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Calculation of hydropower generation capacity of India using average regression integrated model

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Abstract
Hydropower is a prominent energy source contributing for more than 60% of global renewable electricity. It plays a key role in green power generation and has a fundamental influence on power market prices. As a result, precisely predicting the yearly hydro-power generation is need of the hour for the present situations. India is endowed with rich hydropower potential to the tune of 148 GW, which will be able to meet a demand of 84 GW at 60% load factor. Various factors have contributed to the slow pace of hydropower development, resulting in the declining share of hydropower in India's energy mix. The issues have been exacerbated as hydropower development has largely remained under the ambit of state governments with varying policies. Hydropower's critical role in our nation's energy security is based on the elements of sustainability, availability and affordability. I believe this conference will highlight the industry's collective concerns and issues impacting the development of the hydropower sector. The present study focused on predicting the hydropower generation of India through Average Regression Integrated Model (ARIM) on the basis of the historical data from the year 1990 to 2020. The model helps to monitor and understand the nonlinear behavior of India's hydropower generation as well as energy markets in India.

Keywords: Hydropower generation; ARIM Model; Calculation; India

1. Introduction

Energy is a basic human necessity that has a considerable impact on economic growth in developing countries [1]. The world's energy consumption is continuously increasing as a result of increased population and industrialization [2]. As a result of rising energy demand, excessive use is diminishing conventional energy resources such as coal, nuclear, and petroleum [3]. Fossil fuels also pollute the environment and upset the ecosystem's balancing. On the other hand, renewable energy resources including hydropower, bioenergy, solar, geothermal, and wind are limitless, abundant, and pollution-free [4]. Several countries are moving toward renewables as a result of the diminishing supply of fossil fuels and the increasing rate of Green House Gas (GHG) emissions [5-9].

Hydropower is the world's largest producer source of electricity. Traditional fossil-fuel power plants with 50% efficiency, however modern hydropower plants have an efficiency of over 85%. Hydropower meets 19% of the world's energy demand and is the most expense renewable energy source for electricity production. Furthermore, depending on the water flow rate, hydropower can be used to generate electricity on a large or small scale. As a result, hydropower is the most important RER here on universe. Hydropower supplied 4370 TWh of worldwide electricity generation in 2020, the most of any renewable energy source. India has built almost 51.0 GW of its total hydropower potential, making it the world's fifth greatest installed hydropower capacity. However, especially in the last two decades, India's hydropower sector has been on the decline. To meet India's lofty renewable energy ambitions, hydropower must be brought to the forefront of the country's energy revolution [1-9].

India is endowed with rich hydropower potential to the tune of 148 GW, which will be able to meet a demand of 84 GW at 60% load factor. Various factors have contributed to the slow pace of hydropower development, resulting in the declining share of hydropower in India's energy mix. The issues have been exacerbated as hydropower development has largely remained under the ambit of state governments with varying policies. Hydropower's critical role in our nation's energy security is based on the elements of sustainability, availability and affordability.

2. Methods

The study considered collecting the hydropower generation producing in India during the period 1990-2020. The ARIM model approach for the analysis of the univariate time series data was first introduced by George Box and Gwilym Jenkins [10, 11]. This modeling plays vital role in forecasting and predicting the future values on the basis of the past values. In this study, the analysis is done through ARIM in three stages. Now, considering as:

$$W_t = \mu + \{[\Theta(B)] / [\emptyset(B)]\} a_t \quad (1)$$

where t is the indexes time, W_t is the response series Y_t, μ is the mean term and B is the backshift operator.

The three stages are:

Identification Stage: In this stage, for stationary checking of hydropower generation in India are found to be non-stationary, so they are converted to stationary by the method of differencing the dataset from 1990 to 2020. Then, it is used for forecasting the next 10 years i.e., 2021 to 2031. Significant spikes in autocorrelation and partial autocorrelation functions were used to determine the ARIM model's parameters p and q. At this point, one or two models are chosen based on their statistical significance.

Estimation Stage: The ARIM model is fitted and the model's accuracy is checked, i.e., the error optimized model is obtained using the following methods:

Low AIC and BIC: Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) are both useful criteria in model selection, where, AIC is estimated by AIC = (−2log(L) + 2m) , where, m = p+q and L is the likelihood function. Similarly, BIC can be estimated by BIC = −2log(L) +mlog(n) .

Significance of autocorrelations: The autocorrelation aids in capturing all of the correlation between the series' values, and the residuals obtained should be independent of one another.

Forecasting Stage: In this stage, the future values are forecasted on the basis of the past values, through the obtained model.

3. Statistical analysis results

Table 1 gives the descriptive statistics of hydropower generation of India. The mean values with standard deviations of India (84.32 ± 37.14 TWh). The distribution of hydropower generation of India is identified as positively skewed (0.6466) and value of kurtosis is identified as negative nature and data follows a playcutic distribution. From the Table 1, it is observed that there is a consistent growth in generation of hydropower observed for India.

Table 1. Descriptive statistics for hydropower generation in India

Country	Mean	Statistic Deviation	Skewness	Kurtosis
India	84.32	37.14	0.6466	- 0.7146

The ARIM residuals' ACF plot indicates that all correlations are within the threshold levels, signifying that the residuals act like white noise. The PACF also shown is suggestive of model. Both ACF and PACF were represented in Figure 1 and 2.

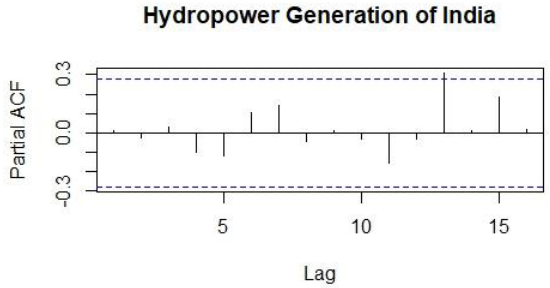

Figure 1. ACF of the Hydropower Generation of India.

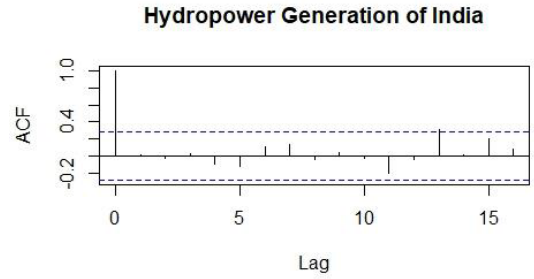

Figure 2. PACF of the Hydropower Generation of India.

Table 2. ARIM model with different p, d and q values.

ARIM Model	AIC Value
ARIM (0, 1, 0)	354.8432
ARIM (0, 1, 0)	351.4856
ARIM (0, 1, 1)	351.3464
ARIM (0, 1, 2)	351.5436
ARIM (1, 1, 0)	352.2462
ARIM (1, 1, 1)	356.4678
ARIM (1, 1, 2)	355.6423
ARIM (2, 1, 0)	354.2461
ARIM (2, 1, 1)	354.1234
ARIM (2, 1, 2)	Infinitive

To understand the future hydropower generation requirements of India, the study further forecasted next decade values, which is represented in Table 3 as well as displayed the forecast values with confidence intervals in Figure 3.

Table 3. Calculated hydroelectric generation values in India

Years	Hydroelectric Generation (TWh)
2021	164.214
2022	165.324
2023	166.465
2024	168.356
2025	170.686
2026	172.312
2027	174.567
2028	176.124
2029	179.045
2030	181.246

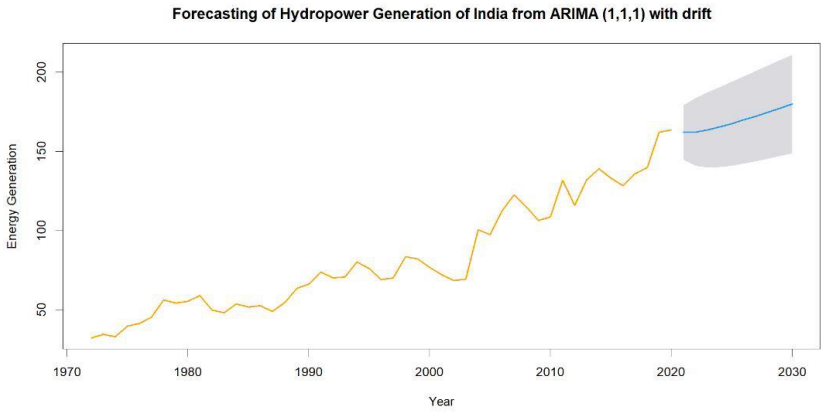

Figure 3. Forecasting of Hydropower Generation of India

4. Conclusions

Hydroelectric power, or simply hydropower, is one of the most ancient and cost-effective methods of generating energy from water. Hydropower projects with a capacity of more than 25 MW are classified as renewable energy. Renewable energy production is considered essential for modern world, and one of the major sources of such energy is hydropower. As, the time series model building with ARIM method was very popular in most of the fields, the study also focused on predicting the hydropower generation of India. Based on the forecasting results, it may be concluded that ARIM model could be successfully used for forecasting hydropower generation of India for the immediate subsequent years. The study helps to understand the hydropower is essential for country's future energy requirements.

References

[1] Kaygusuz, K. Hydropower and the world's energy future. Energy Sources,
2004; 26(3), 215-224. 2.
[2] Kaygusuz, K. Potential and utilization of hydroelectric energy in Turkey. Journal of
Engin. Research Applied Science 2019; 8: 1077-86, www.journaleras.com/(01.11.2021)
[3] Yükseli, I. Hydropower for sustainable water and energy development. Renewable and
Sustainable Energy Reviews, 2010; 14: 462-469.
[4] Karumanchi, H., Mathew, S. Forecasting of hydropower generation of India using
regressive integrated moving average model. J. of Algebraic Statistics 2022; 13: 3124-28.
[5] Sharma, NK., Tiwari, PK., Sood, YR. A comprehensive analysis of strategies, policies and
development of hydropower in India: Special emphasis on small hydro power.
Renewable and Sustainable Energy Reviews 2013; 18: 460-470.
[6] Ullah, K., Raza, MS., Mirza, FM. Barriers to hydro-power resource utilization in Pakistan:
A mixed approach. Energy Policy 2019; 132: 723-735.
[7] Pata, UK., Aydin, M. Testing the EKC hypothesis for the top six hydropower
energy-consuming countries: evidence from Fourier Bootstrap ARDL procedure.
Journal of Cleaner Production 2020; 264: 121699.
[8] Attri, M., Sharma, S., Bhargaw, N. Assessment & analysis of hydro power potential
in India. Int. J. of Engineering Research & Technology (IJERT) 2017; 6: 312-315.
[9] Saklani, U., Shrestha, PP., Mukherji, A., Scott, CA. Hydro-energy cooperation in South
Asia: Prospects for transboundary energy and water security. Environmental Science &
Policy, 2020; 114: 22-34.
[10] Klee, H., Allen, R. Simulation of Dynamic Systems with MATLAB® and Simulink®
Third Edition, CRC Press Taylor & Francis Group, Boca Raton, FL, 2018.
[11] Fong, CM., Kee, DD., Kaloni, PN. Advanced Mathematics for Engineering and Science.
World Scientific, London, 2003.