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Title :- Operational Strategy for Bhakra Reservoir Under Changing Climate

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Abstract

Flourishment of civilization and survival of living species on earth is heavily dependent on availability of water resources. Due to global warming, there is a rise in the temperature of the earth's atmosphere and oceans resulting in significant changes in the hydrology of any region. Satluj river an important water resource system, originates from Himalayan region and is a critical source of water in northern region. This region is considered most sensitive to global warming. A major dam in the basin is Bhakra dam with a storage capacity of 9621 million m^3. Due to changes in the precipitation pattern, considerable impact is likely on the stream flows. Changes in the streamflow magnitude and timings pose a serious challenge to water management, particularly at Bhakra. Due to rapid urbanization and high rate of population growth water resource system are stressed and climate change creates an additional stress. Design and operation of hydrological systems, including reservoirs have traditionally been carried out on the assumption of stationarity of hydro-meteorological data, but under the impacts of changing climatic conditions the assumption of stationarity of hydro-meteorological data is not valid. To make water resources more reliable, in their management, design and operation the effects of climate change should be considered. For efficient operation of Bhakra reservoir, the forecast of inflows that are representative of future climatic conditions is crucial.

The main objective of the present research is to comprehensively review the existing strategies used in reservoir operations at Bhakra dam and suggest improvements while taking into account the impact of climate change in the Satluj River basin. To evaluate the impact of climate change in the basin, an analysis of hydro meteorological data has been carried out in this research. The historical climate data at 56 nodes in the Satluj basin has been obtained from the Climate Research Unit (CRU) of the University of East Anglia, United Kingdom. The RCP based projections of climate variables at 8 different locations in the Satluj river basin has also been obtained for several combinations of GCMs and RCPs from the Climate Change Knowledge Portal of the World Bank, thus enabling an analysis of the impacts of climate change in the basin for two future duration, namely 2020-2039 and 2040-2059.

In the present research, Long Short Term Memory (LSTM) – a machine learning technique has been developed and applied for the forecast of inflows at Bhakra. The LSTM model is trained using historical inflow data for 20 years from 1999-2018 at Bhakra Dam.The performance of the model is measured on the basis of Root Mean Square Error (RMSE) and coefficient of determination R^2. The LSTM model overcomes the shortcomings of other approaches by using forget gates, which helps it to capture very long temporal relationships. The Thomas-Fiering model has also been used in this research to forecast inflows at Bhakra. A comparison of the monthly inflow forecasts and daily inflow forecasts made using Thomas-Fiering model and LSTM model clearly indicate the superiority of the LSTM model. Use of LSTM to forecast daily inflow provides undisputed results and real time inflow can be successfully used to decide optimal operation policy. With the use of LSTM model floods and droughts can be predicted more accurately.

Research Contributions

The contributions of the research carried out in this thesis may be summarized as follows.

- To put the work carried out in this thesis, an extensive review of literature has been carried out
- With a view to understand the impacts of climate change in the Satluj River basin the climate data at several nodes in the basin has been obtained from the CRU of the University of East Anglia, United Kingdom, thus creating a valuable dataset that could be utilized for further research.
- RCP based projections of climate variables at different locations in Satluj River basin have been obtained for several combinations of GCMs and RCPs from the Climate Change Knowledge Portal of the World Bank, thus enabling an analysis of the impacts of climate change in the basin.
- A Python software based inflow calculator has been developed which would enable engineers and policy makers to determine the storage available in the dam for the given values of water level and release made from the reservoir.
- A Thomas-Fiering model has been developed and applied for the forecast of monthly average and daily inflows.
- An efficient model to forecast inflows to Bhakra has been developed, and its effectiveness in reservoir operations at Bhakra has been clearly demonstrated.