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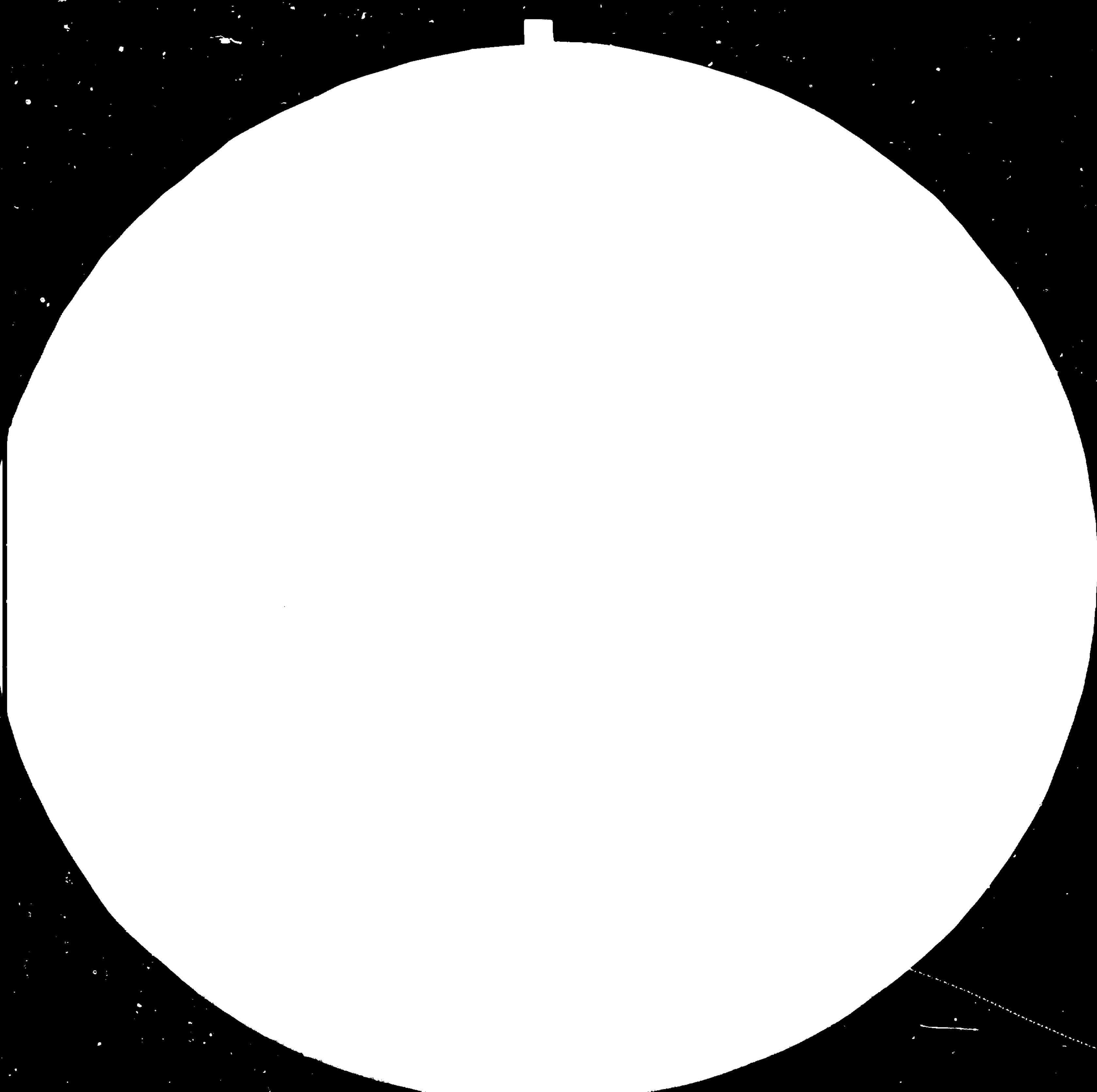

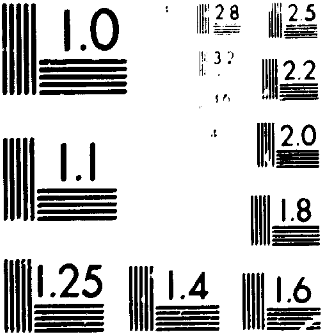

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WAYS AND MEANS OF COST REDUCTION COMPATIBLE WITH VIABILITY AND UTILITY REQUIREMENTS*

by

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SUMMARY

The paper covers a brief write-up on the activities of the National Electricity Board on its small hydropower projects with special reference to the ways and means of cost reduction adopted. The subject of cost reduction is discussed from all aspects of Small Hydro Power Generation from the feasibility stage of the project right up to the operation of the station after commissioning. To obtain a sequential format this paper is written with the subheadings as follows:-

1.0 INTRODUCTION
2.0 FEASIBILITY STUDIES
3.0 SURVEY WORK
4.0 ECONOMIC FINANCIAL ANALYSIS
5.0 TENDERING PROCEDURES
6.0 CIVIL DESIGN AND CONSTRUCTION
7.0 ELECTROMECHANICAL EQUIPMENT
8.0 TRANSMISSION AND DISTRIBUTION SYSTEM
9.0 CONCLUSION

As a utility, there is the need for the N.E.B. to achieve a compromise between cost reduction and the resulting quality. Hence the methods of cost reduction adopted were such that the end product is still in compliance with the safety requirements and satisfying the local Building Bye Laws, the local Machinery Department and various other authorities. The concept of cost reduction is at all times adhered to during design and construction stages. Whether the result is immediate or only realised through time, cost reduction remains a continuing exercise in the implementation of small hydropower projects in this country. What this paper hopes to achieve is to bring to surface, for purpose of further discussions, both the obvious and the non-obvious areas and aspects of SHP generation where cost can be further reduced or even completely eliminated. In short, the criteria here is 'cost effectiveness' of the design and methodology adopted.

1.0 INTRODUCTION

At present within the N.E.B. there is limited grid extension to rural and isolated areas due to long distances, difficult terrain and most important of all, the small demand. These factors contribute to the very high cost of bulk supply to these areas. The very isolated areas are now given electricity supply by diesel generation where supply is given for only 12 hours per day. Despite the high operating cost, this form of supply is still practised in areas where use of alternative forms of energy is not feasible. Presently the N.E.B. is working full speed ahead on SHP generation with its 22 pilot projects which are in various stages of completion. Preparation work for the implementation of another 82 projects with the year 1985 as the target is being carried out concurrently and with this amount of involvement, it is only logical to have the cost reduction aspect more seriously considered. It is undeniable that SHP projects are highly capital intensive and requires a longer time span when compared with diesel generation. However, when a detailed economic evaluation by the method of the present value analysis is made, it has been found that there are possibilities of making the projects economic. Use of micro computers has been adopted with a specially designed programme whereby speedy assessments of the economic feasibility of a project using cash flow analysis can be obtained. Despite the availability of such aids, the concept of cost reduction need still remain with the engineers in all stages of the project. This is to avoid the adoption of attitude or concept that SHP is a scaled down major hydro electric project. This is especially so with SHP projects whereby the design and the subsequent cost to be incurred is so site specific and with the extreme geographical and physical variations. With the pilot projects the cost ranges from US$1000 to US$4000 per KW as shown in Fig. 1. The wide range of cost is attributed to the fact that the cost is so site dependent and factors like construction of access roads, transport charges, adversity of site conditions and terrain, available head and flow, type of turbine installed etc. heavily influences the final cost of each project. However it ought to be remembered that cost reduction need not be confined to materials and manpower only. Considerable savings can be achieved by the closer examination of the methodology involved. Work procedures in, for example, feasibility studies, surveying, purchasing etc. constitutes a considerable portion of a project as a whole.

2.0 FEASIBILITY STUDIES

As a fact we know that for any rural area earmarked for SHP hydrological data will be scarce and coupled with the large variations in the hydrological patterns, these little few datas available are not on all occasions completely reliable. A complete and detailed study would be very costly and time consuming and may be a contributary factor to the increase of the final project cost. A good source of information for a given SHP source would be from the local inhabitants who are in the position to give approximate information on annual rainfall patterns, high flows or flood levels and other hydrological information. The N.E.B. has up to now relied on topographical maps and even aerial photographs, where available, for the preliminary information. As such, research in the office and a brief site visit is all that is necessary up to this point. As for the hydrological data, the N.E.B. is privileged with the data made available by the other relevant authorities in the country. Studies on specific large catchments are used as parallels to our mini hydro potentials in the neighbouring areas. The subsequent site visit would only be for confirming the data available to ensure that recent logging activities and developments for water and land irrigation schemes has not altered the catchment conditions.

3.0 SURVEYS

In order to avoid high cost of site surveys, the work is initiated with a reconnaissance survey for the approximate location of the intake structure, pipeline route and the power station. Initial levels are measured by means of altimeters and the abundant use of site photographs has been found to be of great use to the designers when executing office work.

The actual detailed survey is carried out only after the preliminary details are obtained. These surveys would normally involve the determination of accurate contours and providing also the accurate pipeline route, surge tank position, intake structures and the power station location. Drawings are also made at site wherever possible to avoid the making of numerous subsequent site visits when errors and misreadings are detected.

4.0 ECONOMIC FINANCIAL ANALYSIS

With all the relevant data available the power generation is used to determine the Benefit/Cost Ratio and the Internal Rate of Return (IRR) for the particular project i.e. the discount rate which equates the present value of the scheme's expected benefits to its estimated costs. The following economic parameters are used in our evaluations:-

(1) discount rate
(2) revenue escalation
(3) operation and maintenance escalation
(4) years of escalation

The cost stream for each scheme is based on our experience from projects already carried out. A 20% contingency and 10% indirect cost is included in the evaluation. The cost stream includes civil works, electromechanical equipment, transmission and distribution cost.

With the above procedure, the most important aspect considered by the N.E.B. is a good internal rate of return. Based on this evaluation, a scheme is considered viable if the IRR is more than 10%. It sould be noted that the analysis has very much to do with the capital cost of the projects. As such, great emphasis is put into the reduction of the total cost of each project. As a utility, the N.E.B. also has to meet its socio economic obligations. If any of the projects were found to be rather low in the financial IRR, the next step is to look into the intangible benefits and other unseen quantities that may be able to push up the internal economic rate of the project. In all the analysis, all future costs and revenues are discounted to present value of cost and revenues. To facilitate this whole procedure, the use of micro-computers have been adopted and has been found to be very suitable for this purpose.

5.0 TENDERING PROCEDURES

The National Electricity Board, as a utility, has its own tendering procedures. For the civil works, the present method used is the Bill of Quantities method. With this method it has been found that the final contract sum tends to depart from the original sum by a considerable amount. This may be attributed to the fact that several design changes were made during construction as these projects were actually pilot projects. However, it is now generally felt that this method of tendering leaves the employer with very little control on the project cost and also requires a very close supervision. Efforts are, however, being made to look into other ways of tendering the civil works.

With this in mind five projects were given out on 'FULL TURNKEY' basis and these projects are in progress at time of writing this paper. Projects given out on this basis cost more than the projects that we have carried out ourselves. The possibility of cost reduction using this basis is yet to be proven. The potential savings here may be in the reduction of implementation time. The Mini Hydro Department is at the moment studying into the possibility of tendering on the 'Lump Sum' basis which will render the employer of the contract a better control on the project cost and avoid variation orders which may go beyond control at times. However, this method will require the contractor to make a very accurate assessment during tendering and the employer will need to furnish the contractors with accurate final drawings during tendering. This method is still being studied and it is hoped that this subject will be of common interest at the discussions at this Workshop where this paper is to be presented. Whatever the tendering method is adopted, the rule to adopt at all times is SIMPLICITY. A simple tendering procedure with simple and precise specifications will definitely help to reduce the tender prices. This is also true for the electromechanical equipment procurement. It seems very common to have specifications for Mini Hydor equipment that are so elaborate that it actually seems to have been written for major hydro equipment. Specifications should be simple and not restrict the tenderer to the extent that the modifications he has to carry out on his equipment in order to satisfy the requirements will increase his cost and these modifications may not even be beneficial after all. Strict specifications will also discourage the manufacturer of turbines to mass manufacture but instead manufacture to design requirements as in major hydro turbines.

6.0 CIVIL DESIGN AND CONSTRUCTION

The civil cost constitutes the major portion of the total cost of a small hydro power scheme and it is in this area where a greater effort for cost reduction is called for. It is also agreeable that it is in this area that cost reduction can be easily exercised to the maximum. It is here that we must fully utilise the site assets and to concentrate on local materials and alternatives. Technology development and adaptation can largely contribute to reducing investment cost and to increasing the use of local equipment and materials. The National Electricity Board has taken advantage of the site assets like wood, boulders, rocks etc. as part of the structures to reduce cost. Concreting works has got to be minimised especially when it involves bringing into the project area large amounts of cement and steel. This is especially true where transportation to site is difficult and expensive. Where possible and practical, N.E.B. erects the weir structures on rock beds and incorporating well secured boulders as part of the system. Apart from saving concrete cost, the cost of expensive blasting activities is also avoided. Wood is also used as part of the weir structures.

For the water conduction system, use of easily available high density polyethylene pipes are being adopted for the low pressure section. The cost of these pipes are comparable to their steel counterparts but considerable savings can be achieved due to their easier and cheaper handling qualities. Furthermore they do not require the normal maintenance like painting of the steel pipes.

Anchor blocks for the pipeline is another item where large concreting is involved. Here cost can be minimised by burying the pipes where suitable. Use of bedrocks for anchoring also reduces cost considerably. With careful design of the electromechanical system, slow closing time of the emergency inlet valve can reduce the size and numbers of anchor blocks required. Use of used and discarded items like wooden poles, which is abundant in a utility like N.E.B. for use as pipe supports can also in a small way reduce cost.

For the construction proper, use of indigenous methods should be thought of. Bringing sophisticated machineries to these project sites is expensive. Hence methods like the use of cables and log rolling for handling pipes and other heavy items are also to be further developed.

7.0 ELECTROMECHANICAL EQUIPMENT

Various types of turbines like the Propeller, Kaplan, Francis and Pelton are expensive due to the simple reason that these turbines are actually scaled down designs of high capacity major hydro turbines. These designs involve intricate castings and very high precision machining. There are, however, other designs like the cross flow, lift translator, water wheels, etc. These designs are very much simpler and also suitable for their purposes. Their manufacture involves mainly steel fabrication works and very little or no casting at all. These turbines can be manufactured cheaper and are in fact simple enough for local development and manufacture. Therefore, although the choice of turbine is actually site specific, it may be worthwhile to look into the newer 'breed' of mini hydro turbines.

This concept has led the N.E.B. to venture into the local manufacture of mini hydro turbines and is at present actively designing and manufacturing prototypes in the last one year or so. The concept adopted is the design and manufacture on the basis of technologies adapted to the level of the industrial development of the country and taking into account the availability of materials and equipment. Both our own designs and those obtained from overseas are being used and successfully manufactured by averaged sized local engineering companies. For better end results, the local companies involved are encouraged to actively participate by giving their suggestion to design changes where necessary. Several cross flow turbines have been manufactured with capacities of approximately 48 KW. Although earmarked for their respective sites none are in operation yet. There is, however, very little doubt on their performance capability since the original design on which these turbines are based on are already tested in other countries. Although every effort is put in to use local materials, the generators, inlet valves, the power cylinder for the inlet valve operating mechanism etc. are still imported items. Nevertheless these items are all standard stock items and hence they are very reasonably priced. A locally designed propeller turbine of around 45 KW. capacity was also manufactured and already tested at one of our low head sites. A few problems were encountered with this unit especially on the transmission gearing assembly. A propeller turbine requires precision machining and castings and as a first off production, there still remain a lot of room for improvement in the standard of workmanship. Modifications are being made as a continuous learning process to put right the problems encountered. Generally we are in a position to comment that our local manufacturers have the competence and can be further developed. The cost for the manufacture of local turbines are also very encouraging considering they are on a one off basis. Prices are expected to be lower with bulk manufacturing. For the turbine proper only, the cost of 48 KW. cross flow turbine is approx. M$4,000/- and the cost for the propeller was approx. M$15,000/-. Pelton turbines of capacities up to 105 KW. are also being manufactured. At the moment more concentration is placed on the cross flow turbine which are actually suited for mini hydro. The N.E.B. is also developing the use of combinations of cross flow turbines to increase the capacity of an installation. These turbines, say three in number will be driving a common shaft which will in turn run the generator.

Work is also being started on the design of a simple governing system for the mini hydro turbines. However, this is still too premature for discussion.

8.0 TRANSMISSION AND DISTRIBUTION SYSTEM

Several cost reduction techniques have also been adopted in this area. The N.E.B. is currently using aerial cables for transmission. Cross-linked polyethylene insulated cables are used and these have the advantage of easier jointing, simpler installation and since they are insulated they do not impose much rentis problem. This is cost reduction from the aspect of right of way and compensation. Furthermore, the rocky areas close to mini hydro sites make heavy demands on cable laying and therefore underground cables are avoided where possible. One problem aspect of this type of cable is the high reactance faced where the mini hydro station is on isolated operation. However, experiments of installing inductors are at the moment being carried out.

Distribution systems are generally of little problem as insulated wires are used. For small generating system, work is currently being carried out to minimise maximum demand requirements by using batteries in the consumer system. This 'limit charger system' is anticipated to provide the rural consumer with 240W maximum demand for lighting and television and yet shows a constant charge rating of 60W for 24 hours of the day.

9.0 CONCLUSION

The high cost of small hydro power schemes has brought about the need for implementors of such schemes to look further into the different methodologies and materials available in this field. As briefly described in this paper, the experience gained by the N.E.B. is varied and without doubt the other countries involved in this field has their own share of successes and failures. Only discussions and exchanges of information can promote further the technology in this field and it is thus hoped that this paper and this workshop as a whole can further assist the different countries to reduce their cost in implementing these schemes.