Hydro Power from Existing Irrigation Reservoirs in Sri Lanka

HYR Perera[1], GTF de Silva[2], S Bogahawatte[3]

[1,2,3]*General Sir John Kotelawala Defence University, Ratmalana, ,* Sri Lanka
{[1]hyrp, [2]gtf,[3]bogahawatte}@kdu.ac.lk

Abstract— *For over four decades from the time oil producing countries started increasing prices, the local intellectual community had been discussing and debating the subject of the use of alternate energy sources. Some progress has been achieved using mini and micro hydro technologies to harness energy from streams which have adequate heads. However, the feasibility of harnessing energy of water released for irrigation purposes from the many tanks that are in existence from ancient times has not been tried out.*

Until recent times what was technically acceptable had been that large head difference is required to generate hydro power. However, recent research work had demonstrated that it is possible to produce electricity from heads even as low as 5 m. Many of our existing reservoirs have head differences over 5 ms. The focus of this paper is on studying at a basic level the possibility of generating electrical power from the many existing reservoirs that have been used for centuries without affecting irrigation purposes that support agriculture.

I. INTRODUCTION

It had been noted that the electrical power capacity as well as generation had been increasing steadily as evident from Table 1. However, due to the rise in population due to social and political pressures need for an increased supply had been very essential. A further factor is the many high rise buildings such as hotels, apartments, office complexes and factories that are coming up which adds to the setting up lifts and air conditioning putting a greater demand for electrical power. As such it would be rather difficult to forecast future need for electricity over even for 5 to 10 year period. It could be for this reason that there is not much literature on the future electricity need.

In a gazette notification in 2008, the Minister of Power & Energy, [1] had laid down a policy paper, as the ‘ National Energy Policy & Strategies of Sri Lanka’, and some important matters related to this research are stated below:

Table 1: Available power capacity and energy

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
Available Capacity MW	2,230	2,243	2,378	2,411	2,434	2,444	2,645	2,684	2,817
Generation GWh	6,951	7,612	8,159	6,769	9,389	9,814	9,901	9,882	10,714

“In 2004, hydro-electricity production in the NRE. The target year to reach this level of NRE is 2015.”

“To make available the incentives for NRE technologies, the government will set up an ‘Energy Fund.’

In a recent paper Abeygunawardana [2], had indicated that hydro power contributes only to 40-50 % of the total requirement of about 33 GWh/day. He had also estimated the capacity requirement at about 1200-1400 MW during day time and that at around 2000 MW during peak hours.

Figures of the total power generation at present are given below in Table 2, using data taken from the official Electricity Board website.

It is well known that the cost incurred from thermal power sources is substantially high and the government is under pressure to add this cost to the consumer tariff through a fuel adjustment charge especially during drought periods when water reservoirs run low.

In a document prepared jointly by the Secretary to the Ministry of Power and Energy and Additional General Manager (Transmission), Ceylon Electricity

Board, points out the need to expand the use of solar & wind energy and other sources and also had estimated the investments needed for such projects, [3]. These figures are given in Table 3.

This section summarizes that. “With the vast renewable energy resource base, Sri Lanka can look forward for a better future than most other countries. The pivotal role of the renewable energy development programme will be developing indigenous knowledge, technology and capacity. As a nation, our primary focus ought to be in this area, as economic development of any nation is still very much the child of the marriage between the Engineering industry and Energy industry”.

It is satisfying to note that the target for mini hydro for 2014, the figure of 220 MW had been achieved as also shown in the figure of 218 in Table 2.

However, it is worthwhile comparing above figures and the statement made by the local ministry spokes persons with the following statement by the Federal Minister of Environment of the German Republic, [5].

“We will already be able to generate 100 percent of our electricity from renewable energy sources in 20 years. Our initial target is to double the percentage of power from renewable sources from 17 % now to at least 35 % in the next 10 years.” It is evident that Sri Lanka has to take a more vigorous approach to meet the energy crisis especially In view of the declining petroleum sources accompanied by rising costs and the increasing demand for electricity.

Table 2: Total Electricity Capacity (MW)

Source	Number of Plants	Total Capacity
CEB - Hydropower		
Mahaweli Complex	8	816.2
Laxapana Complex	7	310
Other Hydro	4	207.25
Sub Total		***1383.45***
Total Mini Hydro	109	218.562
Wind power	3	73.040
Solar power	4	1.378
Dendro power	2	1.5
Biomass power	2	11.00
Thermal (CEB)	10	578.0
Thermal (private)	12	841.5

In a traditional society like ours it is easy to accept already established systems and methods both by the public and by the political leaders. The large irrigation tanks have played an important role from ancient times and tapping electrical power from such reservoirs had been now in place for around a half century. It will be easier to convince the public and the leaders to use water reservoirs to derive hydro power.

Table 3: Progress of Renewable Energy Development

Year	Type	2009	2010	2011	2012	2013	2014	2015	2016
Cumulative Capacity MW	Biomass	20	31	42	53	64	75	80	91
	Mini Hydro	134	151	168	186	203	220	250	267
	Wind	30	54	78	102	125	149	170	267
Investment Opportunity LKR Millions		5724	5724	5724	5724	5724	5724	5724	4057

There had not been any attempt to derive hydro power from the many irrigation reservoirs that are found in the North Central and other provinces. This is mainly because it was held in theory that large heads were needed for generators to work. However, present research shows that substantial capacities could be derived from heads of the order of 5 m.

The authors have done an initial study of the Chandrika Wewa reservoir at Embilipitiya and have found a head of nearly 8 to 10 m. As such electricity in mini hydro level can be generated at the time water is discharged for irrigation purposes.It is also possible to derive some electricity from water discharged from the next smaller tanks thus getting hydro power of micro level. These aspects will be discussed in section II, and the feasible capacities of other leading tanks will be displayed in section III with conclusions and recommendations made in section IV.

VI. PROPOSED METHOD TO OBTAIN POWER FROM EXISTING IRRIGATION RESERVOIRS

As already stated the purpose of this paper is to examine the possibility of deriving electric power from existing reservoirs when water is released for irrigation purposes.

It is established that major structural alterations to the tanks or to the bunds will not be necessary. Only some modifications may have to be made to the portions outside sluice gates. or to the ancient 'Bisokotuwas.'

The scale of the hydro power could be considered as mini hydro schemes or even small hydro schemes as defined by Rai,[5]. As stated by this author, "Up to 1972, hydro engineers concentrated on developing the larger sites... However, with the prospect of rapidly depleting fossil fuel reserves coupled with steady rise in oil prices, attention has returned to the smaller sites previously regarded as uneconomic."

Another reason for the increased interest in smaller sites for hydro electricity was the emergence of low head turbines such as bulb – turbines for power generation. This type being the youngest member of hydro turbines meant for low water heads is in the range of 0.5 to 30 m, unlike the Kaplan and other large turbines which need greater heads and large flow.

The horizontal positioning of its shaft results in a reduced size of the equipment compared to a vertical shaft arrangement.

To estimate power output, as shown in Fig. 1, let Q be the discharge rate and h the gross head. Available power P is given by

P (kW) $=(\eta p Q g h)/1000$, ($p=1000$ kg/m^3, $g=9.81 m^2/s$)

-where η is the efficiency of the system and g the acceleration due to gravity.

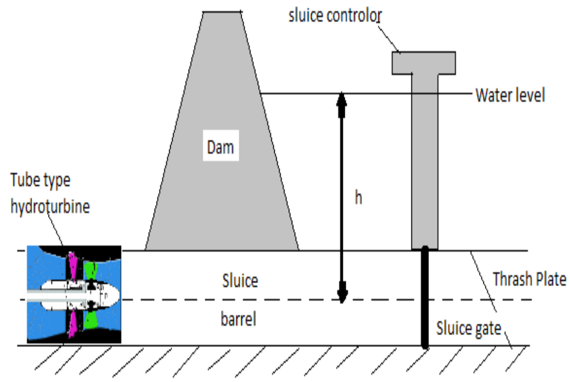

Figure 1: Water Releasing System

Irrigation water is discharged from ancient tanks through a arrangement known as 'BisoKotuwa', BK, an ancient form of a valve pit situated in the dam of the reservoir. There can be up to two or three such outlets depending on the requirement.

As indicated in Fig 2, the BK is a rectangular pit formed inside the reservoir closer to which a strong board is kept to be raised or lowered by a pulley system to allow the flow of water to an irrigation canal or to stop the flow from the reservoir.

Tisa Wewa and Rajangana reservoirs were selected due to their proximity to study the possibility of obtaining hydro electricity according to the design proposed in the previous section.

VII. RESULTS OF A TEST CASES OF TISA WEWA AND RAJANGANAYA IRRIGATION ESERVIOR(ANURADAPURA) :

Tisa Wewa

Sluice gates allow water to be released to the Basawakkulama Wewa which itself has a dam that releases irrigation water. It was noted that a head of water of about 8.5 m can actually be obtained by placing the generator downstream of the canal by a small distance.

Figure 2: Sluice Gate at Rajangana Left bank

For the sake of convenience and also lack of data, Left Bank (LB) and Right Bank (RB) releases given are taken together.

The table 4 shows the hydro power that could have been realized from the arrangement proposed from the discharges of water that had been utilized only for agricultural purposes. However, this arrangement will make it possible to harness electricity without hindering flow of water to irrigation canals.

It has to be noted that period of the study is from 19th January 2009 to 9th April 2009; a period of some rain and some days without rain.

Above results are summarized in Table 4, for days when water had been discharged during the period of study.

Monthly average revenue for three months is Rs 484,090.00. Therefore annual income is Rs 5,809,088. There can be simple concrete structure to carry the turbine and generator and a simple building to house them and modification of lower part of the canal section to form the tail race. There is no cost for dam, canals, penstock etc. Hence the cost of the hydro turbine and generator and civil works will be 2,500,000. Therefore, the simple payback period is less than 5 years.

Table 4: Average Water Releases & Average Power Generation of Tisa Wewa

Days Water Released 2009	Number of Days	Average Daily Releases (mm)	Average Daily Power Generated (k W)	Energy Generated kWh	Income Rs
19-01 to 08-02	21	0.061	81.81	41,232	690,636
11-02 to 14-02	4	0.050	64.62	6,203	103,900
18-02 to 21-02	4	0.058	72.84	6,992	117,116
26-02 to 28-02	3	0.067	83.82	6,035	101,086
16-03 to 22-03	7	0.040	58.65	9,853	165,035
30-03 to 04-04	6	0.091	113.81	16,388	274,499

Power generation at Rajangana Reservior

The low head water turbines from the capacity of fraction of kW to 2MW or higher are now developed by different companies and they could be installed at the entrance of the canal where water is released from the sluice gate.

Calculation for average daily power output and the possible generation of energy have been calculated as shown in Table 5. Also the revenue earning by generating electricity from the water releases from the 2 sluice gates for 12 months of 2009-are given in the table.

Normally water is issued continuously during the first two months as paddy fields need water continuously for paddy growing at the beginning of the season and then released weekly or two to three days per week. The mean power is calculated with 5% to 10% confidence level.The evaluation methods of energy economics have been adopted as done by PUCSL for cost of energy calculations.

There are two sluice gates at Rajangana tank. The average power output, Energy, and revenue are calculated

Figure 3: the left bank canal just below the sluice outlet

The normal method of computing the capacity of hydro generator is drawing the excedence curve and deciding at around 40% excedence. But when water is released from irrigation tanks large quantity of water is released at the beginning of the cultivation season.

At large amount of energy could be extracted during this short period. Hence it is necessary to consider 5% to 10% of the excedence to decide the capacity. Hence average power generated in the above table could be considered in deciding the capacity of hydro generators for Rajangana reservoir which worked out to 500 kW on each of the banks.

There is no much civil work such as canal; penstock etc needed. Only a suitable generator room over the canal closer to the output side of the sluice barrel is sufficient. Hence the cost will be only for Hydro turbine, building and formation of canal as suitable for mounting of hydro generators. It is estimated that the cost is for Rs 100 Mn per 1MW. With the results of table 4 of Rajangana annual income is 31Mn . Hence the simple payback period is around 3 years. Hence it could be considered that Rajangana is a very good viable mini hydro project for early development.

Possibility of harnessing Energy along the irrigation canals

Figure 4: Left bank canal with water control unit of Rajanganaya 5km away from the dam

The picture in figure 4 shows that there are several similar places along the canal which has sufficient head for electricity generation in the range of 5kW to 25kW by installing low head generators. In the field visit it was observed that the farmers are paying Rs. 1200 per hour as electricity charges for pumping of water for their cultivated lands which are situated 1m to 2 m above the water level of canals.

If hydro turbines are installed to harness the energy from the flow of water in the canals, the generated electricity could be used for pumping using the net metering arrangement with CEB.

VIII. CONCLUSION

The generating of hydro power from the water release from the irrigation reservoirs without disturbing the irrigation is possible. There is no much cost in civil engineering as the generators are installed at the opening of the canals. The water release during the year is sufficient to earn reasonable revenue to cover the cost within few years and then only the operation and maintenance cost have to be met. The capacity of the hydro turbines should be higher than that for normal mini hydro schemes as it is required to harness energy at the periods in which release of water is more. Department of irrigation could earn revenue utilizing same for the maintenance of canals and pumping of water to the lands which are in higher elevations.

The study revealed that the power and energy could be generated from the release of water of other irrigation reservoirs in Sri Lanka.

Table 5: Revenue earning by generating electricity from the water releases from the 2 sluice gates for 12 months of 2009

Month	No of days		Water release cumec		Daily power kW	Energy kWh			Total energy kW	Income Rs
		Head m	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank		
January	31	11	5	4	293	200	218132	144071	367203	6,150,664
February	19	11	3	3	160	155	107621	103984	211576	3,543,896
March	18	11	3	0	156	115	115714		115704	1,938,042
April										0
May	30	9	5	0	146		183367		183367	3,071,398
June	30	8	4	4	184	176	132721	126967	259688	4,349,715
July	31	6	4	4	132	129	96005	98195	194200	3,252,852
August	24	5		3	76	83	40672	56724	61401	1,028,464
Sept.	27	4		3	80	0	20890	25870	46760	790,274
October										0
Nov.	15	8	3	2	132	102	94999	73332	168331	2,819,545
Dec.	19	10	5	3	268	152	194693	11254	1131462	5,235,078
Total	244	83								
year average	244	7	3	2	132	89	1155104	716358	1931462	31,389,654,

*cumec-cubic meter per second

ACKNOWLEDGEMENT

It is highly appreciated that the assistance and the cooperation given for providing the data by the Director General, Eng Badra Kamaladasa, Diretor Water Management Eng. Janakie Meegastenna and Divisional Irrigation Engineer, Rajangna, Eng ABK Konagedra of Department of irrigation.

REFERENCES

Ministry of Power & Energy Website and The Gazette of the Democratic Socialist republic of Sri Lanka, June 10, 2008

Abeygunawardana, Asoka, 2013, Energy Forum, Ministry of Power & Energy, www.lankagaslk.com/uploads/1/0/4/7/1047656/electricity_generation

Ferdinando,M.M.C., Gunawardana R.I.,2014, Electricity Generation from Alternate Energy Sources in Sri Lanka Future Directions , Ceylon Electricity Website.

Rottgen Norbert, 2011,Magazin Deutschland, March issue.

Rai, C. K. 1989, 'Non-Conventional Energy Sources', Khanna Publishers

AUTHOR BIOGRAPHY

[1]Author is a Professor in Electrical Engineering at University of Moratuwa currently functioning as the Dean, Faculty of Engineering at General Sir John Kotelawala Defence University. He graduated from University of Moratuwa and obtained his Dipl.-Ing. and Dr. Ing Degrees from RWTH Aachen, Germany. His research interests include Power Systems Reliability, Mathematical Modeling and Renewable Energy Development. He has produced more than 30 international and local publications. He also served as Director General/CEO of Public Utilities Commission Sri Lanka from April 2008 to December 2009.

[2]Professor G.T.F. De Silva, served University of Moratuwa as Lecturer, Head of the Department of Mathematics and as Vice Chancellor. He was the Director General of S.L.I.A.T.E and Managing Director of Media Defined, the Sri Lankan Branch of a USA Company working in e-Learning. Currently he is attached to the Department of IT & Mathematics at KDU. He holds DIC & M. Phil. in Mathematics & Computing, D. Phil (H.C.) from University of Moratuwa, MBCS, C. Eng and MBIS.

[3]Eng S Bogahawatte is a senior lecturer in Electrical Engineering at General Sir John KotelawalaDefence University.He completed his Engineering education from the Institution of Engineers of Sri Lanka and obtained his MEng Degree in Electrical Engineering from theUniversity of Moratuwa.He worked in the Ceylon Electricity Board in different positions as an ElectricalEngineer, Chief Engineer, Project Director and Deputy General Manager. He obtained Advanced Engineering Training from Germany. He served as Secretary of the Electrical Sectional committee ofthe Institutionof Engineers Sri Lanka.