Vol. XIV & Issue No.03 March - 2021
INDUSTRIAL ENGINEERING JOURNAL

FORECASTING OF SALES AND PRODUCTION IN CHEMICAL INDUSTRY USING SPSS WITH TIME SERIES MODELER: A CASE STUDY

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Abstract

Any forecast can be termed as a calculation or estimation which uses historical data and combined with the recent trends to know what will probably happen in future event. This is known by everyone that it is impossible to forecast with accuracy of 100% but sound planning of any product depends on forecasting and extrapolation that how trends, such as GDP or unemployment also changes in the coming quarter or year using forecasting by stock analysts. Hence it is necessary to have an estimate of product demand. Forecast of sales and production with the help of previous data may predict the future demand. In the present work, the sales, production and consumption of raw materials for making caustic soda lye are analyzed and predicted using SPSS with time series modeler. The actual and modeled data are compared and found close agreement with minimum errors. The performance index was considered for evaluation of parameters are R squared value and RMS value.

Keywords: Time series modeler, caustic soda lye, trend projection, R squared value, RMS value, future prediction, exponential smoothing model.

INTRODUCTION

Chemical industry of India is one of the fastest growing industries, which contributes to about 13% of the Indian GDP and it is growing annually at a rate of 10% to 12%. Chemical Industry is a multi-product industry based on the idea of diversification. Forecasting of sales and production required for better performance of the plant and fulfill future demand. SPSS is the basic and well proved tool for forecasting and optimization of the variable parameters. Box G.P., & Jeenkins, G. (1970) foccused on practical techniques and explored statistical models for time series and their use in forecasting, model specification,estimation and checking [1]. Tong, H. (2011) considered selective review of threshold model development over the past 30 years in time series analysis which refer revisit the motivation, describe the various expressions, highlight principle underlying them and main probabilistic & statistical properties and finally listing of recent offspring of threshold model and finishes with some on going research in context of threshold volatility [2]. Ltkepohl, H. (2007) considered a wide range of models and methods for analysing and forecasting multiple time series. It bridges the gap to the difficult tachnical literature on topic [3]. Dhrymes, P. (2017) introduced time series modeling. This model concern with input, output, transfer function and some indicators which conclude that time series model can be unvariate,where a time series is modeled only by it's past values, or multivariate [4]. Pongdatu, G.A.& Putra, Y.H. (2018) studied the comparison between sales forecast result of SARIMA model and Holt Winter's exponential method. On the basis of comparison SARIMA gave lesser mean absolute deviation value which conclude this model is feasible to use for further forcasting [5]. Momani, P.E. (2009) studied to built ARIMA model using Box-jenkins methodology for monthly rainfall data taken from Amman airport station with 936 previous readings. This model forecast the upcoming 10 years monthly rainfall to help decision makers for managing water demand [6]. Karmaker, C.L., Halder, P.K., & Sarker, E. (2017) developed a model to identify best method among 8 methods for prediction based on the least values of errors using Minitab 17 software. And on the basis of accurate forecast analysis shows that Winter additive model gave best performance with lowest error [7]. Ratnasari, S.L., Yuniaristanto, & Zakaria, R. (2019) studied to implement 5 parameters exponential smoothing to predict no. of newspaper demand in future with various methods of time series to get best forecast result and to select forecast method using mean squared deviation and mean squared error. And the result showed that for demand forecasting in newspaper industry additive Holt Winters method with damped trend is suitable [8]. Akpinar, M., & yumusak, N. (2017) examined day ahead demand forecast for the natural gas sector. In this approach demand estimations are performed using over 4 years of daily data and applying simple, double, linear, damped trend exponential smoothing method and result showed that the simple exponential smoothing method gave the best result which gave lowest mean absolute percent error 14.1% and R^2 0.917 for 4 years [9]. Permatasari, A.G., & Hambali, F. (2011) used simple moving average and single exponential methods for prediction analysis in sales and applicator epoxy polymer. By using the moving average on period 3 months forecast sales were obtained with the rate of 2568.71 units error and with weights moving average method using 3 weights forecast sales were obtained with a margin of 2393.17 units error. The forecast result is important in planning and supervision [10]. Olatunji, K. (2013) studied the sales of marble chipping in tons in Glister success ltd, to evaluate the performance of marble market by modeling and make future forecast. For modeling and forecasting of sales with the help of previous record of sales exponential method of trend analysis and forecasting were used in MS excel. And resulting model recommend the production planning for future demand [11]. Zhang, G. Putawo, B.E., & Hu, M. (1998) used artificial neural networks (ANNs) in research activities to forecast. This paper presented a state of the art survey in forecasting of ANN applications to provide research direction for future, insights on ANN modeling issues and published research synthesis in this area [12]. Wang, J., & Zivot, E. (2000) considered a trending dynamic time series model as deterministic in which multiple structural changes are modeled and by the use of Gibbs sampler model estimation was possible. To select most appropriate model from the data compared the use of marginal criterion. They evaluate bayesian approach efficiency using a small monte carlo experiment [13]. Hansun, S. (2016) introduced a new approach of Brown's double exponential smoothing in time series analysis in which calculation of weighting factor in weighted moving average combines and result implement with the Brown's double exponential method. The proposed method tested on Jakarta stock exchange composite index data and the proposed method result showed a promising result in this work [14]. Monfared , M.A., Ghandali, R., & Esmaeili, M. (2014) generalized the simple exponential method into revised simple exponential method to non stationary level shifts recognisations in time series as an alternative method which showed accuracy of forecasting process improved and this is done by controlling the number of observations and smoothing parameter. The result showed how the new revised exponential smoothing method performed traditional counterparts of simple exponential smoothing [15]. Bing-fe, Z. (2014) built up the model baaed on the nonlinear dynamic 3 exponential smoothing model in time series to fit square error value and for the evaluation of data source and by making the minimum index to calculate the optimal time series. After analysis of actual time series it conclude that error evaluation index can reduce prediction error to make it more accurate and dynamic exponential smoothing established [16].

With the advent of sophisticated computation platforms, management has been a sudden increment in forecast problems. There are several techniques to forecast or to estimate future trends. In this paper, time series modeler has been used for predict demand of sales, production & consumptions to make caustic soda lye and fitting of model has been also used to compare actual and predict demand of same. It is necessary to have an idea of future trends of sales, production & consumptions for such a predictive analysis so as to manage the ergonomics and logistics for the same. Since most of the industries are heavily rely on prediction of future demand for consumptions as well as for the economy, it becomes even more important to work on an accurate predictive analysis. However, the prediction of future demand with low errors and high accuracy is challenging due to assumptions, approximations, normal conditions etc. are basis of any forecasting method. The ultimate aim of the analysis was to predict the sales, production, consumptions & compared them to actual demand of same in chemical industry for optimization of inventory and process of the plant.

NEED OF STATISTICAL ANALYSIS IN FORECASTING

For highest possible quality result, when large amount of data involved the role of statistical analysis is natural and utilizing the capabilities of statistical models is beneficial too. It come with a variety of forecasting model and these analysis gives more accurate forecast than produced by general packages such as excel and these algorithms are quite advanced. There are different types of models which give different level of quality according to actual demand pattern. The biggest challenge is accessing the accurate future trends using analytical analysis. It is often difficult to find patterns in non-linear data set and hence analytical analysis has not been able to be too accurate for time series prediction problem. Hence, the mathematical model which is statistical analysis is being preferred over analytical analysis for more accuracy of prediction.

IMPORTANCE OF SPSS IN FORECAST

In academic research for editing, analysis and presenting numerical data, a general purpose statistical package is widely used which is SPSS means "statistical package for social science". It is compatible with all file formats that are commonly used for structured data such as excel, paint text files and rational database. Researchers can predict the trends and develop forecasts quickly easily and more accurately using SPSS forecasting without being an expert statistician. With the help of SPSS forecasting experience analysts can validate their models and people who are new to forecasting can create sophisticated forecasts that take into account multiple variables.

SYSTEM DESIGN USING EXPONENTIAL SMOOTHING BY TIME SERIES MODEL

Time series forecasting has many applications, such as stock prices forecasting, weather forecasting, business planning and many others. To predict the systematic component of demand and estimate the random component is the goal of any forecasting method and the systematic component of demand data contains a level, a trend, and a seasonal factor in general. It may take a variety of forms for calculating systematic component as given below.

- Systematic component = level * trends * seasonal factor (For multiplicative demand)
- Systematic component = level + trend + seasonal factor (For additive demand)
- Systematic component = (level + trend)*seasonal factor (For mixed demand)

Depending on the nature of forecast demand, the specific form of systematic component is applicable. And for each form companies may develop both static and adaptive forecasting method. In static method, the estimates of level, trend and seasonality within the systematic component do not vary and assumed as new demand is observed whereas in adaptive forecasting, after each demand observation the estimation of level, trend and seasonality are updated.

The adaptive forecasting method is most preferred depends on the characteristic of demand and the composition of the systematic component of demand. The following are various adaptive forecasting methods and in each case the period under consideration "t" was assumed.

1. Moving average
2. Simple exponential smoothing
3. Trend-corrected exponential smoothing(Holt's model)
4. Trend-and seasonality-corrected exponential smoothing (Winter's model)

Simple exponential smoothing: The simple exponential smoothing method was found suitable when demand has no observable trends or seasonality. In this method,

Systematic component of demand = level

The average of all historical data is presented in equation [i] for initial estimation of level, L_0 because there have no observable trend or seasonality assumed for demand.

$$L_0 = \frac{1}{n}\sum_{i=1}^{n} D_i \quad [i]$$

For all future periods, current forecast is equal to the current estimation level

$F_{t+1} = L_t$ and $F_{t+n} = L_t$

After observation for period t+1, the demand D_{t+1} the estimated level is presented in equation [ii].

$$L_{t+1} = \alpha D_{t+1} + (1-\alpha) L_t \quad [ii]$$

Where, α = smoothing constant for the level, $0 < \alpha < 1$.

The revised value of the level is a weighted average of observed value of the level (D_{t+1}) in period t+1 and the previous estimate of the level (L_t) in period t. So now from equation [2], it expressed the level in a given period as a function of current demand and the level in the previous period which is shown in equation [iii].

$$L_{t+1} = \sum_{n=0}^{t-1} \alpha(1-\alpha)^n D_{t+1-n} + (1-\alpha)^t D_1 \quad [iii]$$

Here, the weighted of all the previous observation of demand is equal to the current estimate of level, with recent observations weighted higher than previous observations. A forecast is more responsive to recent observations, when α corresponds to higher value, whereas forecast is less responsive to recent observations, when α corresponds to lower value.

In this present work, the theoretical and mathematical analysis was performed to predict future demand from previous data using simple exponential smoothing method of time series. And on the basis of this analysis simple exponential smoothing method in time series model using SPSS was used and compared the modeled data and actual data of chemical plant.

EVALUATION PARAMETERS

The polarity errors may be both negative and positive, therefore it is not important to consider errors with signs because it may lead to cancellation and hence evaluation of error may inaccurate. Therefore we consider root mean square error (RMSE) or root mean square deviation (RMSD) as performance index for evaluation and prediction the output data. Root mean square error is a standard way to measure the model error in predicting quantitative data. RMSE finds the error between two dataset and compares a predicted and an actual value. Root mean square error or deviation presented in equation [iv].

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}} \quad [iv]$$

Where, $\hat{y}_1, \hat{y}_2, \ldots\ldots \hat{y}_n$ = Predicted value

$y_1, y_2, \ldots\ldots y_n$ = Actualvalue

And n = number of observations

Another parameter is R-squared and it is also known as the coefficient of determination. R-squared is a statistical measure of how close the predicted values are to the actual values which is presented in equation [v].

$$R^2 = 1 - \frac{SSR}{SST} \quad [v]$$

Where, SSR= Sum squared regression and SST = Total sum of square

R-squared value is always lies between 0 to 100%. The minimum R^2 value means less similarity between predicted and actual values, whereas maximum value of R^2 means complete similarity between predicted and actual values.

RESULTS

The data has been simulated on SPSS (Statistical package for the social science) SPSS 16.0 with time series modeler.

The modeled results were compared with the actual data of sales, production, power, steam and water consumption of three years with the following settings-

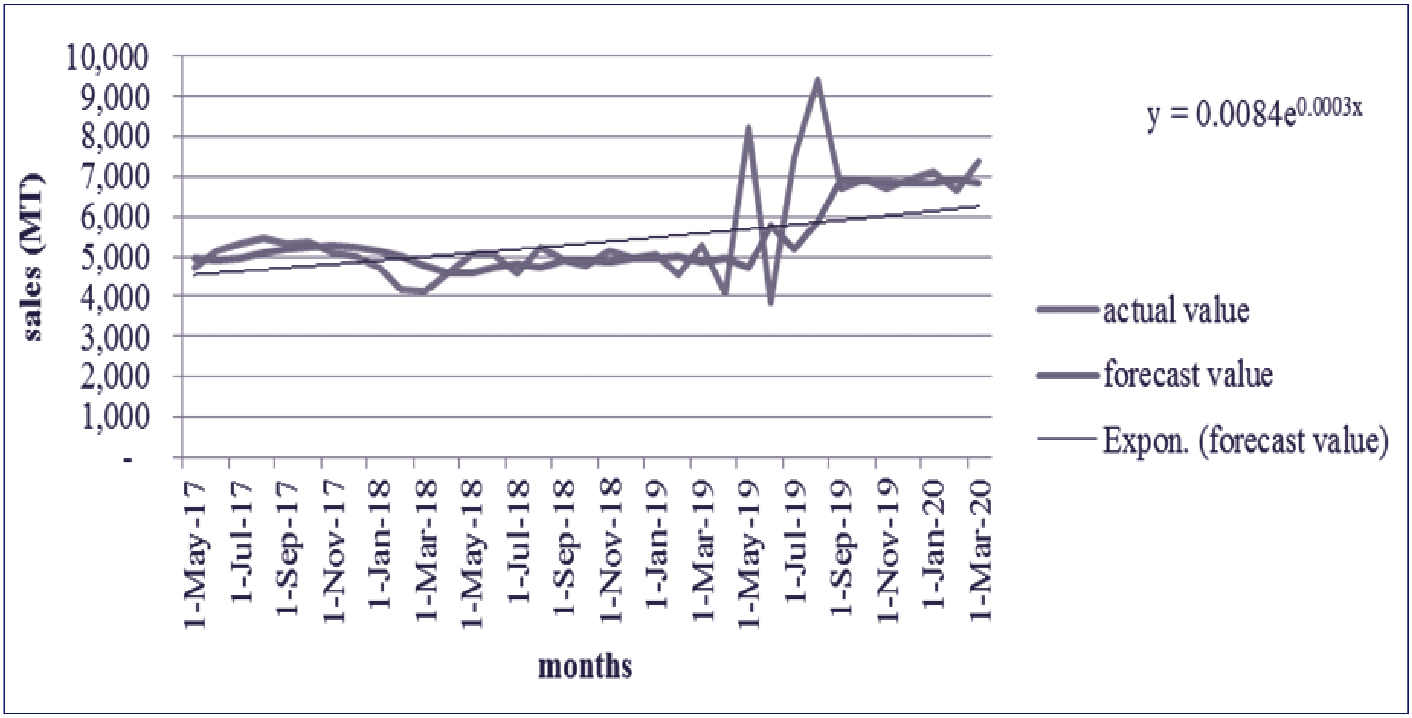
- Thirty six months data used for prediction.
- Simple exponential smoothing model used as training algorithm in modeling.
- Fit measures display R^2 and root mean square error values.
- Dependent variables are used for prediction.

The modeled and actual sales are compared where R^2 value and root mean square error were found which are 0.325 and 1.04E+03 respectively. The graph shown below follows exponential trend for modeled sales which is presented in mathematical equation [vi].

$$y = 0.0084e^{0.0003x} \quad [vi]$$

The sales patterns of the organization was analyzed and compared with the predicted values. The predicted values were found almost similar which are shown in Figure 1.

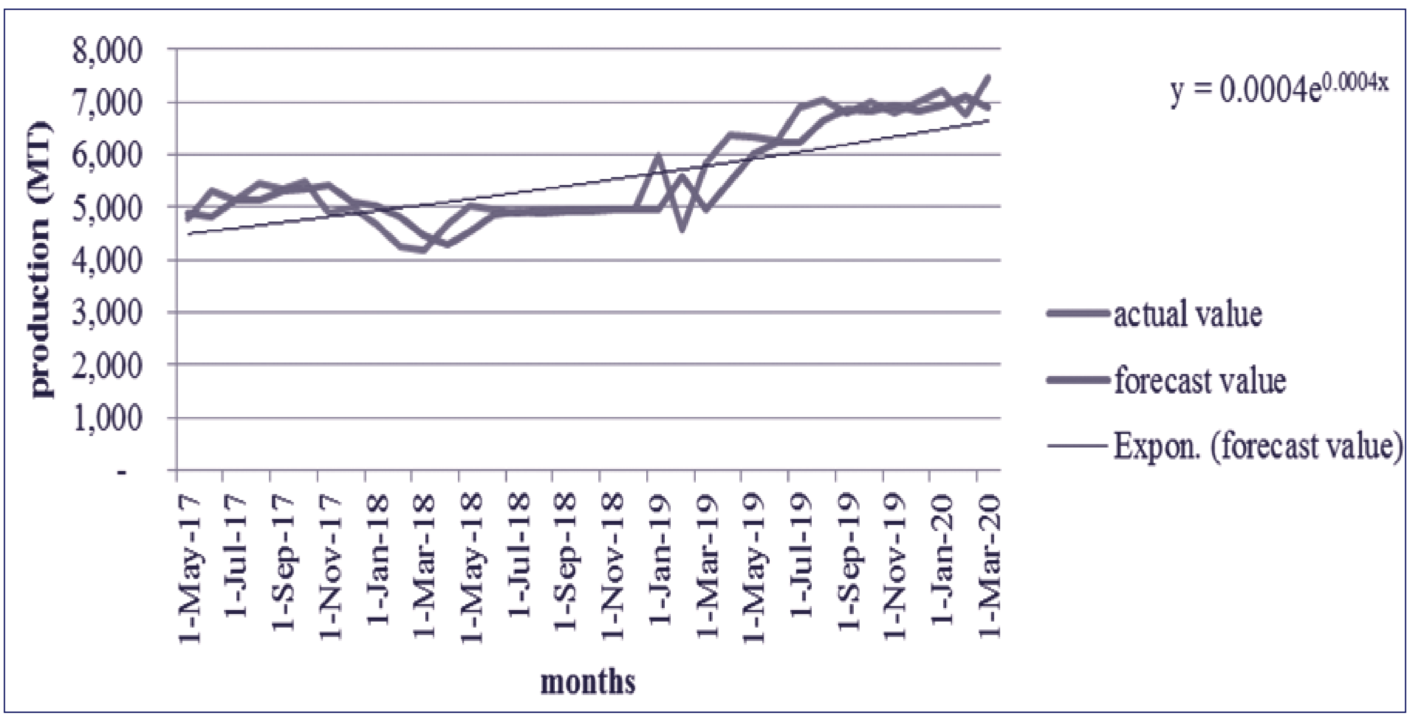
Figure 1. Comparison between modeled and actual sales.



The modeled and actual production were compared with the performance index R^2 value and root mean square error were found which are 0.793 and 435.7 respectively are shown in Figure 2. The modeled outputs are presented mathematically which is shown in equation [vii].

$$y = 0.0004e^{0.0004x} \quad [vii]$$

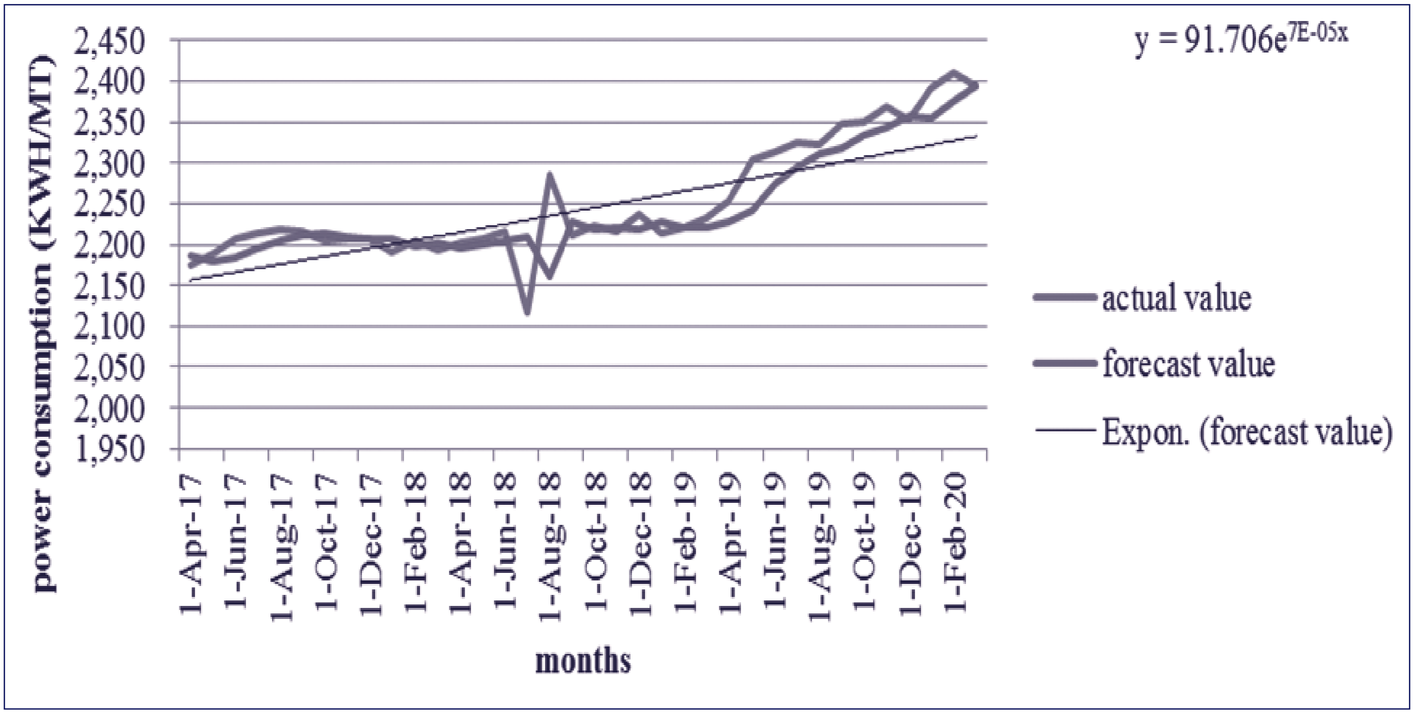
Figure 2. Comparison between modeled and actual production.



The power consumption is also a significant parameter for production and it depends on the loading on the processing equipments.The modeling of power consumption has been done and compared the modeled results with actual power consumption as shown in Figure 3. The R^2 value and the root mean square (RMS) values were found wich are 0.794 and 33.225 respectively.The power consumption may be presented in the mathematical form as shown in equation [viii]. The variation of power consumption was found exponential trend.

$$y = 91.706e^{7E-05x} \quad [viii]$$

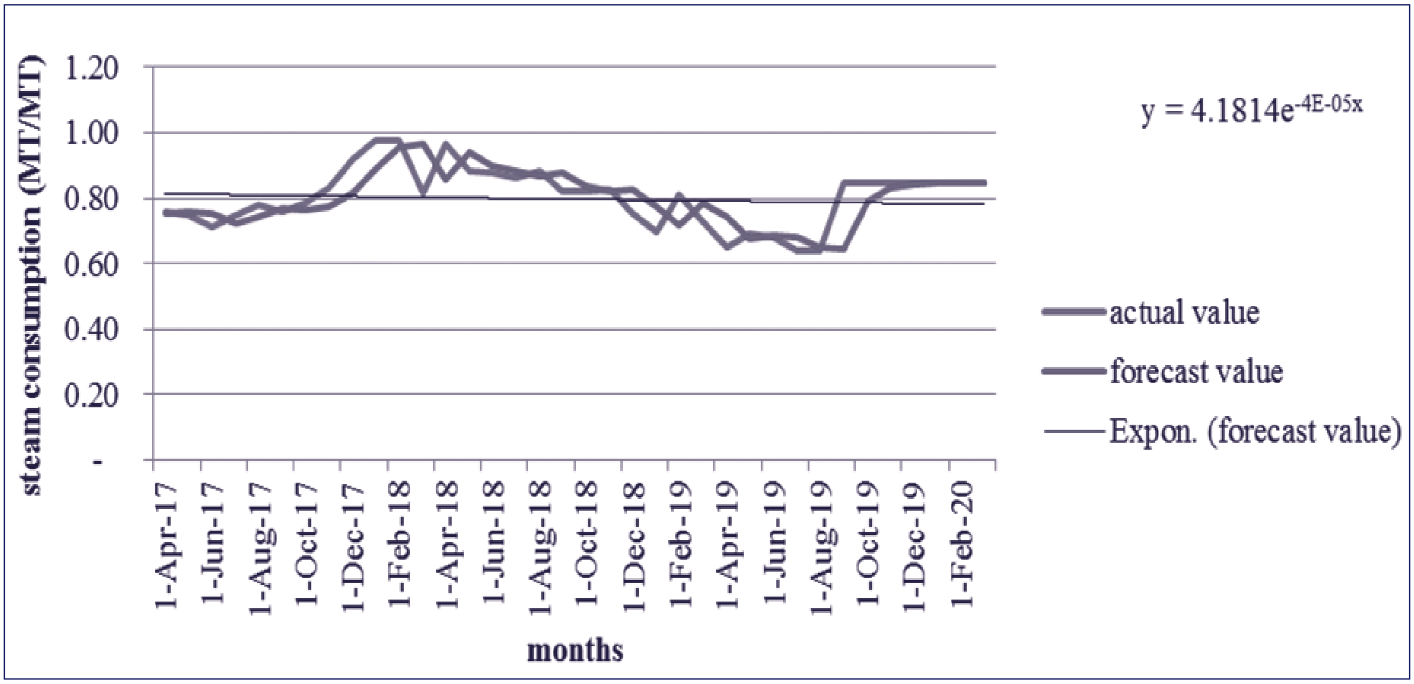
Figure 3. Comparison between modeled and actual power consumption.



The steam is required for production of caustic soda lye and its consumption for three years are presented in Figure 4. The forecasting of the steam consumption has analyzed and compared with the actual consumption of the steam. The forecasting and actual data were found almost similar with minimum RMS value. The predicted consumption of steam may be presented in the form of mathematical equation [ix].

$$y = 4.1814e^{-4E-05x} \quad [ix]$$

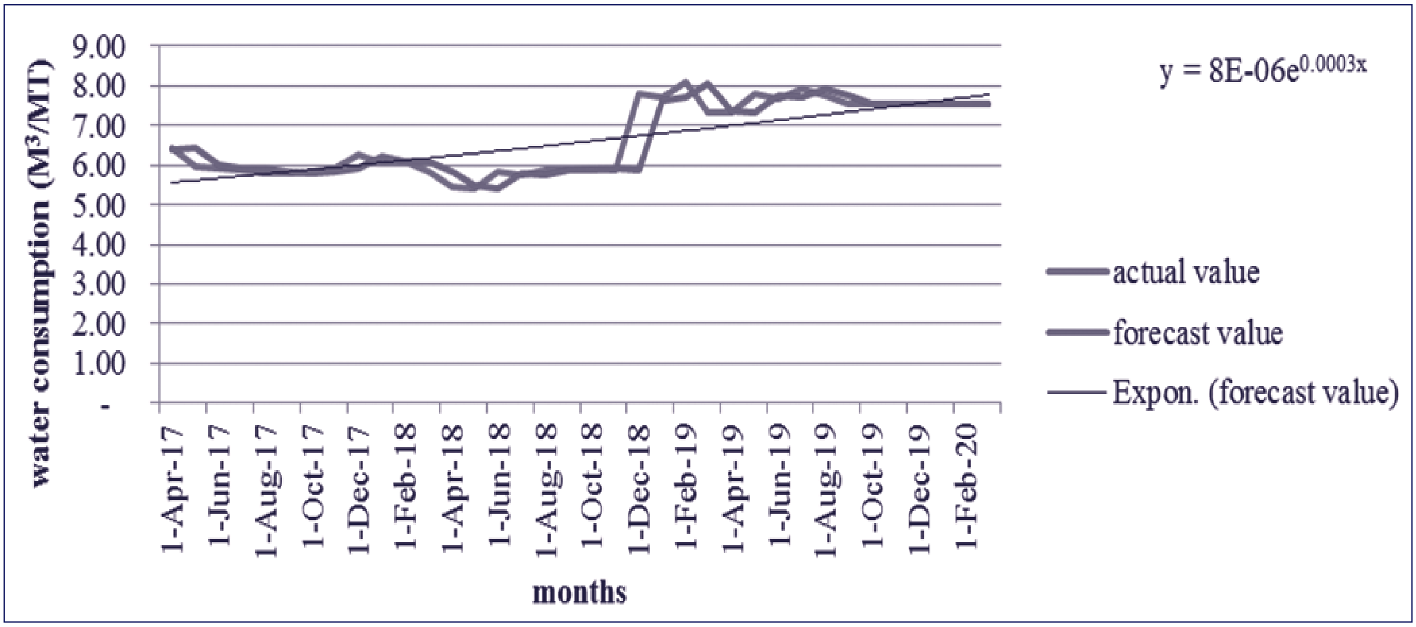
Figure 4. Comparison between modeled and actual steam consumption.



The amount of water required in production of caustic soda lye was modeled with presented methodology. The R^2 value and root means square error were found which are 0.812 and 0.392 respectively. The results were compared with actual consumption of water in the process and very close agreement was found which is presented in Figure 5. The variation of water consumption with number of days are presented in equation [x].

$$y = 8E - 06e^{0.0003x} \quad [x]$$

Figure 5. Comparison between modeled and actual water consumption.



CONCLUSION

Time series forecasting has many applications, such as stock prices forecasting, weather forecasting, business planning and many others. The sales, production, power and water consumption for making caustic soda lye was analyzed and predicted using SPSS with time series modeler. In the present research work, a simple exponential smoothing based model for prediction of future demand was used for prediction the useful parameter to produce caustic soda lye. The root mean square (RMS) errors and R^2 values were selected as performance index. The predicted water consumption has minimium value of RMS error i.e. 0.392 than other parameter. The other parameters were predicted using SPSS with time series modeler for optimization the quantity of raw materials to produce caustic soda lye and also for easy handling of inventory.

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Statement As per/ Press and Registration of Books
ACT 1967 FORM IV
INDUSTRIAL ENGINEERING JOURNAL (SEE RULE 8)

1.	Place of Publication	:	Indian Institution of Industrial Engineering National Headquarters Sector 15, Plot No. 103 CBD Belapur Navi Mumbai – 400 614
2.	Periodicity of its Publication	:	Monthly
3.	Printer Name	:	Dr. B E Narkhede
	Nationality	:	Indian
	Address	:	Same as above
4.	Editor's Name	:	Dr. B E Narkhede
	Nationality	:	Indian
	Address	:	Same as above
5.	Publisher's Name	:	Dr. B E Narkhede
	Nationality	:	Indian
	Address	:	Same as above
6.	Name and address of Individual who owns the News paper and partners Of share holders holding More than one percent of The total capital	:	Indian Institution of Industrial Engineering National Headquarters Sector 15, Plot No. 103 CBD Belapur Navi Mumbai – 400 614 Website: www.iiie-india.com Email: journal4iiie@gmail.com

I hereby declare that the particulars given are true to the best of my knowledge and belief.

Dr. B E Narkhede
Editor, Printer & Publisher

Navi Mumbai
15-03-2021