more common in recent years. In many cases, savings are possible where rock foundations would be poor near ground elevation, or if location of a plant at the foot of a high steep hill would expose it to landslides or avalanches. This applies also in the case of high-head plants, where the cost of bringing out a number of penstocks and building them to withstand very high pressures is in excess of excavating them in the mountain. For protection against possibility of civil disturbances or sabotage, underground stations are evidently safer and easier to protect.

Power Dam

When the power dam is a separate structure from the generating station, its construction may give an opportunity to consider several alternative designs. If transportation to the site is very expensive and prolonged cold periods are likely to prevail, use and storage of cement may prove expensive. Rock-fill dams which are now built for

/heads exceeding

heads exceeding five hundred feet are often an economic solution, especially where suitable materiales can be found near by. Recent studies have shown for one case that total costs of a gravity concrete dam and a rock-fill dam would be equal if the ratio of the corresponding prices for rock-fill and concrete were approximately 1 to $4\frac{1}{2}$.

A tight construction schedule of the probability of estended rainy periods hampering the placing of clay or impervious blanket may favor the use of concrete. The necessity of providing ample spilling capacity in a narrow valley or gorge may also rule out the rock-fill dam alternative.

Outdoor type station

On account of difficult climatic climatic conditions resulting from long and severe winters, we have not, so far, utilized the outdoor type of generating station. The occurrence of minimum river flows and the piling up of ice in intake canals offer an opportunity to effect major overhauls of generating units during winter at stations where production is curtailed during such period. Because two or three units may be stopped for work, several totally enclosed powerhouse cranes would be required. Taking into account additional precautions to protect against freezing and small difference in overall installation cost, we do not believe that very appreciable savings could result from such practice. The situation would be different, of course, in more moderate climates or where only one unit is expected to be available for repairs during the winter.

Remote or automatic control

For distant locations, where access is difficult and presence of operating staff requires construction and maintenance of a townsite with all facilities requires construction and maintenance of a twonsite with all facilities involved, substantial economy can result from the use of remote or supervisory control of small or medium-size stations. But for large stations, with several hundred thousand horsepower, we have not yet found it advisable to rely exclusively on performance of equipment remotely or automatically controlled.

Where such practice is accepted, special attention must be given to the training and presence of skilled technicians because such combination of communication and relay circuits are generally beyond the competence of ordinary maintenace men.

/Size of

Size of units

Other considerations being equal, the economic size of generating units, is often found to be, for small systems, a compromise between two opposite trends: the larger the unit size and the station, the lower the unit price of a H.P., (See figure I); but depending on expected load growth, the longer will be the unproductive period until all power installed has been absorbed.

The capacity of a small or medium-size station having been established, the maximum unit rating is often dictated by the following requirement: to guarantee continuity of firm power, a spare unit equal in capacity to that of the largest on the system, must be held in reserve. On the other hand, in very large stations, other limitations relative to space, weight or strength will govern the largest size of unit to be recommended.

Turbine type

The proper type of turbine to be used, whether fixed-blade propeller, Kaplan, Francis, Pelton, Derriaz etc. has been the subject of many papers and could lead to a long treatment beyond the scope of this presentation. One must remember however, that noticeable improvements have been achieved in recent years. The recommended range of heads for which various types were specified a decade ago or so, has been extended towards a higher limit, thus enabling substantial economy to the users without having to incur cavitation or vibration difficulties.

Transmission

When powerful generating stations are located at considerable distance from the load center, the capital invested in transmission may represent a high percentage of the total cost of providing power (1/3 in some cases, for our system). The selection of proper line voltage, capacity and type of construction will offer, at first glance, many possible combinations that will prove to be more or less attractive, according to weight given to various factors such as

a) Minimum initial cost of kW that can be transmitted

b) Ease of patrolling and repairing

/c) Presence

c) Presence of local difficulties such as reggedness of country, forests and rate of growth of vegetation, termites, etc.

d) Degree of reliability expected, assuming

   1 Ordinary or average conditions

   2 Possibility of occasional forest fires

   3 Possibility of heavy sleet storm

   4 Possibility of violent hurricane

e) Degree of stability of system with given number of lines tripping out.

f) Length or permanency of service to be supplied.

In an area where rapid expansion is to take place, it may be wise and economical to provide in advance for rights of way of future transmission lines. A glance at the layout of incoming lines. A glance at the layout of incoming lines to Montreal in 1947 and eleven years later, in 1958 shows what tremendous changes have taken place. (See figures 2 and 3,) Originally, a 60 kV ring was found ample, with odd step-down stations at 12 kV and 4 kV; very soon after, a 120 kV ring had to be built around the first one, as the major link between generating stations, until recently, that was superseded by 300 kV lines terminating at three main points and encircling more than half the Metropolitain District. Some rights of way probably cost now ten times or more what they were purchased for, ten or fifteen years ago.

II. INTERCONNECTION

Advantages to be derived from interconnections are numerous and the most usual ones are mentioned hereunder.

1. It becomes possible to supply the combined loads of two or more systems with less total power resources because load characteristics are different both as to shape and period of maximum loading.

2 Maintenance can be coordinated so as to reduce reserve capacity required. Similarly, probability of unscheduled outage of equipment is reduced, thus decreasing reserve capacity to be held.

3. Surplus capacity from one system can be transferred to the other.

/Frequency regulation,

4. Frequency regulation, voltage conditions and continuity of service can be improved.
5. The amount of dependable firm power can be increased on account of stream flow diversity and coordinated utilization of reservoirs, and whenever possible, combination of hydro and steam generating plants.
6. Overall energy cost will be reduced
7. Capital investments are decreased because it becomes possible to install larger units, to stagger plant additions and to avoid duplication of transmission lines.

Figure 4 shows a diagram of Canada U.S. Eastern Interconnection.

Disadvantages are relatively few and result mostly from additional cost of equipment and supplementary staff. Possibility of protection or other equipment failure must not be overlooked.

The main disadvantages are:

a) Incremental costs resulting from annual charges on investments such as interconnecting lines, switching equipment, automatic control, communication equipment, relays and recently, computers.
b) Incremental costs resulting from additional staff required to discuss, allocate and assess benefits to be derived and expenses to be incurred.
c) If proper protection and control is not provided, faults occurring on one system may affect the other, and load changes initiated by large cyclic loads may be set up larger oscillations between systems.

III. COMBINATION OF THERMAL AND HYDRO PLANTS

As was pointed out earlier, the first step is to establish the probable load pattern and additional peak power and energy required annually. In other words, the load factor of the additional blocks of power must be determined.

Surveys for a hydro site will permit calculation of approximate annual energy available and its distribution monthly, weekly or daily, according to river, storage and pondage used.

/Knowing the

Knowing the maximum dependable power from a given site and its annual kWh output, one can assess the number of years during which load requirements can be met and whether there will be an initial shortage of power or energy.

If a shortage of peak power is foreseen, and there is an ample supply of energy for some years, this may point out the need for a thermal station, requiring a minimum of investment.

If there is first a shortage of energy, the best solution could be another hydro plant of higher capacity factor. If the only one available is of low capacity factor, it may become preferable to use an efficient steam plant for base load and let the hydro plant take care of short peak periods, provided its energy production can be so disposed of.

There are many other characteristics peculiar to either steam or hydro stations.

For rapidly increasing loads of sustained duration, a hydraulic unit will meet such conditions more easily and satisfactorily than a steam unit; however, for instantaneous changes, steam units perform better on account of the slower response and higher inertia of hydraulic turbines.

Adequate spinning reserve is more important for steam units, not only because they cannot pick up load as rapidly but also, because low frequency operation affects numerous motor-driven auxiliaries such as draft fans, feedwater pumps, etc.

Both types of units can be operated as condensers for the control of reactive power, but steam turbines are more costly of operation for that purpose and not nearly so convenient.

The dependable energy capability of a steam plant is its continuous full load rating, less due allowance for maintenance. It is not always possible to have full control of long-term output of hydro plants on account of unpredictable run-off or storage conditions and one has to be conservative in estimating their dependable energy capacity.

Once built, a hydro plant should be operated as much as possible in order to get full return from the money invested. In contrast,

/steam units

steam units involve considerable expense for fuel for every minute's operation. Fuel or heat rates vary for different loads and it is worth spending a great deal of time and effort to ensure that the least fuel is used for every kilowatthour generated.

Transmission line losses may be comparatively high, particularly at peak load times and that may have a bearing on cost of power from remote stations as compared to that generated locally from a thermal plant.

To obtain the most advantage from combined steam and hydro interconnected systems, it is recommended that:

1. Interconnecting lines between stations and load areas be large enough to supply power into an area, in case of a deficit, and out in case of a surplus, all without producing unsatisfactory voltage or stability conditions.
2. Load dispatchers and system operators should have readily available, in convenient form:
   a) Input-output data for all units
   b) Incremental loading charts for transmission line loss data
   c) Typical daily area load curves for normal week days, week ends, and also for holidays and other days of abnormal loading.
   d) Sufficient communication, telemetering and load control equipment to enable them to maintain system frequency, tie line and plant loadings, within prescribed limits at all times.
3. Information on individual stream behaviour and watershed response to precipitation and other weather manifestations.
4. The maximum freedom in the use of storage basins, forebays and streams for storage, accumulation and transportation of water.

IV. CASE OF AREA POSSESSING NO, OR ONLY INDIVIDUAL POWER PLANTS

Considering the case of an area possessing no power plant, the governing criteria are generally

a) Reliability
b) Economy

/If hydraulic

If hydraulic conditions permit, the plant should be located as close as possible to the load center, which would agree with both criteria mentioned above.

Number and capacity of generating units should be such that at least one can be lost without affecting customers. If the economic balance does not allow similar practice for transmission circuits, they should at least be made very reliable, with good communication facilities. Much valuable time can be lost when patrolling or repairing lines in a remote area, if crews cannot readily communicate with switching stations at both ends.

In the development stage of such an area, radial lines to several customers have to be accepted, and operating personnel has to be kept to a minimum. For 25 kV sub-transmission or lower voltages, 3-shot repeater-type fuse cutouts may be found advantageous. Substations must be designed, in the initial stage, for the necessary additions that will follow.

It may also be very important, depending on type of technical help available, to avoid any unnecessary complications or automatic controls which may require more knowledge or a special training that is not always available. For instance, disagreeable situations have been experienced at some remote storage dams with failure of electronic tubes controlling a simple oil burner operation, for the heating system, or in the electronic controls of motors for the hoisting mechanism of sluice gates.

Where a few individual power plants exist and have to be interconnected and supplemented by an additional station, other characteristics become important.

The governing systems at each plant should be checked and probably improved, to make sure that loads are divided proportionately. Interconnecting lines should be verified as to maximum capacity of transfer expected on account of plant capability and load variations.

Rupturing duty on breakers and system protection will have to be revised, as well as communication facilities. Higher capacity units will be permissible in new generating stations, following interconnection of existing plants and increased spare capacity.

/V. CRITERIA

V. CRITERIA FOR THE DETERMINATION OF PRIORITIES IN ELECTRICITY DEVELOPMENT

These will evidently vary, depending on the organization proceeding with the development, whether it is government owned or privately owned.

When a mining industry develops in some uninhabited district and power must be provided by said organization to carry on its operations, it becomes evident that industrial requirements have top priority and those of the small community adjacent to it are next. Any additional requirements some distance away and not directly related to that industry will be served if excess power is available and can be disposed of for an attractive return.

If a government owned agency is directed to extend the services of electrical power to a new district, it will probably attempt to reach the largest proportion of the population involved, without incurring a larger deficit than can be absorbed. Preference will be given to that portion of district which although it may have same density of population at the time, is susceptible of more rapid expansion due to some favourable economical or geographical position. Similarly if an industry demonstrates interest in setting up in the area, consideration will be given to the benefits resulting from additional production and employment; perhaps, more attractive rates will be devised on a temporary basis.

In other works, development of electricity in the hands of a well-managed private organization will give top priority to maximum return on monies invested, while respecting the framework of state or national legislation and preserving harmonious public relations.

Development of electricity under government sponsorship aims at optimum national benefit including various indirect returns resulting from increased trade, employment, production, standard of living, etc. and may consider investments in power developments in new districts with the same overall policy that dictates spending of public funds for roads, bridges, agriculture, forestry etc.