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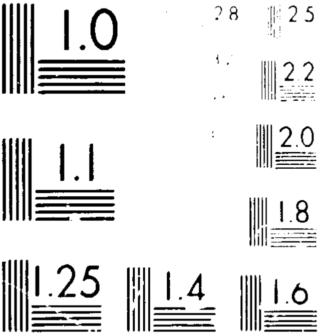
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FACTORS AFFECTING THE FEASIBILITY OF SMALL SCALE WATER POWER PLANTS*

by

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WATER POWER PLANNING

First I want to go briefly through the main elements which enter into water power project planning, - just to show how the choice to be made interfere with other elements and the end result.

INTRODUCTION

1. A study of a water project should start with a general presentation of the power site, its geographical location, main properties and considerations on how it could be utilised to the benefit of the society.

ABSTRACTS OF PROJECT CHARACTERISTICS

2. An abstract should consist of a description of the project, its location, key characteristic data such as head (m), plant water absorbtion capacity (m^3/s), installed capacity (kW), number of generating sets, yearly average producibility (kWh), grid interconnections (transmission lines), total costs (money units (mu)) and cost per unit of yearly producibility (mu/kWh).

WATER POWER PLANT ENGINEERING STUDY

Choice between alternative sources

3. In general one should observe:

- If several different power sources are available, one should select one of which the production capacity would be fully utilised a few years (4-6) after commissioning.

- Small power plants normally give higher specific costs (i.e. cost per kWh yearly producibility or cost per kW installed capacity) than bigger stations, see ref. [13]. It means that one should select a source as big as possible and investigate if more remote supply areas should be connected to the plant.

- In water power planning one faces often the choise of "now or never" or the concept of "no return", for instance when determining the dam height, cross sections of tunnels, space for power house when blasted in rock, how much of adjacent catchment areas should be included in the scheme, extension of the fall stretch to be developed etc. Examples of "cannibalism" of water fall energy resources can be seen from time to time. It will always be regretted by future generations and should be avoided. It may, however, be justified for local supply during the stage of initial electrification. In such cases one should try not to destroy for ever a better future use of the resource.

Cartographic material; surveying

4. Usually contour maps of the scale 1:50000 and 1:5000 and contours of 20 and 5 metres respectively are used. If the project is of limited extension, say within an area of 2-3 km, maps of only 1:5000 would be sufficient.

5. For the examination of water fall energy over long stretches of water courses, topographical maps of 1:50000 and 20 metres' contours may serve to give a rough first picture of the potential.

6. For a site selected for closer examination in situ surveying is required to get sure data on the fall stretches and of the contours of the terrain where civil work components are planned to be placed.

7. Reliable cartographic material and carefully executed surveying is of outmost importance as basic material for an engineering study.

8. In cases where topographic map material is not available or non existent one should see if the area concerned has been subject to aerial photographs taken for the purpose of map production. By stereoscope methods the topography of selected areas may be determined.

Hydrology

9. Uncertainty regarding the water flow, - its seasonal variation and its difference from year to year - represents one of the, if not the, greatest risks of failures to be run in water power project planning. As many years in advance as possible hydrologic observations should be initiated in rivers which

may sooner or later be of interest for water power development.

10. A "normal" observation series, which covers a period of 30 years, is desirable as a basis for water power planning. In developing countries series of such lengths are very rarely available. Then the planning will have to be based on shorter series, hence greater risks are involved.

11. Even in areas where registration of the hydrology of main water cources has been executed over a long series of years smaller rivers or tributaries to the main rivers may not be included in the hydrologic network system, - as will often be the case when considering small scale water power projects. Data on hydrology may then be established synthetically.

12. Reference [1] and [2] describes hydrological work in general but it is especially aimed at developing countries. Reference [3] presents a model which may be used to establish hydrologic data in small catchment areas based on parametres such as hydrologic data in adjacent water cources, meteorological data, data on vegetation and soil, transpoevaporation etc.

13. For the determination of the size of reserveoir and dam height, spillway, water ways and turbine capacity it is necessary to have reliable information on the water flow at the intake, covering its seasonal variation and yearly difference. Figures on extreme high and low flows must also be established.

Topography and geology

14. The properties of the terrain at and around the fall stretches under consideration determina to a large extent how the power plant has to be designed.

How much of the water fall or the rapids should be included, i.e. choosing the site of the intake dame and location of the power house and its outlet, is an exercise of optimization. It involves also the dam hight, i.e. size of reservoirs.

15. Different right-of-ways of the water ways may be chosen. Whether or not the power plant as a whole or parts of it should be placed under ground is an important decision to make. The geology of the site must be examined. When underground design is considered, which may be favourable even for small scale plants in the megawatt range, the properties of the rock may be decisive for the outcome of the economy. Modern methods of rock drilling and blasting technology make underground solutions more attractive. [4]

Power plant design

16. The energy produced must be made available for the consumer according to his demand, with its daily and seasonal variation. The natural properties of the energy resource must be utilised to its possible extent in storing available water for later releasing according to load. To some extent it is possible to purposely get the demand adopted to the available water flow, i.e. to energy available from the plant, see ref. [5].

17. Without water reservoirs of any measureable extent for load variation the design of the power plant water ways and machinery will normally be based on minimum water flow,- especially under single plant operation. Higher capacity should be considered when it is, or it is expected to be, connected to a grid supplied by more plants,- hydro or thermal.

18. Possibilities for building of dams for daily and seasonal regulation should be examined. If large volumes of water are to be retained in the reservoirs from periods with high flows to the low water period, areas of considerable size, depending on the topography, will have to be flooded. Reservoirs for seasonal regulation may be established further up in the water course and on several places. In such cases a reservoir for daily regulation should be built near or at the intake to the power plant.

19. The dam design type must be selected with due consideration to economy and security. The structures including the spill ways will have to stand extreme floods. Therefore deviation of parts of the flow of big rivers for small scale development may be a costly affair. If cement is difficult or costly to obtain, earth fill or rock fill dams may be interesting solutions, allowing also for large involvement of local man power. [6]

20. The water ways may be of the open type channels combined with pressure tubes on the fall stretches. Channels may sometimes be damaged by land slides during heavy rain. If so, the channels may stretchwise be fitted with side walls and cover made of impregnated wood. Pressure tubes are often made of steel or plastic. Such tubes may also be made of impregnated wood kept together by steel bandages and placed on stone work or concrete supports.

21. Trash racks are installed in front of gates. They should be designed for easy cleaning.

22. Under homogeneous rock conditions, blasted or drilled head race tunnels as well as pressure shafts may be used. Even pressure shafts may be without steel lining. In Norway head race tunnels,- even when

blasted -, are never equipped with concrete lining, except on stretches with bad rocks. [7]

23. To reduce pressure shocks in the water ways at sudden shut down of the plant surge chambers may be of the open type or the compressed air type, see ref. [8].

24. At low falls, where no turbine front valve is installed, air intake valves must be installed at the upper end of the closed water way to prevent collapse of tubes due to the build-up of underpressure when closing the upper gates.

25. Power houses may be of wood, concrete or it may be blasted out of the underground rock. In Norway most,- also small scale power houses with capacity down to a few megawatts - are placed under ground for economical reason. Where suitable solid rock is not available, power houses of concrete or brick work would be chosen.

26. Outlet water ways may be designed similar to the head race water ways.

27. Stoplogs, gates and valves in the water ways, - in dams, at the intake, in front of and after the turbine and at the outlet to the river course - are important components. Some of those mentioned may be exempted in simpler designs. Steel and cast iron are usual material in such components, but impregnated wood may also be used where water pressures are low.

28. If the water carries silt and sand particles, it will cause damage to turbines and valves. The water should be analysed in order to determine if remedies are required. Desilting and desanding devices are placed upstreams of the power plant water ways and designed such that the silt and sand collected can be washed away,- usually back to the river bed.

Roads, transport and accomodation facilities

29. Access to construction sites requires roads. Ropeways may be used under difficult conditions. The weight of the heaviest pieces to be transported determines dimensions and design of roads and ropeways. Special care must be taken when designing ropeways which are to be used also for the transport of personnel.

30. Accomodation of the labour force and storing of machinery and equipment require premises and space. Fenced areas for outdoor storing and parking of construction machinery must be planned for.

31. Temporary electricity supply to construction sites will normally have to be based on dieselgenerating sets. Where possible, such equipment should be selected and installed so that it could be connected to the permanent system of the power plant when it starts to operate.

Power plant equipment - in briefs

32. The power plant equipment consists of:

A. Plant front water ways equipment

- Spillway gates in the dam.
- Trash rack in front of the gate discharging water to the plant.
- Discharge gate.
- Gate in front of pressure tubes.
- Surge chamber.
- Air intake valves.

B. Water fall energy conversion equipment

- Connection piece between the pressure tube and the turbine front valve.
- Main valve in front of the turbine.
- Turbine.
- Outlet tube from turbine.

C. Electrical energy conversion equipment

- Generator, synchronous or asynchronous type with magnetising machine (for synchronous generators).
- Conductor connections from generator to switching equipment.
- Bus bar and switching equipment.
- Transformer for voltage stepup (if generator voltage is too low for transmitting power to the consumption areas or for interconnections to other power plants).
- Terminals of outgoing lines.

D. Equipment for control and operation

- Direct current battery for operation of control equipment.
- Operation of valves and gates.
- Regulation of water flow and rotational speed of the turbo-generating set.
- Regulation of voltage.
- Operation of circuit breakers and isolators.
- Transformers for measuring of voltage and current.
- Instruments for indication of water reservoir level, water pressure on turbine and of voltage, current, active and reactive power on generating set and on line connections.
- Counters for energy produced and/or delivered.
- Auxiliary generating set.

33. Telecommunication equipment is usually required for internal communication with the water gates at the

dam or the intake weir, to operators' living quarters and externally to interconnected stations and to the main office of the power supply unit. Such external connections may be cheaply provided by the commercially operated telecommunication network. VHF (Very high frequency) system connections on high voltage transmission lines to interconnected stations may be a feasible solution for more powerful high voltage systems (66 kV and above).

Construction planning

34. The capital requirements, i.e. input of material and manpower, for building a power plant, draw interest also during the construction period. Therefore the process of constructing a power plant should be carefully planned with the view of achieving a short construction period and procurement of the most capital intensive equipment on terms which means payments at a latest possible stage before commissioning.

35. In developing countries, however, one will have to take into consideration the impact on the local labour market, i.e. it should take place as a gradual development during a certain period of time to allow for training on to skilled man power of a certain number from the locality.

36. It is also part of the construction planning to see that different parts of the work fit in so as to assure a smoth development of the whole scheme.

Cost of different components

37. Costs of etablishing the plant are understood as capital used at commissioning to cover planning,

construction work, material and equipment, administration, contingencies and interest on capital during construction.

38. For water power plants where considerable amounts of civil works are involved in the construction of dams, weirs, tunnels and other rock works or excavation of earth masses, the civil works component will draw more than half of the cost. If no massive water reservoirs are involved, the electro-mechanical machinery components will be dominating the costs.

Requirements from national sources versus sources abroad

39. Normally some parts of the materials and services required will have to be acquired from abroad. This part of the total costs should be specified. For many if not most developing countries it is desirable to provide as much as possible of the required materials and services from internal resources. To cope with such a policy the planning of a power plant will have to include also planning on how to prepare the ground for internal provision of required commodities, materiel, equipment and services. It may be necessary to include separat plans for development of say a wood impregnation plant, a mechanical workshop for the manufacturing of simple steel structures and components etc. Supplementary projects of this kind should be included in the construction plan, with realistic schedules for development and financing.

40. Components which may normally be supplied from internal sources are:

- Ordinary manpower (not skilled).
- Manpower with insight in some parts of the work, such as construction of channels and small earth fill dams.

- Some material and equipment locally made.
- Road building.
- Accomodation quarters.
- Supply of commodities to living quarters, food etc.

41. Imports will often be required of:

- Skilled and specialised manpower, such as experienced engineers, monteurs, geologists.

- Special machinery and equipment such as construction equipment, electro-mechanical components to the power plant, electrical material for system establishment etc.

42. Developing countries having promising water power sources should try to start immediately to prepare their skill for power plant and power system development. It will take 10-20-30 years before full benefits are derived from the efforts. Top priority should be given to:

- Hydrologic investigations in promising water cources.

- Training of engineers and other technical manpower.

Simplified planning and design

43. The specific cost of energy from small scale plants normally becomes high compared to the same cost of larger plants and units. Much efforts have been given to counteract this scale effect for small units and plants:

- By standardization of the turbogenerating sets to given water flows, heads and rotational speeds.

- By the use of simplified regulation and control devices.

- By reduced degree of automation, i.e. using more manpower for plant operation.

44. Standardization efforts being made for small scale plants which are to be interconnected to large supply systems may in many respects be utilised as well for plants which are built for isolated operations. In Norway a large number of small scale plants from the initial stage of electrification of the country were then equipped for isolated operation. They were gradually taken out of service as the system developed with big scale plants. Recently a rehabilitation programme of these plants has started. To get costs down to acceptable levels unit standardization and simplified design has been adopted,- even for complete plants, see ref [9].

45. One should observe that standardization and simplified design generally means reduced efficiency and operation properties. Simplified design may be favourable in view of maintenance, control and repair. It may also lend itself better for local manufacturing at an initial stage when transfer of know-how is required.

46. Obviously, standardised and simplified design also means less project related planning.

<u>Rehabilitation of abandoned small scale plants</u>

47. Sometimes one comes across abandoned small scale water power plants in developing countries,- plants which could be brought back to operation by rather cheap means. In such cases project planning would be very simple and could be done by potential suppliers

or manufacturers of electro-mechanical equipment required. In some cases even the old equipment could be revised and used,- a work which could be executed in local workshop when supervised by specialists on such equipment.

48. Contracting of manufacturing firms directly to supply plans for rehabilitation work and for suitable equipment chosen from the manufacturers programme of standardised units seems quite feasable and could probably bring the cost of planning and preparation down to a minimum. It would also secure an economic choise of equipment.

49. The same procedure could also be adopted for development of virgin type small scale projects suitable for equipment of standardised and simplified design.

50. One should notice that the customer (future plant owner) will have to be safeguarded against wrong design and construction of plants. Risks attached to the planning means risks for breakdown and malfunction of the plant, which may, depending on the contracts, transfer great responsibilities to equipment suppliers, risks which are out of proportion to their involvements. It could be prevented by letting the suppliers of equipment contract the whole project. Mistakes done in the planning would mean higher risks for breakdowns and malfunction. In the long run too high risks means too high costs.

51. Often customers go too much in details when giving specifications in tender documents. It may prevent suppliers of equipment to present bids from their list of standardised units at lower prices. The result may be higher costs.

Critical choices

52. The market, which can absorbe the energy, forms the basis for all planning of the utilization of a power source. As already mentioned the market may to some degree be adapted to the characteristics of the power source.

Example: Number and size of turbo-generating sets in small scale water power plants.

53. Several factors are involved:

- Available water flow.
- Water storing facilities
  - for seasonal use
  - for daily use.
- Whether the plant is single in the supply system or it operates interconnected to other water power plants or thermal power plants, e.g. diesel plants.
- Implications to consumers at plant operation stop, i.e. stops for revision and maintenance or due to breakdowns and repairs.
- Can the power consumers adapt their demand to the available water flow over seasons and days and nights?
- Turbine efficiency and operating ability at low loads.

54. Extra costs are involved in splitting up the total plant capacity in several turbo-generating sets. However, the production will have to be adapted to available water at any time and to the demand. Besides, there are requirements for periodic stops for control and maintenance. Only one turbo-generating set in a small scale plant would give the lowest specific costs. For different reason more than one set may have

to be chosen. Two to three sets may be justified even in small scale stations when operated on isolated supply systems. Three sets may be justified where the water flow varies considerably and if the power load or part of it is very sensible to supply interruptions.

Utilization of available energy and plant capacity

Fig. 1 55. Figure 1 shows the seasonal (monthly) variation of the natural water flow in a typical river. The straight dotted line indicates the water absorbtion capacity of a power plant in that river. This plant may deliver energy at full capacity except for a short period (approx. three months) during the low water season (winter).

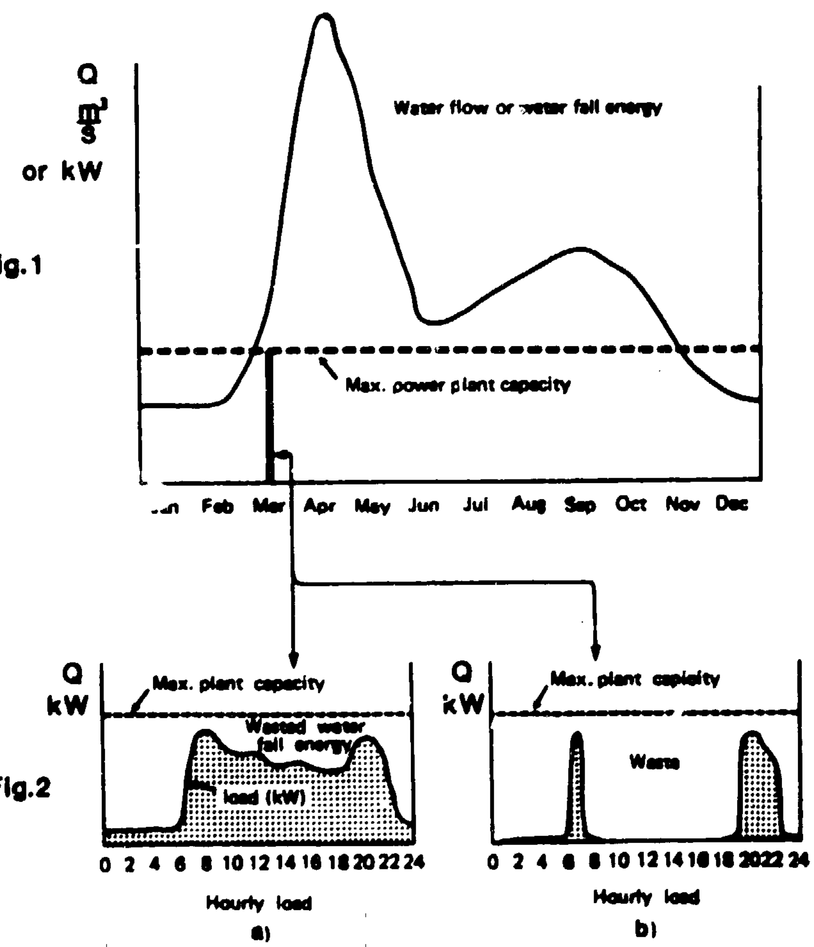

Fig.1

Fig.2

Fig. 2 56. Figure 2 illustrates how the plant installed capacity may be utilised depending upon the characteristics of the demand:

a) shows a reasonably good utilization of available water flow.
b) shows a poor utilization.

57. The demand curve b) is more typical for systems supplied by diesel-generating sets with high energy price reflecting the cost of the diesel fuel. The figures are presented to underline how important it is and how useful it can be to the consumers to adopt a reasonable power pricing system (tariffs) allowing them to benefit from all water fall energy available for the plant operation. The energy delivery capacity which is marked "waste" in figure 2a, should be put to the disposal of the consumers for the best purpose possible. This can be achieved if offered to the consumers on terms interesting to them. (I have discussed this matter more in details in ref. [5].)

58. From the figures 2a and b one will see that the amount of energy really consumed and consequently sold may be much less than the amount of energy available from the system. If water fall energy is wasted in the form of water discharged in the river parallell to plant capacity which could produce electricity, such water fall energy could as well be delivered free of charge to consumers which could make better use of this resource. Such pricing, - pay according to maximum load (kW) only - was successfully practiced in Norway during the initial stage of electrification, see ref. [10].

59. We also see from the figures 2a and b that energy cost is a notion which is not solely dependant on the production unit or the supply system. Cost is the result of an interplay between production and consump-

tion. Specific capital cost, for instance, for installed machine capacity or for yearly producibility is not a clear notion and may confuse more than it clarefy.

COST ESTIMATE OF PROJECTS

60. To establish preliminary costs estimates of projects figures experienced from establishment of similar projects under similar conditions form the basis. The figures must be adjusted to actual money value. Information may be derived from contractors and from suppliers of similar materiel and equipment.

61. More exact cost estimates can be obtained through firm offers from well qualified contractors and suppliers and based on tender specifications. Tenders should not be asked for unless the project is seriously thought to be realised.

62. A typical cost estimate is presented in table 1.(The figures are chosen from a real project in Norway. This station is planned to operate interconnected to the country-wide power network).

63. Costs of operation, maintenance etc. will have to be added to the capital costs, which add 1 to 2 per cent to the capital costs for large power plants and probably somewhat more for small scale plants.

64. Economic operation of self sustained power supply units must secure that the income is at least balancing the expences. (Pricing at marginal cost, i.e. cost of extending the delivery capacity of an existing system for additional consumption may be introduced at a more advanced stage.)

65. The income is provided by the number of sold units (kWh og kW). (Not the producibility nor the installed capacity.) The expences for water power production is highly depending on the capital charges.

TABLE 1

Preliminary cost estimate (NOK[1]) of "Unidohill" water power plant

Plant water absorbtion capacity, m^3/s	4.0	5.0	6.0	7.0
Number of turbo-generating set	1	1	1	1
Turbo-generating set total capacity, kW	3000	3800	4500	5300
Civil works, mill. NOK	7.00	7.05	7.20	7.40
Electro-mechanical equipment, mill. NOK	10.20	11.75	13.00	13.95
Planning and administration, mill. NOK	1.50	1.50	1.50	1.50
Sum	18.20	20.30	21.70	22.85
Interest rate (13 per cent) during construction (2 years)	2.10	2.30	2.45	2.85
Total cost, mill. NOK	20.80	22.60	24.15	25.43
Specific capital costs, NOK/kW installed plant capacity	6930	5947	5367	4798
Yearly producibility (2) MWh	15700	17800	19500	20900
Utilization of installed capacity, hours	5230	4680	4333	3940
Specific capital cost, NOK/kWh yearly producibility (3)	1.32	1.27	1.24	1.22
Marginal specific capital cost, NOK/kWh		0.86	0.91	0.91

(1) 1.00 US$ ≈ 7.00 NOK
(2) Delivery to consumption with given load curve.
(3) Specific capital cost per kWh yearly consumed may be much higher.

PROJECT EVALUATION

66. A project may be evaluated in mainly three ways:

a) Project related; i.e. the cash flow during its economic life is calculated on the basis of economic parametres only tied to the project alone (interest and amortization of borrowed capital, estimates on obtainable prices, operation expences and taxes).

b) Company related; i.e. the cash flow as defined under a) is added to the cash flow of the company's other activities.

c) Society related; i.e. in real terms (money units of fixed value independant of the inflation). The cash flow is based on the parametres of economic life (useful life), capital "opportunity cost" in the society concerned, operation expences etc.

67. Comparing projects of different characteristics is done by calculating the present value of all present and future costs and of sold power from the plant or the system.

68. In the case of society related evaluation the "inconvenience cost" to the consumer of power shortage, i.e. energy not delivered, enters into the calculation, ref. [11, 12].

69. We see that the evaluation principle mentioned under a) is most relevant to units established during the initial stage of electrification. In more developed systems the methods b) and c) are more interesting.

69a. Project evaluation may be based on real economic valves or on financial terms and transactions. Projects can also be considered from the society point of view or from the company or private point of view.

CAPITAL COSTS VERSUS CONSUMERS PURCHASING CAPACITY, - "THE INITIAL STAGE BARRIER"

70. The feasibility of any project depends on obtainable price of the power sold, i.e. of the market. Small scale water power plants for the electrification of remote areas in developing countries at an initial stage will serve societies which have very poor ability to pay for commodities from a supply system. People often perform a barter-economy at such a stage. The market has to be developed.

71. Embarking upon a water power project would be easy if there exist a mass of consumers possessing a purchasing capacity even at an initial stage. In rural and remote areas it could as well be zero or negligible. If there are reason to believe that it will grow during the economic life time of the scheme there is a good chance to arrive at feasible solutions by the time.

72. Annex A analyses more in details different pay back profiles on loans as compared with an estimated purchasing capacity of the market. Special attention should be given to borrowing on "real value pay back terms".

73. Development projects considered in this way are not limited to water power plants. The principle lends itself for all kind of projects, not only for those giving priceable products. It seems especially well justified for capital intensive projects which are likely to operate over an economic life span considerably longer than the amortization period of loans given on traditional terms. Obviously, risks are involved, but risks should be reflected in the interest claimed.

74. One special feature should be mentioned regarding water power plants. The economic life span of many of its components (rock tunnels, channels, dams, underground power houses etc.) is very long (- perhaps in the order of one hundred years). This technology is not likely to be obsolete if the resource is well utilised. The remaining real value of such plants when the borrowed capital is fully amortised may be of considerable magnitude (at least 60 per cent even after 40 years for power plants built in solid rock). This future asset should also be taken into account.

MAIN FACTORS AFFECTING THE FEASIBILITY

75. By feasibility of a project we mean whether the project can be or should be realised when compared to alternative projects or solutions. In developing countries - and especially in remote areas at the initial stage of electrification - the problem is more whether it is possible at all to embark upon an electrification scheme. Usually one can choose between different technical solutions. The problem is related to the exposed gap between the purchasing ability of the power consumers and the income required by the supply unit. This gap is strongly enlarged because of the financing terms of traditional borrowing.

76. The first task in arriving at feasibility of projects in such cases is to negotiate financing terms to get them in harmony with the purchasing ability of the potential consumers.

77. Rapid, but harmonious development of the societies in the low productive areas is a goal. If it is taken for granted that productivity will rise, it follows that the purchasing ability of the people concerned also will rise with the time. Financing of projects should then be on terms giving capital charges which

are very small at the beginning. It can gradually raise later on (as explained in annexe A).

78. Obviously, real capital will have to be transferred - from high productive areas to low productive areas, - which is unfortunately against economic interests - at least in the short run. One will also have to act against forces created by the effect of economies of scale. However, I see no harm in such arrangements. On the contrary, it will help in developing sound economy of the society av long as the systems established help creating a rise in the real values within the total economy, ref. [13].

79. The quarters lending out money, for say water power projects, could as well secure its interests by keeping their real values linked to one project compared to frequently replacing their capital from one project to another by claiming much shorter pay-back times of loans than the real economic life span of the projects. Under a more long-term pay-back system, in which the remaining loan at all time is adjusted according to the change of the money value, transfer of capital between money lenders and money borrowers would happen less frequently. Therefore one would not expect such a system to be praised by banks and credit institutions. It should, however, have a fair chance to be adopted in affairs between nations - e.g. as part of aid programmes. I believe it would be a more sound principle of aid than grants combined with money lending on traditionel terms. It would be especially appropriate when dealing with water power projects for starting of the electrification of remote areas of developing countries.

80. This concept may be worth while considering, not only for projects such as power plants, but also for establishment and starting up of say industrial

activities such as the manufacturing of power plant components and other power system equipment.

SIMPLIFIED PLANNING OF SMALL SCALE WATER POWER PROJECTS, - IS IT FEASIBLE?

81. Generally considered - the answer is no. The "economies of scale" effect relates also to plans and studies required before decision making. The work involved in each part and phase of this preparatory work, as briefly presented previously in this report, takes less time and may be less costly than for larger scale projects, but all principal elements in the project must be considered - at least if it is a "taylored-in" project. Standardization of plant design and/or of plant components may reduce to a considerable degree the cost of the preparatory work (as well as the cost of the material itself).

82. The cost component represented by preparatory studies seen in relation to the total costs of water power tends to rise inversely to the size of the project. This effect may be counteracted by standardization.

83. The risk of doing mistakes in planning, which is putting hasards to the economy of the whole project, is not reduced with small scale projects when referring to the unit of producibility or the unit of installed capacity. Therefore, it is no real saving in simplification of the planning work except simplification through the use of higher know-how.

84. By perusing the elements in planning - all the way from basic material,- information about the resource and choises to be taken in different parts of the work and at different stages, the financing terms and the interplay with the power market - I wanted to

demonstrate how it is all linked together. I also wanted to make clear that it is not wise to divide planning in techniques and economy. Real engineering of the totality of a project must involve all disiplines - also the terms of financing and power sales policy.

"Knowledge provides simple solutions.
There are no short cuts to knowledge."

SUMMARY

87. Planning of small scale water power plants requires skills within the full range of power technology.

88. The best advice I can possibly give to developing countries is that one should prepare the ground for establishment of local know-how, i.e. inside industrial plants, supply units and also inside governing bodies and other relevant institutions, to make the country's own people able to handle planning, construction and operation of power plants and power supply systems.

89. Power technology knowledge is required also for small scale power plants. Technical education on all levels takes time. It should start at an early stage and such personnel should as much as possible be tied to local projects.

90. To prevent economic hasardious risks because of lack of sufficient basic material, hydrologic investigations must be started at an earliest possible stage - many years in front of project planning and realization.

91. Small scale water power plants lend themselves well to standardization of components and even whole plants, which reduce planning costs and counteract the economies of scale of power plants.

92. Depending on resources available power plants should be introduced into the supply system in order of rising costs of supplied power. Because of the exposed economies of scale of power plants, one should investigate carefully if there is a potential market for the energy from the biggest plant before choosing the smaller plants.

93. Power projects - especially small scale projects at the initial stage of development - should be planned in conjunction with the power market and the power market should be adapted to the characteristics of the power plant, i.e. to its production capabilities.

94. The feasibility of projects should be evaluated as a part of the economy of the society which is to be served by the plant.

95. Loans given on traditional terms represent a barrier for development of power supply in low productive areas. Financing terms should be modified to be more in harmony with the estimated development of the purchasing ability of the society concerned.

REFERENCES:

[1] Østen A. Tilrem: Manual on Procedures in Operational Hydrology, Volume 1 - 5, Ministry of Water, Energy and Minerals, Tanzania and Norwegian Agency for International Development (NORAD) 1979.

[2] Hydrology in Developing Countries, Nordic IHP Report No. 2 from the Nordic Meeting, Nord-Torpa, Norway, 21-23 November 1978.

[3] Dan Lundquist, Norwegian National Committee for Hydrology, Oslo. "Use of a conceptual rainfall - runoff model in water resources planning", (Proceedings of the Helsinki Symposium, June 1980, IAHS - AISH Publ. no. 130).

[4] Ø. Myrset: Under Ground Hydro-Electric Power Stations in Norway, report presented to "Rockstore 80", Norwegian Water Resources and Electricity Board, Oslo, Norway.

[5] Asbjørn Vinjar: Electricity Sales Policy, in systems supplied from water power plants with little or no storage capacity. Paper presented to the "All India Seminar on Renewable Sources of Energy at Allahabad on October 20-21, 1982. (The information given in this paper would be of particular interest to developing countries for areas at an initial stage of electrification and where the supply is entirely based on water power).

[6] Small Dams: A guidebook for planning. construction and maintenance, by the Norwegian Water Resources and Electricity Board (NVE) issued by NVE/Universitetsforlaget, Oslo, Norway 1982 (in Norwegian).

[7] "Norwegian Hard Rock Tunelling", Publication no. 1 issued by the Norwegian Soil and Rock Engineering Association, Tapir Publishers, 1982, University of Trondheim, N-7037, Trondheim-NTH.

[8] L. Rathe: An Innovation in Surge Chamber Design, Water Power Dam Construction June/July 1975. (Describes surge facilities based on compressed air at the Driva Hydro-Electric power plant in Norway).

[9] "Hydroelectric Power Technology in Norway, with special emphasis on small scale power plants", Paper presented by the Norwegian Water Resources and Electricity Board to the UNIDO Seminar - Workshop on Mini Hydro Electric Generation Units, Kathmandu, Nepal 10 - 14 September 1979.

[10] Asbjørn Vinjar: The Electrification of Norway over a period of 100 years. (Experiences which may be useful to certain developing countries - in particular concerning the utilzation of water power sources). UNIDO Seminar/Workshop on Small Scale Water Power, Kathmandu, Nepal, 10-14 September 1979.

[11] A. Vinjar, J. Tveit, A. Johannesen and B. Steine: Intergrated planning of the Electrical Energy Market and the Power Generation System in Norway, Report 31-12/1982 to CIGRE, Paris.

[12] A. Vinjar, J. Tveit and E. Solberg: Integrated energy planning in Norway. Report Energy/SEM.2/ R.16 presented to the Symposium on the Comparative Merits of Energy Sources in Meeting End-Use Heat Demand, Ohrid (Jugoslavia), 6-10 September 1982.

[13] Asbjørn Vinjar: Electrification of Rural Areas, based on small scale Hydro-Electric Plants, Report under section 2.2. to the 11 th World Energy Conference, Sept. 8-12, 1980 Munich.

Annex

WHY NOT BRING THE PROFILE OF CAPITAL CHARGES MORE IN LINE WITH PEOPLE'S PURCHASING ABILITIES?

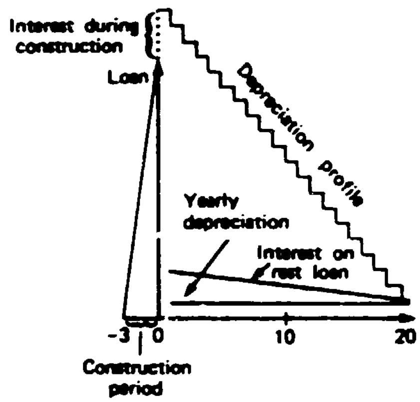

Figure 1
Linear depreciation

Figure 1 illustrates the yearly capital charges of a loan used for building a power plant. Depreciation of loan in equal shares over a period of 20 years after 3 years period of construction and at 10 per cent interest rate.

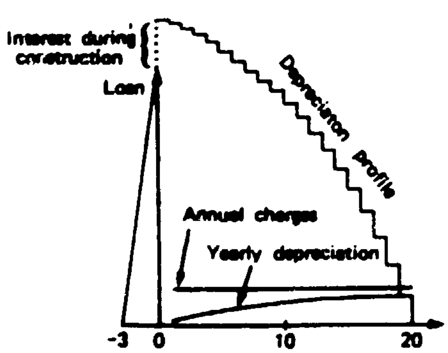

Figure 2
Constant yearly capital charge

Figure 2 illustrates the same, but the capital charges are paid as a fixed annuity, i.e. depreciation plus interest charges is a constant amount each year.

Inflation, i.e. yearly reduced value of the nominal money, has not been taken into consideration.

The loan types presented here are common on the capital market. Characteristics of such loans are:

- During periods of inflation the money lender gets back less in real value than was put to the borrower's disposal during the period of construction. Money lenders therefore tend to shorten the depreciation time and they apply high interest rates for these types of loans.

- The borrower has problems in dealing with the capital charges during the first part of the pay-back period, while he will have less problems later. If the power plant can still produce when the loan is fully depreciated, he may have a jolly good economic time, - and this is normally the case with water power plants.

It is justified to ask why the charges on borrowed capital are kept in such a disharmony with the real values involved. There may be different explanations. However, I want to look at how things should be, and primarily consider how to overcome the "initial stage barrier", which is important when dealing with small scale water power projects for the start-up of electrification of remote and rural areas in developing countries.

First I want to state some facts about the parties involved in initial stage electrification projects:

- The power market, i.e. the people in the surrounding areas, has a very low purchasing ability. Such societies are still to a large degree in the stage of barter-economy, i.e. keeping a natural household with very little money involved.

- The potential of rise of production in such societies is high if initiated in the right way.

- The risks involved seen from outside parties, e.g. from money lenders, are relatively high, but these risks may be less in the distant future than in the near future.

- Money lenders naturally worry about the expected rate of inflation.

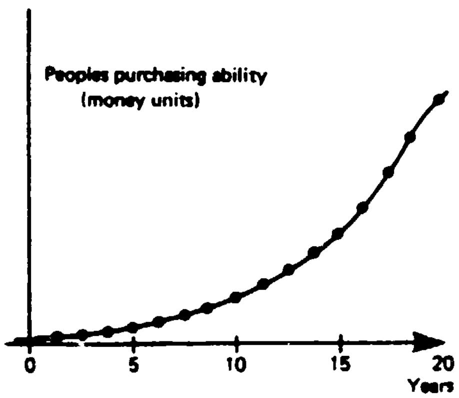

Figure 3

Figure 3 indicates how people's purchasing ability, i.e. their willingness to allocate money for buying, say electricity, is supposed to develop during the years after commissioning of an electricity supply system.

How should the terms be for loans given for the establishment of power plants and electrification schemes to coincide with reality in the society concerned?

Figure 4 shows the yearly capital charges of an "indexed loan". The depreciation is gradually growing with the time (following a geometric series). Yearly capital charges are calculated as interest (3 per cent) on the "indexed" rest loan and the depreciation according to the depreciation factor for that year. "Indexation" of the loan means yearly adjustment of the rest loan according to the reduction of the value

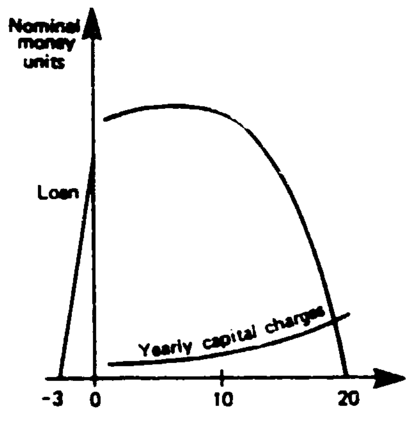

Figure 4
"Indexed" loan

of the nominal money (e.g. 4 per cent inflation or/and appreciation of the change rate). If the interest rate, the appreciation and the depreciation period is known, the growing depreciation factors in the form of a geometric series can be calculated.

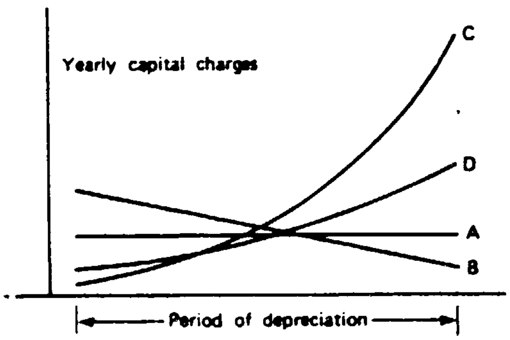

Figure 5

Figure 5 indicates different depreciation profiles and capital charges of loans:

A: Annuity type depreciation at nominal money value

B: Linear depreciation at nominal money value

C: Depreciation in the form of gradually increasing yearly pay-back shares and interest on the "indexed" rest-loan, i.e. adjusted for inflation, (e.g. 8 per cent inflation and 1 per cent interest rate).

D: Same as C but lower inflation rate and higher interest rate (say 4 per cent inflation and 3 per cent interest rate).

Logically, the interest rate should reflect the risks involved in the project. The length of the depreciation period should correspond to the economic life span of the financed object. For water power plants it would mean 20-30 years for the electro-mechanical equipment and much longer for the civil works, (10-20 years for diesel power plants, 20-25 years for coal-fired or fuel-oil fired plants, 30-40 years for transmission lines, 20-30 years for distribution networks, etc.).

If money lenders want to keep their capital fixed to real values, it is hard to understand why they should wish to take it away from one real value object to place it in another, provided sufficient compensation is given for changes in the value of the nominal money unit.

The real interest of the money lender must be to safeguard his capital in terms of real values. The borrower would wish to obtain terms he can substain.

Figure 3 and 4 show how the interest of the two parties can be and should be combined.

Some financing institutions may like to arrange the capital market in such a way that financial transactions take place as frequently as possible. It seems to me that the economy in many countries is dictated by this wish. It also seems that traditional type terms of financing (see figure 1 and 2) are kept alive even during periods when different terms would be justified. My impression is that the financing institutions have not been clever in introducing financing terms which could help to overcome barriers laying in the way for good projects, and which could lead to sound economic development. Traditional financing may cause economic depressions.

Financing of water power projects should be arranged in such a way that the capital charges develop in harmony with the purchasing ability of the people to be served.