JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 3124-3128
https://publishoa.com
ISSN: 1309-3452

Forecasting of Hydropower Generation of India using Autoregressive Integrated Moving Average Model

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ABSTRACT

Hydropower is a prominent source of energy, 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. The present study focussed on predicting the hydropower generation of India through Autoregressive Integrated Moving Average (ARIMA) Model on the basis of the historical data from the year 1971-72 to 2019-20. Significant spikes in the plots of autocorrelation function (ACF) and partial autocorrelation function (PACF) of the hydropower generation data were used to identify the autoregressive (p) and moving average (q) parameters. ARIMA (1, 1, 1) with drift model was found suitable to hydropower generation for forecasting of energy demand for the country needs. Prediction of hydropower generation is done for the next decade using best fitted ARIMA model with lowest AIC and BIC values. The model helps to monitor and understand the nonlinear behaviour of India's hydropower generation as well as energy markets in India.

Keywords: Hydropower Generation, India, ARIMA Model, Prediction

1. Introduction:

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

Hydropower is the world 's largest producer source of electricity. Traditional fossil-fuel power plants have a 50% efficiency, however modern hydropower plants have an efficiency of over 85%. Hydropower meets 19 percent 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 Terawatt-hours (TWh) of worldwide electricity generation in 2020, the most of any renewable energy source. India has built almost 51 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.

The academic research focused on the actual role of hydropower producing around the world, as well as its obvious advantages and additional prospects, as well as individual nation initiatives (Kaygusuz, 2004). The authors emphasised the importance of hydropower for Turkey's long-term water and energy development and potential (Yüksel et al., 2010). Another study explored the future of global energy and how hydropower fits in as a solution to the world's sustainable energy dilemma. The study described hydroelectric resource availability, as well as technology, the environment, and climate change (Kaunda et al., 2012). Another study examined the present condition, strategic initiatives, and policies for renewable energy development in India (Sharma et al., 2013). The analysts also explored why Pakistan's hydropower sector has taken such a long time to develop. A mixed strategy including NVIVO analysis and Q methodology was performed to evaluate the impending factors (Ullah et al., 2019). The researchers also looked at the correlations among hydroelectric energy consumption, environmental consequences, and economic expansion for the top six hydropower-consuming countries that used the environmental Kuznets curve (EKC) theory. It also utilized newly created co - integration test and granger causality test with smooth structural changes from 1965 to 2016 (Pata and Aydin,

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ISSN: 1309-3452

2020). The studies concentrated on energy cooperation as well as intergovernmental energy and water security among the BBIN (Bangladesh, Bhutan, India, and Nepal) countries (Saklani et al., 2020).

Most of the studies focussed on the reviewing the status of hydropower potential, the various technologies employed and way as sustainable energy resources in the global scenarios. Forecasting of the future energy generation of hydropower is need of the hour. The current study attempted to forecast the energy generation from India’s hydropower as a major contributor in SAARC countries from the past the years 1972-2020. Understanding the fluctuations in hydropower generation and constructing a suitable Autoregressive Integrated Moving Average (ARIMA) model for the same with the help of Autocorrelation function (ACF) and Partial Autocorrelation Function (PACF) and to enhance level of energy generation to meet the requirements of country’s needs.

2. Materials and Methods:

2.1 Data Collection: The study considered collecting the hydropower generation producing in India during the period 1972-2020. The secondary data was collected from the annual reports of Statistical Review of World Energy (SRWE). Energy generation from hydropower measured in terawatt-hour (TWh).

2.2 ARIMA Model and its notations:

The ARIMA model approach for the analysis of the univariate time series data was first introduced by George Box and Gwilym Jenkins. This modelling plays vital role in forecasting and predicting the future values on the basis of the past values (Paidipati and Banik, 2020 and Tripathi et al, 2014). In this study, the analysis is done through ARIMA in three stages.
Now, considering

$$W_t = \mu + \frac{\theta(B)}{\Phi(B)} a_t \quad \text{... (1)}$$

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:

a) *Identification Stage :* In this stage, for stationarity 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 1971-72 to 2019-20. Then, it is used for forecasting the next 10 years i.e., 2020-21 to 2029-30. Significant spikes in autocorrelation and partial autocorrelation functions were used to determine the ARIMA model's parameters p and q. At this point, one or two models are chosen based on their statistical significance.
b) *Estimation Stage :* The ARIMA model is fitted and the model's accuracy is checked, i.e., the error optimized model is obtained using the following methods:
   - *Low AIC & BIC:* Akaike's Information Criteria (AIC) and Bayesian Information Criteria (BIC) are both useful criteria in model selection, where, AIC is estimated by $AIC = (-2\log(L) + 2m)$, where, m = p+q and L is the likelihood function. Similarly, BIC can be estimated by $BIC = -2\log(L) + m\log(n)$.
   - *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.
c) *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:

3.1 Descriptive Statistics:

Table 1: Descriptive Statistics of Hydropower Generation in India

Country	**Mean**	**SD**	**Skewness**	**Kurtosis**
India	82.62	35.9102	0.6268	-0.6967

Table 1 summarizes the descriptive statistics of hydropower generation of India. The mean values with standard deviations of India (82.62 ± 35.910 TWh). The distribution of hydropower generation of India is identified as positively skewed (0.6268) and value of kurtosis is identified as negative nature and data follows a platykurtic distribution. From the table 1, it is observed that there is a consistent growth in generation of hydropower observed for India. The trend of hydropower generation of India is represented in the Figure 1.

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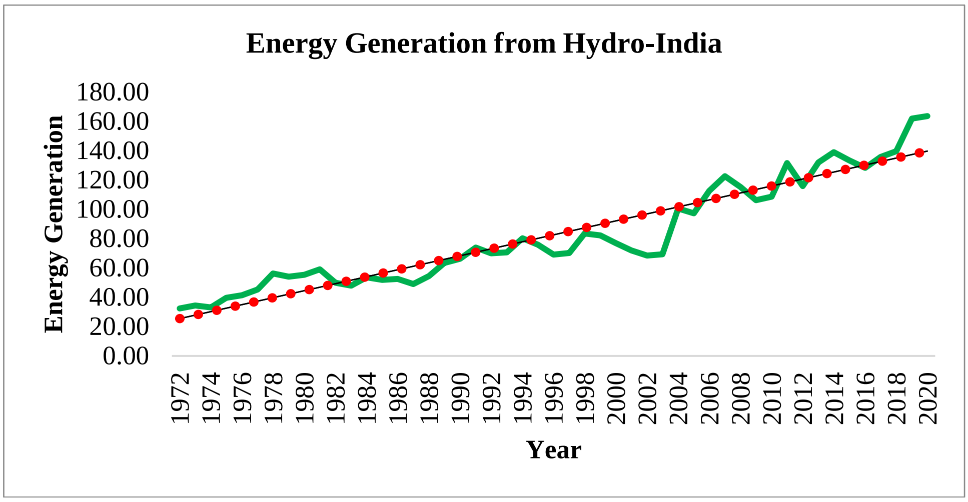

Figure 1: Trend of Hydropower Energy Generation in India

3.2 ACF and PACF of Residuals of Hydropower Generation in India

The ARIMA 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 2 and 3.

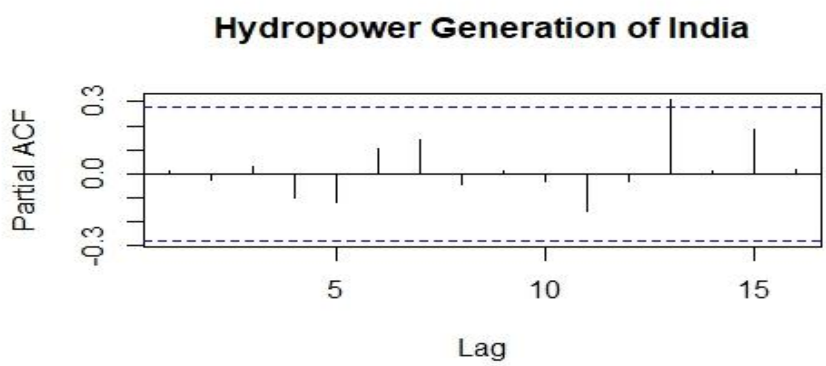

Figure 2: ACF of the Hydropower Generation of India

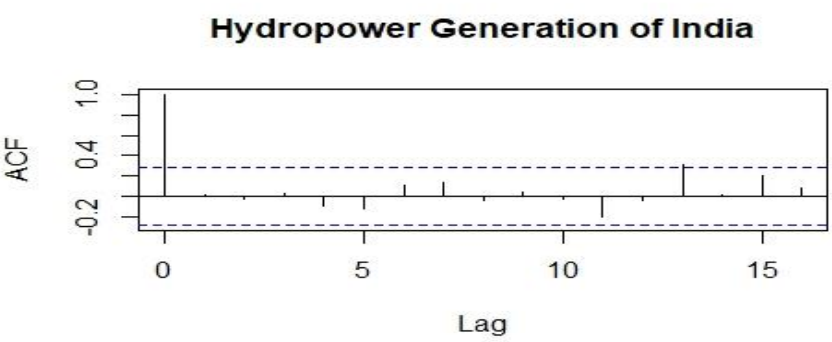

Figure 3: PACF of the Hydropower Generation of India

3.3 ARIMA Model Results:

Table 2: ARIMA Models with different (p, d, q) values

ARIMA Model	AIC Value

ARIMA Model	**AIC Value**
ARIMA(0,1,0)	351.8751
ARIMA(0,1,0) with drift	349.4957
ARIMA(0,1,1) with drift	349.5864
ARIMA(0,1,2) with drift	349.9658
ARIMA(1,1,0) with drift	350.0893
ARIMA(1,1,1)	355.6308
ARIMA(1,1,1) with drift	349.3594
ARIMA(1,1,2) with drift	351.3001
ARIMA(2,1,0) with drift	351.102
ARIMA(2,1,1) with drift	351.2982
ARIMA(2,1,2) with drift	Inf

The auto.arima() function in R fits the ARIMA models. In this study, the function generated various ARIMA models with and without drifts for hydropower generation were displayed in Table 2.

Table 3: Selection of Best Model

Country	**Best Model**	**AIC**	**BIC**
India	ARIMA(1,1,1) with drift	349.36	356.84

Selection of the best model through the lowest AIC and BIC values. In this study, the well fitted best model for hydropower generation of India is ARIMA(1,1,1) with drift having lowest AIC and BIC's which represented in Table 3. As a result, ARIMA (1,1,1) with drift is an initial candidate model, and there are no other apparent candidate models to fit India's hydropower production data. To understand the future hydropower generation requirements of India, the study further forecasted next decade values, which is represented in Table 4 as well as displayed the forecast values with confidence intervals in Figure 4.

Table 4: Predicted Values of Hydropower Generation of India

Forecasting Year (India)	Values (in TWh)
2021	162.0196
2022	162.2555
2023	163.5239
2024	165.3667
2025	167.5289
2026	169.8688
2027	172.3075
2028	174.8012
2029	177.3255
2030	179.8668

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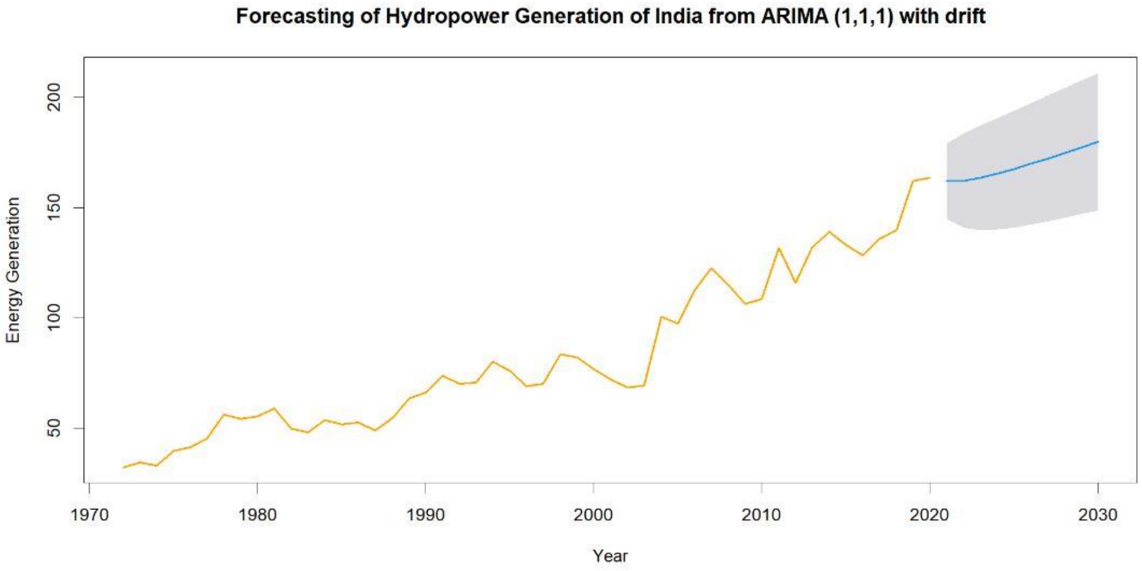

Figure 4: Forecasting of Hydropower Generation of India

Conclusion:

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 megawatts are classified as renewable energy. Renewable energy production is considered essential in today 's modern world, and one of the major sources of such energy is hydropower. As, the time series model building with ARIMA method was very popular in most of the fields, the study also focused on predicting the hydropower generation of India as a major contributor in SAARC countries. Based on the forecasting results, it may be concluded that ARIMA model could be successfully used for forecasting hydropower generation of India for the immediate subsequent years. The study helps to understand the generation of hydropower which is essential for country's future energy requirements.

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