

Evaluation of the Performance Improvement for Application of Short Term Rainfall Forecast Data at Pondage Hydropower Plant

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Abstract—From the short term rainfall forecast data, pondage hydropower plant operators gain valuable information of additional incoming water flow to their plants in advance, which enables them make data-driven water release and/or loading decisions ahead of time. This paper gives a simplified process of converting this raw data into the required valuable information. Besides, subsequent key performance indicators required to evaluate the effectiveness and efficiency of using short term rainfall forecast data is explicated. Moreover, this work extends the evaluation to application via actual rainfall data to assess the accuracy of applying rainfall forecast data. A case application of this approach using short term rainfall data supplied by local meteorological department and actual rainfall data supplied by local irrigation and drainage department supported the feasibility of this approach.

Keywords—energy production, pondage hydropower plant, rainfall forecast, spillage, turbine water release

I. INTRODUCTION

PONDAGE hydropower plant is one of those classified according to the quantity of available water [1]. It is an in-between of storage type and run-of-river type. Storage plants have a sufficiently large reservoir to cater for seasonal regulation whereas pure run-of-river plants do not store water, i.e. use water as it comes. As in-betweens, pondage plants are run-of-river plants with a small amount of storage that can be used for daily to weekly regulation of river flow.

For pondage hydropower plant, which is the emphasis of this paper, water shall be stored during lean periods and then used during peak periods [2]. Without information of incoming water, this operating strategy, however, bears a high risk of water loss from spillage as heavy rainfall or flood flow may strike when the pond's level is high, i.e. storage capacity is limited or none.

As a result, conservative approach was taken by pondage hydropower plant operators. In specific, pond's level is managed at a comfortable level, which has less risk of spillage, but at the same time, yields lower power output as gross head is lower.

This paper aims to evaluate the potential improvements in energy production and spillage reduction via the application of

rainfall forecast data. In this initial attempt to convince pondage plant operators for adoption of this data-driven decision making approach, rainfall forecast data were acquired from local meteorological department. Besides, simplified linear equations were used for quantification of the key outputs.

II. METHODOLOGY

A. Computation of Additional Energy Production from Forecasted Rainfall

In order to evaluate the performance of short term rainfall forecast application for pondage hydropower plant, key outputs such as additional incoming water and subsequently additional energy production of the hydropower plant have to be computed first.

From the supplied rainfall forecast data, the amount of rain in mm for the forecasted period is known. For this evaluation, the period of forecast is 24 to 48 hours ahead. To put this simply, the forecast for 00:00 to 23:00 hour on 2 May 2011 will be delivered by 00:00 on 1 May 2011.

This data will then be used to aid the decision making of hydropower plant operators on 1 May 2011. By knowing the amount of rain forecasted for the next day, plant operators can respond in advance to avoid undesirable circumstances such as spillage due to inadequate storage capacity (when the rain actually falls).

The amount of additional energy production depended upon the amount of additional incoming water, which can be expressed with respect to the forecasted rainfall, as in Equation (1) [3].

$$V_{\text{additional}} = h_{\text{forecast}} \times A_{\text{catchment}} \times (1 - R_{\text{evaporation}}) \quad (1)$$

Where

$V_{\text{additional}}$ = Additional volume of incoming water (m^3)

h_{forecast} = Forecasted amount of rainfall (m)

$A_{\text{catchment}}$ = Area of the catchment (m^2)

$R_{\text{evaporation}}$ = Ratio of evaporation = 0.5

Subsequently, the amount of additional energy production can be expressed as Equation (2) [4].

$$E_{\text{additional}} = \rho_{\text{river}} \times V_{\text{additional}} \times g_{\text{site}} \times h_{\text{gross}} \times \eta_{\text{unit}} \quad (2)$$

Where

$E_{\text{additional}}$ = Additional energy production

ρ_{river} = Density of river water = 997 kg m^{-3}

$V_{\text{additional}}$ = Additional volume of incoming water (m^3)

g_{site} = Gravitational acceleration = 9.781 ms^{-2}

h_{gross} = Gross head of unit (m)

η_{unit} = Overall unit efficiency = 0.8386

B. Evaluation of Performance Improvement

Upon computation of additional amount of incoming water and additional energy production of the hydropower plant for the studied period, the potential performance improvement can be evaluated.

The key performance indicators (KPIs) used to describe the performance improvement include:

- 1) Increase in annual energy production (MWh)
- 2) Projected annual spillage reduction (m^3)
- 3) Rate of conversion from additional water release to spillage reduction (%)
- 4) Average forebay elevation, FBE (mSLE)

The annual energy production can be projected based on total realized energy production for the studied period. Taking into consideration the practicality of implementing the addition in energy production, the additional energy production will only be realized when it reaches the threshold of 0.25 MW.

Similarly, the annual spillage reduction can be projected based on total realized spillage reduction for the studied period. The realization of spillage reduction is counted when additional volume of water release is proven to reduce spillage within the flood return period of the hydropower plant of 21 days.

Next, the rate of conversion from additional water release to spillage reduction can be quantified as the ratio of realized spillage reduction to total water release for the same period.

Finally, the average FBE for the studied period can be computed from the simulated daily FBE. In the meantime, the simulated daily FBE is calculated by considering the daily change in gross head due to additional water release, whilst holding actual daily change in gross head in actual operation.

C. Comparison between Potential and Actual Achievable Performance Improvements

To examine the validity of rainfall forecast data, equivalent outputs and KPIs computed using actual rainfall data of the same catchment area for the same period were used for comparison.

Besides, the accuracy of rainfall forecast data were investigated. In this regard, the number of correct forecast was compared with total number of forecast. In this evaluation, a more conservative approach is adopted, whereby a forecast is deemed as correct only when the forecasted daily rainfall is less than or equal to the actual daily rainfall.

III. RESULTS AND DISCUSSION OF EVALUATION

Table I and Table II show the KPIs derived from the application of rainfall forecast data and actual rainfall data, respectively. Meanwhile, Table III summarizes the comparison in these KPIs derived from both sources using the KPIs from actual data as basis.

TABLE I
KPIs DERIVED FROM RAINFALL FORECAST DATA

No.	KPI	Value
1.	Increase in annual energy production	112.611 MWh
2.	Projected annual spillage reduction	$1.402 \times 10^6 \text{ m}^3$
3.	Rate of conversion from additional water release to spillage reduction	54.00 %
4.	Average FBE	60.020 mSLE

TABLE II
KPIs DERIVED FROM ACTUAL RAINFALL DATA

No.	KPI	Value
1.	Increase in annual energy production	255.121 MWh
2.	Projected annual spillage reduction	$2.979 \times 10^6 \text{ m}^3$
3.	Rate of conversion from additional water release to spillage reduction	50.65 %
4.	Average FBE	59.997 mSLE

TABLE III
DIFFERENCE IN KPIs DERIVED FROM BOTH SOURCES

No.	KPI	Difference*	
		Value	%
1.	Increase in annual energy production	142.510 MWh	55.86
2.	Projected annual spillage reduction	$1.576 \times 10^6 \text{ m}^3$	52.92
3.	Rate of conversion from additional water release to spillage reduction	-3.35 %	-6.61
4.	Average FBE	-0.023 mSLE	-0.04

* Calculated using the KPI from actual data as basis

From Table III, it is clear that increase in annual energy production and projected annual spillage reduction is higher when actual rainfall data was used. This means, the application of rainfall forecast data does not yield results as well as those from applying actual rainfall data. Nevertheless, this apparently less beneficial approach provides a higher rate of conversion from additional water release to spillage reduction. To put it simply, the additional water release, as determined from forecasted rainfall data, are more likely to reduce spillage compared to those water release decision determined from actual rainfall data. This is consistent with the higher average FBE computed using rainfall forecast data.

Next, Table IV illustrates the accuracy of rainfall forecast data.

TABLE IV
ACCURACY OF RAINFALL FORECAST DATA

No.	Item	Value
1.	No. of correct forecast	89
2.	Total no. of forecast	182
3.	Accuracy of rainfall forecast data application	48.90%

As seen in Table IV, the accuracy of rainfall forecast data is a fair 48.90%.

IV. CONCLUSION AND FUTURE WORK

In conclusion, it is clear that applying rainfall forecast data yield positive return, in terms of increase in annual energy production and projected annual spillage reduction to pondage hydropower plant. Besides, the water release decision derived from rainfall forecast data proves to be fairly successful in reducing spillage.

However, a fair accuracy of rainfall forecast data limits the scale of improvement in annual energy production and projected annual spillage reduction.

To improve the accuracy of incoming water flow, detailed rainfall-runoff modeling of the catchment area shall be conducted for streamflow prediction [5, 6, 7]. This shall then be translated into more reliable, more accurate and greater improvements in both annual energy production and spillage reduction.

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