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Software Based Approach for Cost Optimization of Mini Hydro Power Plants: A Comparative Case Study

KEYWORDS: Renewable Energy technology, Levelized cost of energy, Net present cost.

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ABSTRACT *Mini hydro power development can reduce the load on conventional sources of energy. The cost of mini hydro power generation can be maintained at attractive levels, despite periodic modifications in the regime of fiscal incentives through higher efficiencies and improved performance obtained from new hydro turbine designs; larger scale and more efficient manufacturing; better levels of operation and maintenance and development of sites in clusters. HOMER software is significantly used, as analysis is based on the technical properties and the life cycle cost comprised of the initial capital cost, cost of installation and operation of the system.. In the simulation process, different power system configurations for every hour of the year are generated with their technical feasibility and life cycle cost. In the optimization process, HOMER selects one system configuration out of all configurations generated in the simulation process that satisfies all technical constraints and has the lowest life cycle cost.*

Introduction:

Mini hydro power may turn out to be even more competitive in comparison with conventional power if the classical cost calculations for conventional power also reflect all the external social and environmental costs .After 1970's, crude oil prices increased because of the oil crisis and the people's growing ecological sensitivity as well as the corresponding authority's incentives caused mini hydropower emerge as an important source of renewable energy. Attractive policies of few countries (notably Germany) have boosted the mini hydro sector in recent years. The trend is shifting in hydro electricity developments, with installations now reflecting small scale developments similar to the ones of centuries past. Mini hydro turbines with high efficiencies have aided the move back towards small distributed sites.

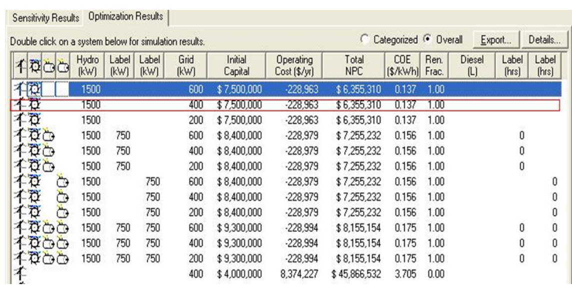
(a) Aleo Manali Mini Hydro Plant (1.5MW): Aleo Hydro electric power plant was allotted to Aleo Manali Hydropower P. Ltd (AMHPL) by Himachal Pradesh Energy Development Agency in March 2001. Aleo HEP is a run of river scheme near Manali town in Kullu district of Himachal Pradesh. The scheme utilizes 1.33 cumec discharge of Allain Nala by developing a head of 290.4 M for 1500 KW generation, in Aleo village close to Manali. The power generated is fed into 33KV H.P.S.E.B. Grid Sub Station at Prini.The various data collected for Aleo mini hydro plant as per requirement of software Homer (2.81 version) for cost optimization has been introduced or substituted in the software for simulation.

(b) Chakshi Mini Hydro Power Plant (2MW) is to produce clean electrical energy in a sustainable manner, optimizing the utilization of water potential available at Chakshi Nala in the Kullu district of Himachal Pradesh state in India. Chakshi 2 MW Mini Hydro Power Project is conceived by Puri oils Mills Limited (POML) as a run of the river project proposing utilization of the flow of the river Chakshi Nala , a tributary of Parvati River. The various data collected for chakshi mini hydro plant as per requirement of software Homer (2.81 version) for cost optimization has been substituted in the software for simulation.

(c) Jirah Kullu Mini Hydro Plant (4 MW) established by Kapil Mohan & Associates Hydro Power Private Limited is an independent power proposing a renewable energy based mini hydro electric power project in state of Himachal Pradesh, India. The project activity is a run-of-river scheme for power generation on Jirah nallah, a tributary of river Parbati. The purpose of proposed project activity is to tap the potential of a natural renewable source i.e. flowing water to generate environmentally clean electricity. The electricity produced from the project would be fed directly to the Himachal Pradesh State Electricity Board (HPSEB). The approximated data collected for Jirah mini hydro plant as per requirement of software Homer (2.81 version) for cost optimization has been introduced or substituted in the software for simulation.

II Optimization and Analysis Results:

(A) Aleo 1.5 MW Mini Hydro Power Plant:



Sensitivity Results | Optimization Results

Double click on a system below for simulation results. Categorized Overall Export... Details...

Hydro (kW)	Label (kW)	Label (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Label (hrs)
1500			600	$ 7,500,000	-228,963	$ 6,355,310	0.137	1.00			
1500			400	$ 7,500,000	-228,963	$ 6,355,310	0.137	1.00			
1500			200	$ 7,500,000	-228,963	$ 6,355,310	0.137	1.00			
1500	750		600	$ 8,400,000	-228,979	$ 7,255,232	0.156	1.00		0	
1500	750		400	$ 8,400,000	-228,979	$ 7,255,232	0.156	1.00		0	
1500	750		200	$ 8,400,000	-228,979	$ 7,255,232	0.156	1.00		0	
1500		750	600	$ 8,400,000	-228,979	$ 7,255,232	0.156	1.00			0
1500		750	400	$ 8,400,000	-228,979	$ 7,255,232	0.156	1.00			0
1500		750	200	$ 8,400,000	-228,979	$ 7,255,232	0.156	1.00			0
1500	750	750	600	$ 9,300,000	-228,994	$ 8,155,154	0.175	1.00		0	0
1500	750	750	400	$ 9,300,000	-228,994	$ 8,155,154	0.175	1.00		0	0
1500	750	750	200	$ 9,300,000	-228,994	$ 8,155,154	0.175	1.00		0	0
			400	$ 4,000,000	8,374,227	$ 45,866,532	3.705	0.00			

Figure 1.1: Optimization Result Details

For Aleo Manali, various combinations have been obtained of hydro system hydro, generator, and grid from the HOMER Optimization simulation. This is shown in figure 1.1.HOMER uses the total NPC as its main selection tool. All the possible hydro system configurations are listed in ascending order of their total NPC in the figure 1.1 shown above. The technical and economical details of all the configurations of the hydro systems from the optimization process are shown in detail in figure 1.1, where the best possible combination of hydro and grid is highlighted in blue and the next best possible combination is marked with a red coloured box. As per the optimization results an optimal combination of renewable energy technology system components are 1500 KW hydro, and 600KW grid. Details of this configuration are shown in figure 1.2. The total NPC, Capital cost and cost of energy for such a hydro

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system are Rs. 6,355,310, Rs.7,500,000 and Rs.0.137 KWh, respectively.

System architecture

Hydro 1,500 KW	
Grid	600 KW

Cost Summary

Total net present cost	Rs. 6,355,310
Levelized cost of energy	Rs. 0.137/KWh
Operating cost	Rs. - 228,963/yr

Electrical

Component	Production (KWh/yr)	Fraction
Hydro turbine	10,003,558	100%
Grid purchases	0	0%
Total	10,003,558	100%

Figure 1.2: Technical & Cost De tails of the Best Suited Configuration for 1.5 MW Hydro Power Plant

This shows the cash flow summary based on the components selected in the system. Hydro and other expenses share the maximum portion of the capital investment. In operating cost other expenses are accounted. Replacements occur majorly in the 25th year of the system, mostly for changing penstock pipe also maintaining generator and turbine. All these cash flow calculations do not consider any discounts, government funding or subsidies.

(B) Chakshi 2 MW Mini Hydro Power Plant:

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. Categorized / Overall | Export... | Details...

Hydro (kW)	Label (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
2002		1000	$ 4,500,000	937,676	$ 16,486,647	0.125	0.95		
2002	1000	1000	$ 5,500,000	953,008	$ 17,682,638	0.134	0.95	775	5
2002	2000	1000	$ 6,500,000	968,115	$ 18,875,762	0.143	0.95	1,550	5

Figure 1.3: Optimization Result Details

For Chakshi hydro plant, various combinations have been obtained of hydro system hydro, generator, and grid from the HOMER Optimization simulation. This is shown in figure 1.3. HOMER uses the total NPC as its main selection tool. All the possible hydro system configurations are listed in ascending order of their total NPC in the figure 1.3 shown above. The technical and economical details of all the configurations of the hydro systems from the optimization process are shown in detail in figure 1.3, where the best possible combination of hydro and grid is highlighted in blue and the next best possible combination is marked with a red coloured box. As per the optimization results an optimal combination of renewable energy technology system components are 2002 KW hydro, and 1000KW grid. Details of this configuration are shown in figure 1.4. The total NPC, Capital cost and cost of energy for such a hydro system are Rs.16,486,647, Rs.4,500,000 and Rs.0.125 KWh, respectively.

System architecture

Hydro 2,002 KW	
Grid	1,000 KW

Cost Summary

Total net present cost	Rs. 16,486,647
Levelized cost of energy	Rs. 0.125/KWh
Operating cost	Rs. 937,676/yr

Electrical

Component	Production (KWh/yr)	Fraction
Hydro turbine	16,504,365	97%
Grid purchases	533,507	3%
Total	17,037,872	100%

Figure 1.4: Technical & Cost detail of the Best Suited Configuration for 2 MW Hydro Plant

This clearly shows the cash flow summary based on the components selected in the system. Hydro and grid share the maximum portion of the capital investment. In operating cost grid has maximum share.. All these cash flow calculations do not consider any discounts, government funding or subsidies.

(C) Jirah Kullu 4 MW Mini Hydro Power Plant:

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. Categorized / Overall | Export... | Details...

Hydro (kW)	GEN (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	GEN (hrs)
4002	1000	1000	$ 10,000,000	351,587	$ 14,494,458	0.123	0.82	10,850	70
4002	2000	1000	$ 11,000,000	776,311	$ 20,923,856	0.177	0.82	21,700	70
4002	3000	1000	$ 12,000,000	1,201,070	$ 27,353,706	0.232	0.82	32,550	70
	1000	1000	$ 2,000,000	13,442,551	$ 173,840,9...	3.324	0.00	28,985	187
	2000	1000	$ 3,000,000	14,604,622	$ 189,696,0...	3.627	0.00	57,970	187
	3000	1000	$ 4,000,000	15,766,755	$ 205,552,0...	3.930	0.00	86,955	187

Figure 1.5: Optimization Result Details

For Jirah, various combinations have been obtained of hydro system hydro, generator, grid and generator from the HOMER Optimization simulation. This is shown in figure 1.5. HOMER uses the total NPC as its main selection tool. All the possible hydro system configurations are listed in ascending order of their total NPC in the figure 1.5 shown above. The technical and economical details of all the configurations of the hydro systems from the optimization process are shown in detail in figure 1.5, where the best possible combination of hydro and grid is highlighted in blue and the next best possible combination is marked with a red colored box.

As per the optimization results an optimal combination of renewable energy technology system components are 4002KW hydro, 1000 KW grid and 1000 KW generator with a dispatch strategy of cycle charging.. The total NPC, Capital cost and cost of energy for such a hydro system are Rs.14,494, Rs.10,000,000 and Rs.0.123 KWh, respectively. This shows the cash flow summary based on the components selected in the system. Hydro and grid share the maximum portion of the capital investment. In operating cost hydro's share is maximum, generator 1 fuel cost is higher. After completion of plant term replacement of power house components and penstocks is required therefore leads to increase in salvage cost will be accounted. All these cash flow calculations do not consider any discounts, government funding or subsidies.

III Summary and conclusion:

Firstly individual analysis of each mini hydro power plant is done using software to design individual optimal cost system. The best suited configuration is designed and results obtained in cost tables are:

(i) As per the optimization results an optimal combination of renewable energy technology system components are 1500 KW hydro, and 600KW grid. The total NPC, Capital cost and cost of energy for such a hydro system are Rs.6,355,310, Rs.7,500,000 and Rs.0.137 KWh, respectively.

(ii) As per the optimization results an optimal combination of renewable energy technology system components are 2002 KW hydro, and 1000KW grid. The total NPC, Capital cost and cost of energy for such a hydro system are Rs.16,486,647, Rs.4,500,000 and Rs.0.125 KWh, respectively.

(iii) As per the optimization results an optimal combination of renewable energy technology system components

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are 4002KW hydro, 1000 KW grid and 1000 KW generator. The total NPC, Capital cost and cost of energy for such a hydro system are Rs.14,494, Rs.10,000,000 and Rs.0.123 KWh, respectively.

Using renewable energy technologies is generally considered to be the best suited alternative to an expensive grid extension for remote areas around. This individual analysis of different mini hydro plants depicts, focuses on creating a model for electricity generation which is based on cost of installation of a mini power plants to satisfy the electrical needs of an off-grid remote location, as rural electrification of unelectrified village location is of prime concern nowdays.

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