Effects of Soil Conditions on Cost of Low Head SHP Schemes

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Abstract: Energy is the engine of growth of any developing economy. Consumption of electrical energy is universally accepted indicator of progress in the agricultural, industrial and commercial sectors, as also of the well being of the people of the nation. India is blessed with many rivers, natural streams, canal networks and mountains offering tremendous small hydropower potential which is clean and technically proven source of energy. Under this study, an attempt has been made to discuss the cost sensitive parameters of small hydropower schemes. Based on the cost sensitive parameters, the methodology for estimation of cost of low head small hydropower scheme has been evolved and the effect of soil conditions on cost of SHP schemes discussed.

Key words: Installation cost, low head, small hydropower, soil types

Introduction

In view of rising fossil fuel prices due to growing energy demand and limited resource availability as well as increased attention towards global warming, it has became essential to identify the different energy options that are renewable and environmentally benign in nature. Fortunately, India is blessed with many rivers and canals, long coastal areas, large animal and cattle populations, as well as many regions that receive reasonably good amounts of solar energy showing enormous potential of hydro, wind, biomass and biogas and solar energy. Different countries are following different standards to distinguish between large and small hydro. In India, hydropower stations up to 25 MW capacities are called small hydropower (SHP) projects. Further, SHP projects are classified as micro, mini and small hydro depending on the station capacity, up to 100 kW, 101 to 2000 kW and 2001 to 25000 kW, respectively (CEA 1982, BIS 1991). For decision making in development of any SHP project, economic and financial viability is very important along with technical feasibility. The cost of a project is estimated based on data availability in terms of survey data, project location, drawings, specifications and prices of various items. In order to estimate the realistic cost of an SHP scheme, detailed investigations on topography, hydrology, environment and ecology, geology, and construction material are required to be carried out in detail.

Stages for Development of SHP Projects

The development of small hydropower schemes follows two well defined main stages: (1) project formulation and planning, and (2) implementation. Each stage takes the project a step forward in the development cycle based on the findings from the actual and previous stage. The major part of investigation, data collection and planning takes place in the first stage, while detailed engineering, design of components, procurement of material and equipment, construction of civil works, commissioning and start up of installations are carried out in the second stage.

Components of SHP Scheme

There are three types of SHP schemes: canal based, dam toe and run-of-river (ROR). Canal based schemes come under low head category. whereas dam toe and ROR schemes cover low head as well as medium and high head categories. It is seen that the dam toe and ROR schemes under medium/high heads are more site specific due to variation in topography. It is also seen that all SHP schemes have their basic components like water condutor system, electro-mechanical equipment and power house building; but the type and size of these components are site specific and according to the type of scheme. The components of an SHP scheme are divided into two major categories: (1) civil works, and (2) electro-mechanical equipment.

Civil works components are different in different types of schemes. Hydro-mechanical equipment such as gates, valves and trash racks have been considered along with civil works wherever required. Turbines being major hydro-mechanical equipment have been considered under electro-mechanical equipment. However, electro-mehanical components are similar for

	Parameters	Value
1.	Annual interest rate	11%
2.	Annual depreciation	3.4%
3.	Annual operation and maintenance cost	1.5%
4.	Annual escalation on operation and maintenance expenses and electricity prices	4%
5.	Debt equity ratio	70:30

same head and capacity irrespective of type of scheme.

Cost Sensitive Parameters

The cost of SHP schemes is site specific based on type of scheme, type of components, land and infrastructural facilities required for execution. The cost of components of the scheme constitute the major portion of cost, which is governed by the physical sizes of the components, construction methodology, type of layout, soil conditions and type of equipment. The sizes of civil works are governed by their discharge carrying capacity and discharge is based on head and capacity of the scheme as shown in the following equation (Nigam 1995): $P=gQH\eta$, where P is the rated output power (kW), g is the acceleration due to gravity (m/s^2), Q is the discharge passing through the turbine (m^3/s), H is the effective pressure head of water (m) across the turbine, and η is the combined efficiency of the generating units comprising of turbine and generator.

In electro-mechanical equipment, turbine and generator contribute major portion towards the cost. The size of turbine is represented by its runner diameter and size of generator is governed mainly by the capacity and speed. The speed of generator depends on the speed of turbine. The runner diameter and speed of turbine are related to the head and capacity of the scheme. Therefore, head and capacity are the most cost sensitive parameters.

Types of Soil

India is a vast country. It consists of different regions having different type of soils. The earth crust consists of two main components; i.e., rock and soil. Rock is defined as hard and compact natural aggregate of mineral grains cemented by stones and permanent bonds. Soil is defined as a natural aggregate of mineral grains, loose or moderately cohesive, organic or inorganic in nature that has the capacity of being separated by simple mechanical process. In case of small hydropower projects, the concern is mainly with the 10-15 meter top mantle of soil. An understanding of soil deposits at the project site is helpful in planning the foundation of the project. Soils are classified on the basis of soil depth, color, texture, structrue, chemical composition, and

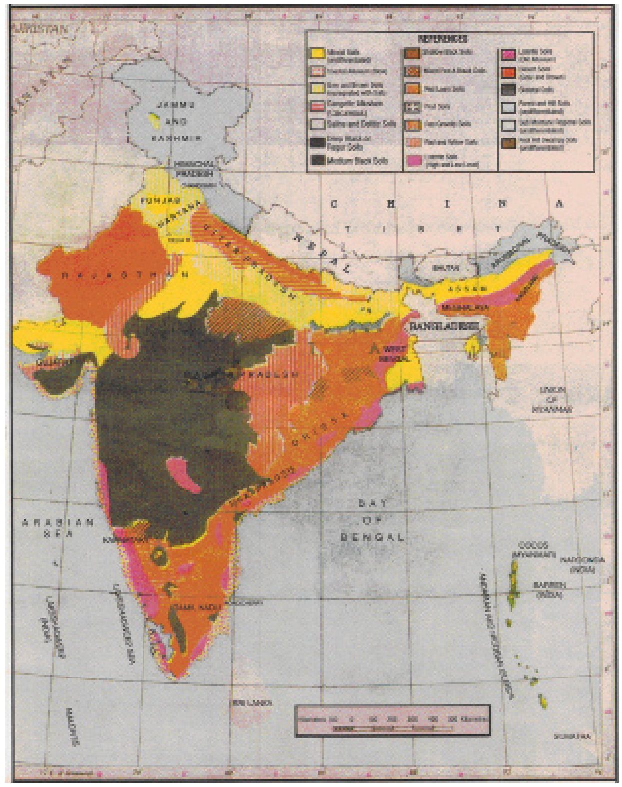

Figure 1. Soil Map of India (Mittal and Shukla 2008)

the presence of certain diagnostic horizons. Diagnostic horizons are based on combinations of thickness, color, chemistry and texture. Soil consists of organic matter, soil organisms like micro flora and flaura and inorganic matter such as macro and micro materials (Singh and Prakash 1990, Vazirani and Chandola 2008).

The important properties of soil are plasticity, cohesion, thixotrophy, consolidation and swelling, as described here. Soil is called plastic if within some range of water content it can be rolled into the threads. The capacity of soil to resist shearing stress is known as cohesion. This strength is basically due to shearing strength of the absorbed layer that seperates the grain at these points. When percentage of water in a fine saturated soil is reduced by compaction or surface evaportion, the volume of voids occupied by water decreases, but the volume occupied by absorbed substances remains the same. This increases cohesion. Soil that develops cohesion is kneaded and remains undisturbed. If, this soil is again kneaded without changing

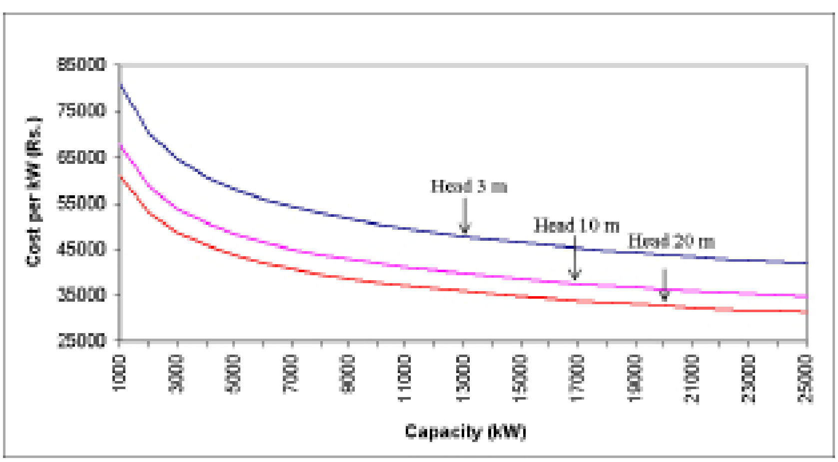

Figure 2. Canal Based SHP Scheme with Two Units

the water-content, there is decrease in cohesion. With passage of time this reduction in cohesion is neutralised. This phenomenon is known as trixotrophy. On application of pressure, water-content decreases and soil is said to be consolidated. In case, pressure on the soil decreases, while free water is available to the soil, water-content and volume of soil increases and the phenomenon is known as swelling.

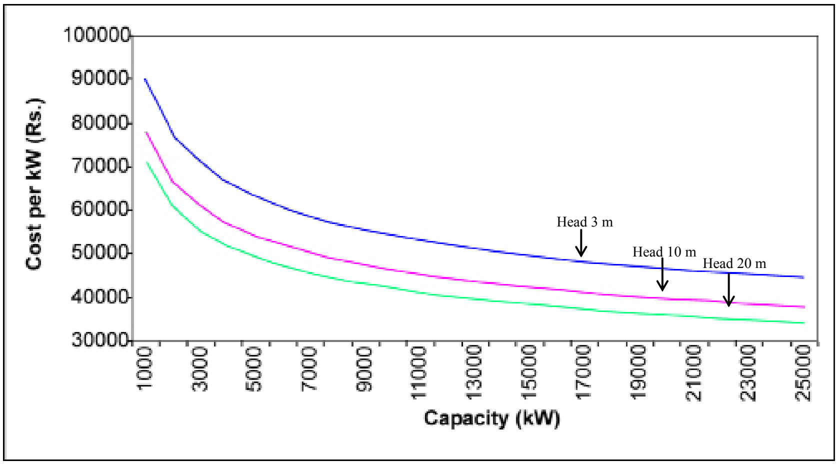

Fig. 3 Cost of run of river SHP scheme with two units

Broadly, soils are categorized as residual soils formed by weathering of rocks but located at the place of origin and transported soils classified according to the mode of their transportation and deposition; i.e., by flowing water, wind, gravity and ice. The types of soils in India are shown in Figure 1 and discussed as below:

Red Soils

The parent rocks are acid granites, gneiss quartizite and felspathis rocks. The colour of the soils is generally red. Such soils are found in Meghalaya, Nagaland, Orissa, West Bengal, Uttar Pradesh (UP) and Tamil Nadu states of India.

Black Soils

The most characteristic black soils cap the volcanic plateau of the Deccan Traps. The black cotton soil is highly argillaceous with a large clay fraction and absence of gravel or coarse sand. Such soils are found in Gujarat, Madhya Pradesh, Chhattisgarh, Maharasthra and Tamil Nadu states of India.

Laterite Soils.

These are salt-impregnated soils. The alkaline content of the soil is high and there is a large excess of free salts and such soils have poor agricultural value. Such soils are found in Jharkhand, Uttar Pradesh, Punjab and Rajasthan states of India.

Alluvial Soils

These soils are sandy loam to clay loam- with light gray colour to dark colour. Such soils are found in plain of Uttarakhand, UP, Bihar, West Bengal i.e. almost all states in Northern and Southern India.

Desert Soils

These soils are mostly sandy to loamy fine sand with brown to yellow colour containing large amount of soluble salts and lime. Such soils are found in Haryana, Punjabs and Rajasthan states of India.

Forest Soils

These soils are dark brown with more sub-soil humus content. Such soils are found in Himalayan forests in some parts of hilly area of Northern India.

Saline and Delitic Soils

These soils contain excess of natural soluble salts dominated by chlorides and sulphates. Such soils are found almost in all parts of India.

Peat Soils

Peat soil is compossed of fibrous particles of decayed vegetable matter. It is light brown to dark in colour. This is a compressible soil. Such soils are found in some parts of Eastern states in India.

Hard Rocks

Hard rocks are found in upper Himalayan region, hilly areas of Eastern and Southern states in India.

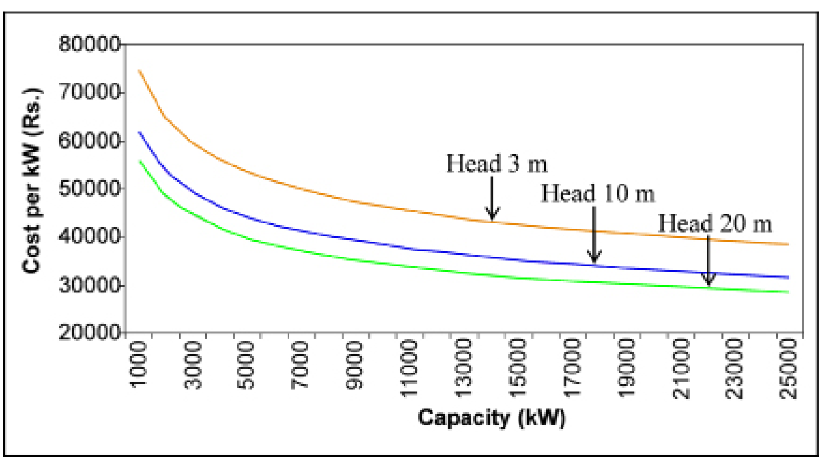

Fig. 4 Dam toe SHP scheme with two units

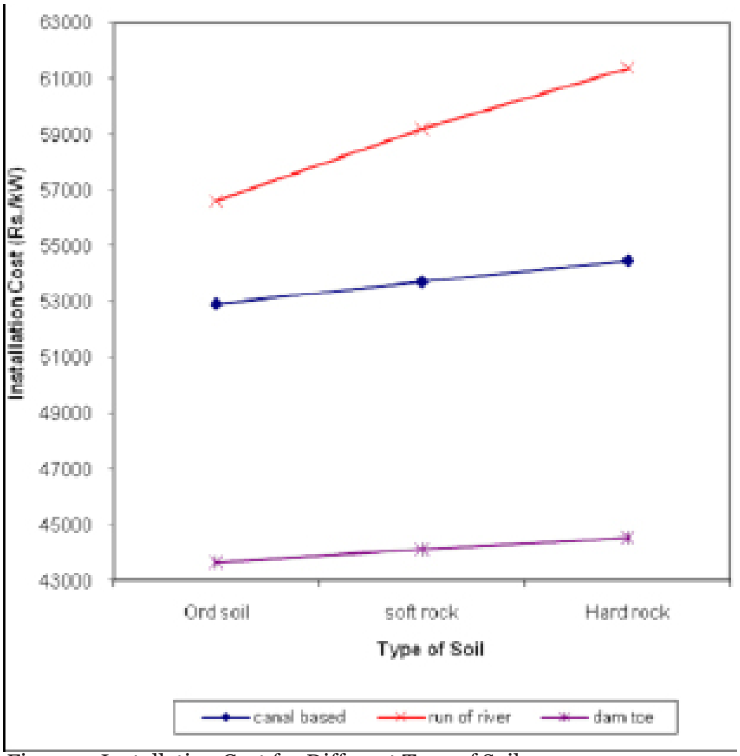

Figure 5. Installation Cost for Different Type of Soils

Soft Rocks

Soft rocks are found in lower Himalayan region and foot hills in Northern states of India.

These various types of soils available are popularly termed as sand, silt, clay, gravel, black cotton, peat, boulder, rocks, etc. From the excavation cost point of view, soil is classified broadly as ordinary soil, soft rock and hard rock. The cost on excavation is different for the different type of soils. Ordinary soil and soft rock are excavated manually or mechanically without using blasting. Hard rock needs blasting for excavation. Hence extra safety measures are required and it becomes costliest for excavation in hard rocks. In case of hard rocks, the bearing capacity of soil is more and also there is no problem of dewatering during construction. The power station and associated structures are constructed near water bodies i.e. canal or river. When, water table is high, lot of expenditure has to be incurred on dewatering to facilitate construction. The problem/expenditure on dewatering is not there in case of soft rocks or hard rocks. In the present study, ordinary soil, soft rock and hard rock are considered for cost analysis.

Methodology for Cost Evaluation

Under the present study, all three types of low head small hydropower schemes under canal based, run-of-river and dam toe having 3 m head with plant capacity 2 MW have been considered. The unit sizes are taken as 1 MW with two generating units. Type of turbine is considered as tubular semi Kaplan type.

In order to find out the overall installation cost for different alternatives under different schemes, the costs of individual components have been determined. Civil works costs have been estimated based on quantities of different items and their prevailing prices. Cost of electro-mechanical equipment has been computed based on capacity and type of equipment taking the prevailing market prices obtained from different manufacturers. Based on the cost of individual components, total installation cost of diferent schemes under different soil conditions such as ordinary soil, soft rock and hard rock are computed. The installation costs computed for canal based, run-of-river and dam toe schemes under ordinary soil conditions at different heads and different capacities are shown in Figures 2, 3 and 4, respectively. Using similar methodology, installation costs under soft rock and hard rock conditions are also computed. The costs are taken in Indian rupees (1 US $= 50 Indian rupees).

Based on the computed installation cost and financial parameters considered for analysis as given in Table 1, generation cost for each scheme has been computed.

Results and Discussions

In the present study, the costs of installation for different alternatives have been evaluated for three different types of schemes; i.e., canal based, run-of-river and dam toe.

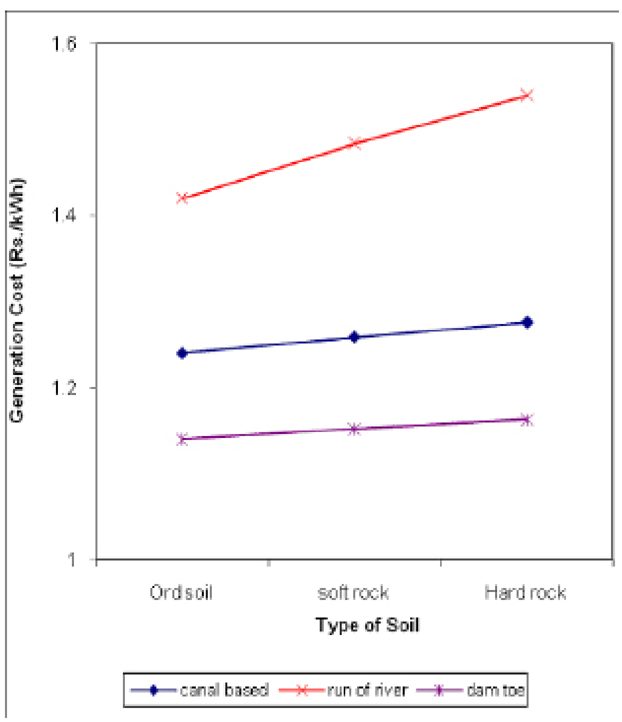

Figure 6. Generation Cost for Different Type of Soils

These costs for a typical case are considered (i.e., layout with two generating units at 20 m head under different soil conditions) and are shown in Figure 5. It is seen that the cost decreases with increase in the head as well as capacity. This is in order. Figure 6 shows the generation cost computed for the layouts considered under different soil conditions. It is seen that the installation cost as well as generation costs are low in case of layouts in ordinary soil conditions and higher is case of layouts in hard rock conditions. In case of hard rock conditions excavation is difficult thus involves more cost; however, it gives favorable foundation condition.

Conclusions

In order to develop small hydropower projects, assessment of cost is essential after establishing its technical feasibility, as SHP projects are site specific. In the present study, all the three types of schemes — i.e., canal based, run-of-river and dam toe SHP schemes under low head – have been considered for cost analysis and a methodolgy for cost evaluation developed. The costs of various components have been determined for different cases based on actual quantities of different items having prevailing prices. In the cost analysis all three types of soils are considered; i.e., ordinary soil, soft rock and hard rock. It is found that the layout with ordinary soil condition has minimum installation cost and layout with hard rock has maximum installation cost as well as generation cost, and the maximum difference in cost with these soil conditions is found to be as 8.4%.

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