Time Series

FORECASTING USING TIME SERIES TECHNIQUES

Forecasting using Time Series Techniques

- Simple Moving Average
- Weighted Moving Average
- Simple Exponential Smoothing
- Double Exponential Smoothing
- Triple Exponential Smoothing
- Time Series Models Comparison

Which technique to choose?

The methods to trace the accuracy and reliability of forecasted results along with comparisons and prioritizing the best among various forecasting technique suiting to the underlying historical data are:

- Mean Absolute Percentage Error (MAPE)
- Root Mean Square Error (RMSE)

Industry related examples

- Consider as a use-case an oilfield with several Electrical Submersible Pumps (ESPs), each instrumented with sensors that continually measure electrical properties of the pump (the streams of sensor data), which are then relayed to a central location. Then by demonstrating a time-series analysis, failure detection and failure prediction from the streams of sensor data can be obtained.

The method involves identifying “shapelets” – short instances that are particularly distinct – in the streams of sensor data.

- Time Series Analysis of Petroleum Product Sales.

- A manager of a private company would need forecast of an hourly volume and type of gas produced and utilized in order to schedule staff and equipment efficiently.

- Forecasting can also be an important part of a process control system through monitoring key processes. It may be possible to determine the optimal time and extent of control action; for example, a chemical processing unit may become less efficient as hours of continuous operation increase. Forecasting the performance of the unit will be useful in planning the shutdown time and overhaul schedule.

Simple Moving Average Method

What is Simple Moving Average?

Simple Moving Average is calculated by adding observations for last K time periods in time series and divide that sum by K.

Ft+1=(Yt+Yt-1+Yt-2+Yt-3+……Yt-K+1)/K

Equal weightage is given to all observations in last K periods. Smaller the value of K, the greater weight is given to each period. Greater the value of K, the smaller weight is given to each period.

How to decide ideal value of K in the above Simple Moving Average formula?

Short term simple moving average responds quickly to changes in sales given in underlying data while Long term simple moving average are comparably slow to react

Continued…

Simple Moving Average Method

Method to determine better K value:

There are two methods to compare the output values of Simple Moving Average for different values of K:

Root Mean Square Error: The formula for calculating RMSE is given by

RMSE= √{[(y1-f1)^2+(y2-f2)^2+…..(yk-fk)^2]/K}

Yk-Actual Sales value in period n

fK-Forecasted sales value in period n

K-Number of periods

Smaller the value of RMSE, better is the forecasting model.

Mean Absolute Percentage Error: The formula for calculating MAPE is given by

MAPE=[abs(y1-f1)/y1+abs(y2-f2)/y2+………..abs(yk-fK)/yn]/K

Yk-Actual Sales value in period n

fK-Forecasted sales value in period n

K-Number of periods

Smaller the value of MAPE, better is the forecasting model.

Continued…

Simple Moving Average Method

Using Simple Moving Average Techniques:

- Recent data should have more impact on forecasted sale. But SMA assigns equal weight to recent & historical data
- SME does not address trending and seasonality factors in the forecasted output.

Weighted Moving Average Method

What is Weighted Moving Average?

In Weighted Moving Average, a weight is assigned to each term to be averaged. These particular weights signifies the relative importance of each term on the average. The sum of all the associated weights should be equal to 1. So WMA has overcome the shortcoming of SME where each term to be averaged has equal weights without addressing the recency factors. The formula for WMA is:

$$F_{t+1}=(W_t*Y_t+W_{t-1}*Y_{t-1}+W_{t-2}*Y_{t-2}+W_{t-3}*Y_{t-3}+\ldots\ldots W_{t-k+1}*Y_{t-K+1})$$

W_t-Weight assigned to Sales in time period t

Y_t- Actual Sales in time period t

Case	Weight1	Weight2	Weight3	Weight4
WMA3	0.6	0.3	0.1	0.0
WMA4	0.4	0.3	0.2	0.1

How to decide better weights in the above Weighted Moving Average formula?

Higher the weight associated with the recent terms, quicker the response to the change in sales happen to the forecasted output.

Continued…

Weighted Moving Average Method

Method to determine better Weights:

There are two methods to compare the output values of Weighted Moving Average for different values of Weights:

Root Mean Square Error: The formula for calculating RMSE is given by

$$\text{RMSE}= \sqrt{\{[(y_1-f_1)^2+(y_2-f_2)^2+\ldots..(y_k-f_k)^2]/K\}}$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of RMSE, better is the forecasting model.

Mean Absolute Percentage Error: The formula for calculating MAPE is given by

$$\text{MAPE}=[\text{abs}(y_1-f_1)/y_1+\text{abs}(y_2-f_2)/y_2+\ldots\ldots\ldots..\text{abs}(y_k-f_K)/y_n]/K$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of MAPE, better is the forecasting model.

Continued…

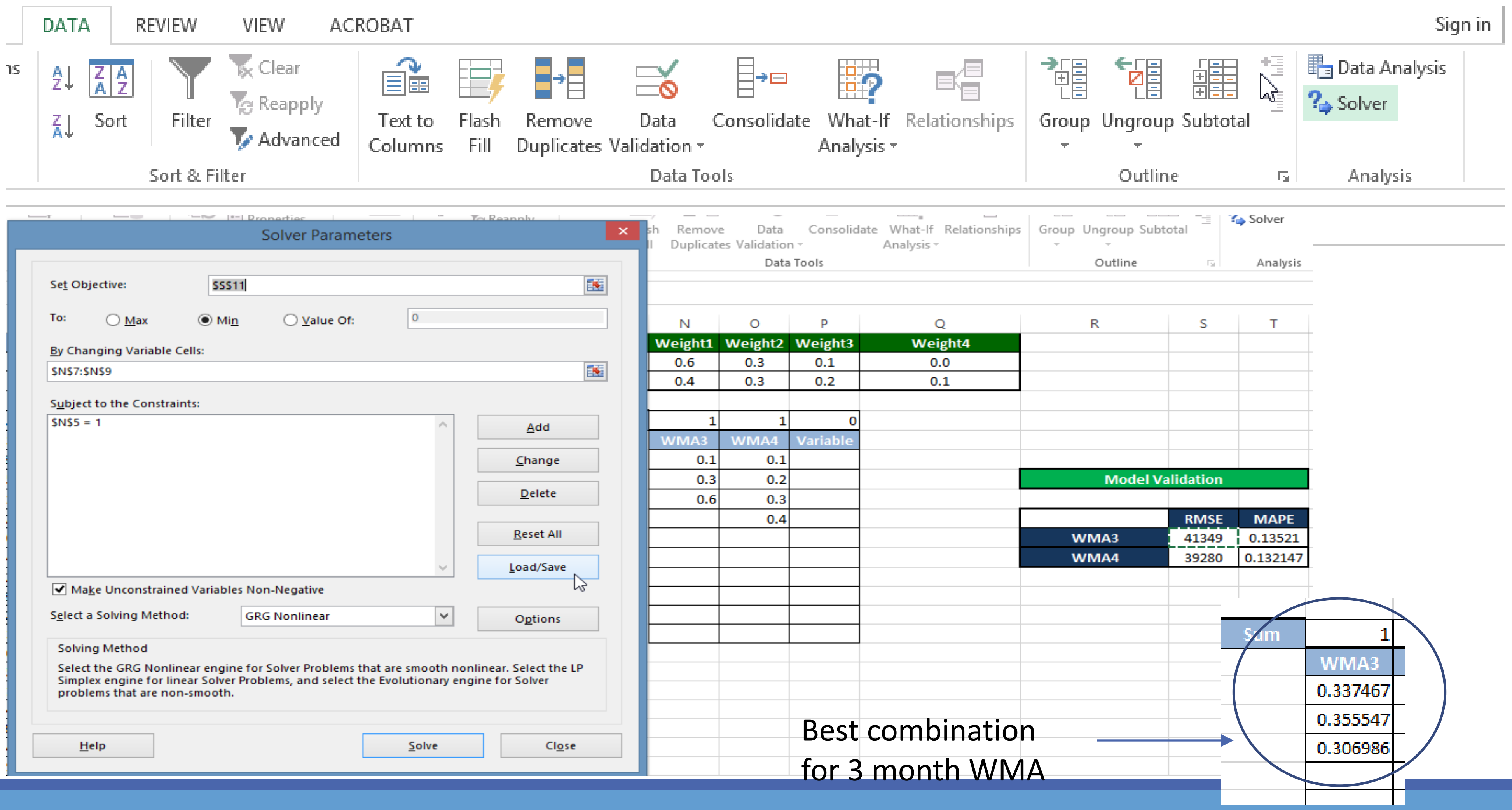
Weighted Moving Average Method

Using Weighted Moving Average Techniques:

- Ideally recent data should have more impact on forecasted sale. And WMA assigns more weight to recent sales data & less weight to the historical sales data
- WMA does not address trending and seasonality factors in the forecasted output.

Best Combination of Weights

Using Solver to find out best combination to minimize RMSE/MAPE



Best combination for 3 month WMA

Single Exponential Smoothing Method

What is Single Exponential Smoothing ?

Exponential smoothing is simply an adjustment technique which takes the previous period's forecast, and adjusts it up or down based on what actually occurred in that period. It accomplishes this by calculating a weighted average of the two values. The formula takes the form:

$$F_{t+1} = \alpha * D_t + (1 - \alpha) * F_t$$

F_t- Forecasted Sales in t period
D_t- Actual Sales in t period
α – Data Smoothing Factor

α should lie in between 0 and 1 so that a part of difference between previous actual sale and forecasted sale is used in updating. If α is close to 1 then it has less smoothing effect and give greater weight to the recent changes in data. If α is close to 0 then it has greater smoothing effect and less responsive to recent changes in data.

How to decide better data smoothing factor in the above Simple Exponential Smoothing formula?

Case	Exponent(0<=Alpha<=1)
SES(0.2)	0.2
SES(0.8)	0.8

Continued…

Single Exponential Smoothing Method

Method to determine better α :

There are two methods to compare the output values of Simple Exponential Smoothing for different values of α :

Root Mean Square Error: The formula for calculating RMSE is given by

$$\textbf{RMSE} = \sqrt{\{[(y_1-f_1)^2+(y_2-f_2)^2+\ldots..(y_k-f_k)^2]/K\}}$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of RMSE, better is the forecasting model.

Mean Absolute Percentage Error: The formula for calculating MAPE is given by

$$\textbf{MAPE} = [abs(y_1-f_1)/y_1+abs(y_2-f_2)/y_2+\ldots\ldots\ldots..abs(y_k-f_K)/y_n]/K$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of MAPE, better is the forecasting model.

Continued…

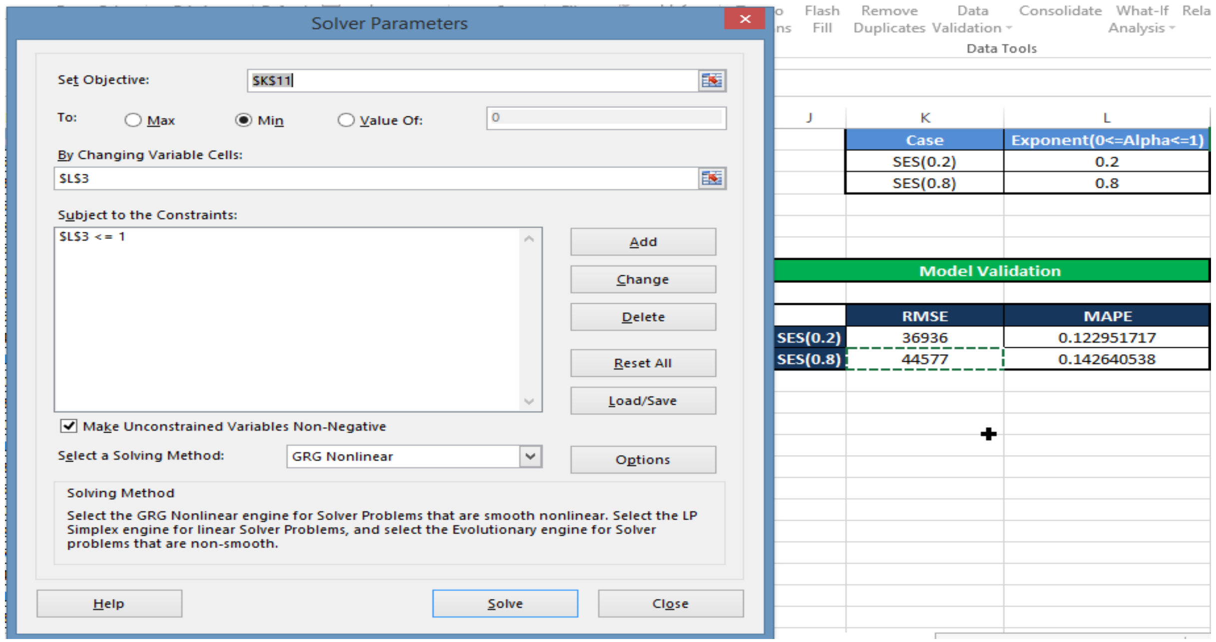
Single Exponential Smoothing Method

Using Simple Exponential Smoothing Techniques:

- Ideally recent data should have more impact on forecasted sale. And SES gives a lot of flexibility in assigning weights to the recent and old data by adjusting the values of α.
- SES addresses only smoothing factor but not trending and seasonality factors in the forecasted output.

Optimum value of α

Use solver to find optimum value of α to minimize RMSE/MAPE



Result

Case	Exponent(0<=Alpha<=1)
SES(0.2)	0.2
SES(0.8)	0.103631817

Model Validation

	RMSE	MAPE
SES(0.2)	36936	0.122951717
SES	36500	0.119540553

Double Exponential Smoothing Method

What is Double Exponential Smoothing ?

Simple exponential smoothing (SES) does not do well when there is a trend in the data. Double exponential smoothing performs better forecasting if data has trending factor in historical sales data. It basically uses two parameters – α (data smoothing factor) and β (trend smoothing factor). The formula for double exponential smoothing is given by:

when $t=1$ $\quad S_1=X_0, b_1=X_1-X_0$

when $t > 1$ $\quad S_t=\alpha*X_t+(1-\alpha)*(S_{t-1}+b_{t-1}),$

$b_t=\beta*(S_t-S_{t-1})+(1-\beta)*b_{t-1}$

$X_{t+1}=S_t+b_t$

α - Data Smoothing Factor

β - Trend Smoothing Factor

S_t - Smoothing component of forecasted value

b_t - Trending component of forecasted value

X_{t+1} – Forecasted value

α should lie in between 0 and 1

β should lie in between 0 and 1

How to decide better combination of data smoothing factor and Trend Smoothing Factor in the Double Exponential Smoothing formula?

Continued…

Double Exponential Smoothing Method

Method to determine better α and β combination :

There are two methods to compare the output values of Double Exponential Smoothing for different values of α and β :

Root Mean Square Error: The formula for calculating RMSE is given by

$$\textbf{RMSE}= \sqrt{[(y_1-f_1)^2+(y_2-f_2)^2+.....(y_k-f_k)^2]/K}$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of RMSE, better is the forecasting model.

Mean Absolute Percentage Error: The formula for calculating MAPE is given by

$$\textbf{MAPE}=[abs(y_1-f_1)/y_1+abs(y_2-f_2)/y_2+..........abs(y_k-f_K)/y_n]/K$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of MAPE, better is the forecasting model.

Continued…

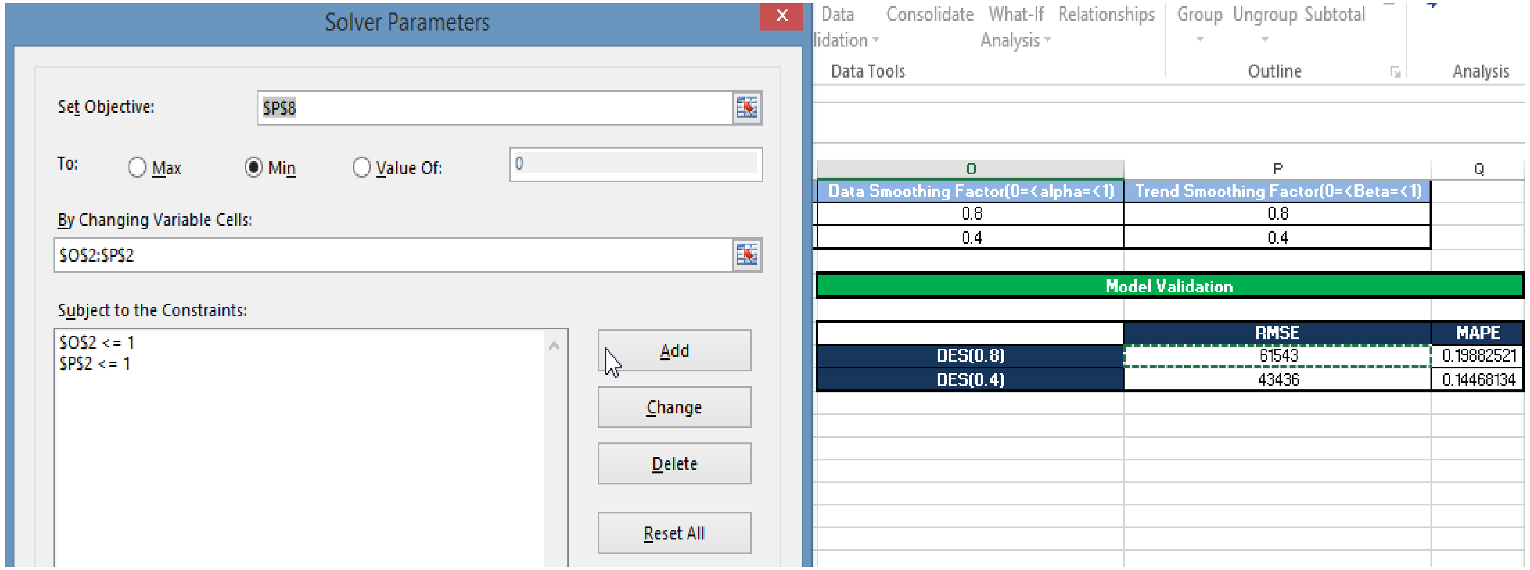
Double Exponential Smoothing Method

Using Double Exponential Smoothing Techniques:

- DES gives a lot of flexibility in controlling the data and trend smoothing by controlling values of α and β
- DES addresses smoothing of data and trend factor but not seasonal factors in the forecasted output.

Optimum Value of α and β

Solver will help us to find best combination of α and β to minimize RMSE/MAPE



Best Combination

Case	Data Smoothing Factor(0=<alpha=<1)	Trend Smoothing Factor(0=<Beta=<1)
DES(0.8)	0.103802079	0.027514232
DES(0.4)	0.4	0.4

Model Validation

	RMSE	MAPE
DES(0.8)	36852	0.12239256
DES(0.4)	43436	0.14468134

Triple Exponential Smoothing Method

What is Triple Exponential Smoothing ?

Double exponential smoothing (DES) does not do well when there is a trend and seasonality both in the data. In such situations, several methods were devised under the name “triple exponential smoothing“ .

Triple exponential smoothing is given by the formulas:

$S_t=\alpha X_t/C_{t-L}+(1-\alpha)(S_{t-1}+b_{t-1}),$

$b_t=\beta(S_t-S_{t-1})+(1-\beta)*b_{t-1}$

$C_t=\Upsilon(X_t/S_t)+(1-\Upsilon)*C_{t-L}$

$F_{t+1}=(S_t+b_t)*C_{t-L}$

S_t- Data Smoothing Component of Forecasted Value

b_t- Trend Smoothing Component of Forecasted Value

C_t- Season Smoothing Component of Forecasted Value

α- Data Smoothing Factor ($0< \alpha <1$)

β- Trend Smoothing Factor ($0< \beta <1$)

Υ- Season Smoothing Factor ($0< \Upsilon <1$)

How to decide better combination of data smoothing factor, trend smoothing factor and season smoothing factor in the Triple Exponential Smoothing formula?

Data Smoothing Factor(0=<alpha=<1)	Trend Smoothing Factor(0=<Beta=<1)	Season Smoothing Factor(0=<Beta=<1)
0.8	0.1	0.8

Continued…

Triple Exponential Smoothing Method

Method to determine better α, β and ϒ combination :

Root Mean Square Error: The formula for calculating RMSE is given by

$$RMSE= \surd\{[(y_1-f_1)^2+(y_2-f_2)^2+.....(y_k-f_k)^2]/K\}$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of RMSE, better is the forecasting model.

Mean Absolute Percentage Error: The formula for calculating MAPE is given by

$$MAPE=[abs(y_1-f_1)/y_1+abs(y_2-f_2)/y_2+..........abs(y_k-f_K)/y_n]/K$$

Y_k-Actual Sales value in period n

f_K-Forecasted sales value in period n

K-Number of periods

Smaller the value of MAPE, better is the forecasting model.

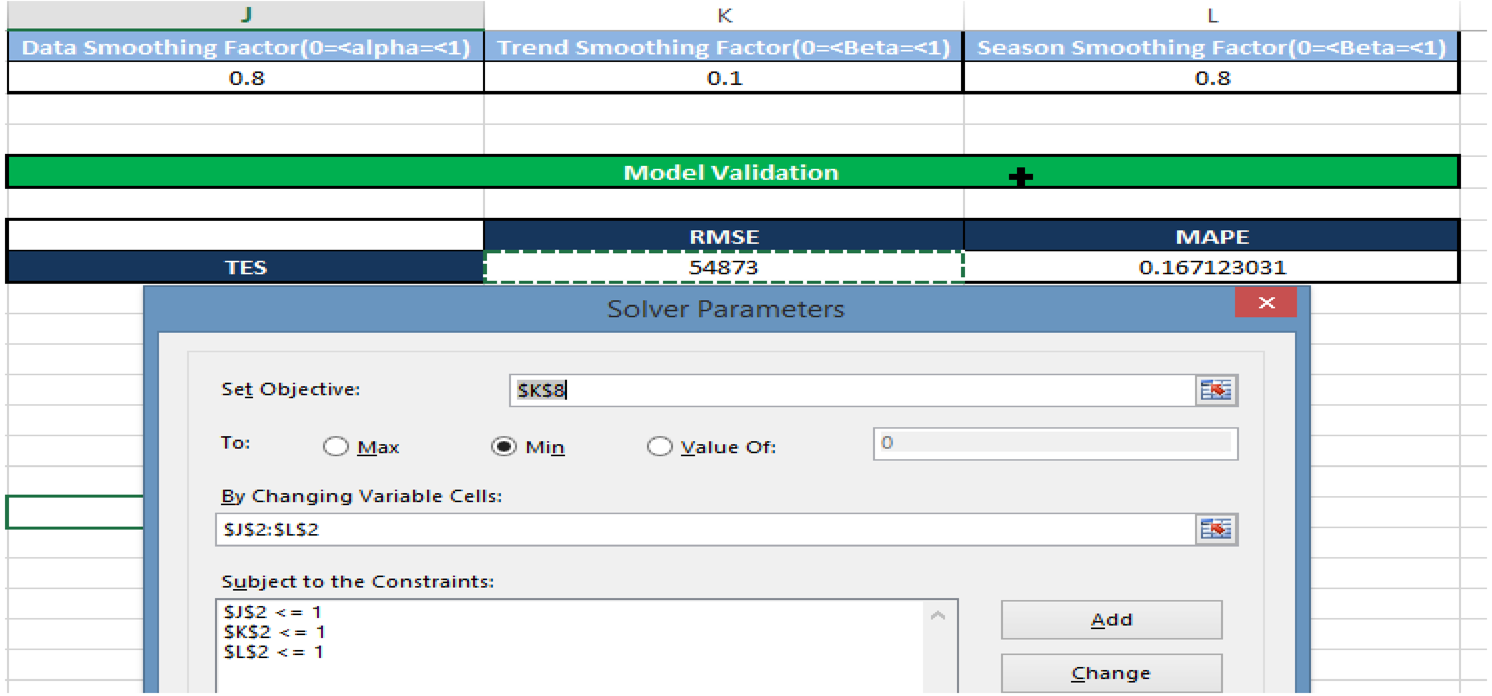
Triple Exponential Smoothing Method

Using Triple Exponential Smoothing Techniques:

- TES gives a lot of flexibility in controlling the data, trend and season smoothing by controlling values of α, β and ϒ
- TES addresses smoothing of data, trending and season factor

Optimizing α, β and ϒ

Optimizing α, β and ϒ to minimize RMSE/MAPE



Result

Data Smoothing Factor(0=<alpha=<1)	Trend Smoothing Factor(0=<Beta=<1)	Season Smoothing Factor(0=<Beta=<1)
0.084804004	0.049114249	0.294576099

Model Validation

	RMSE	MAPE
TES	41446	0.131485476

Continued...

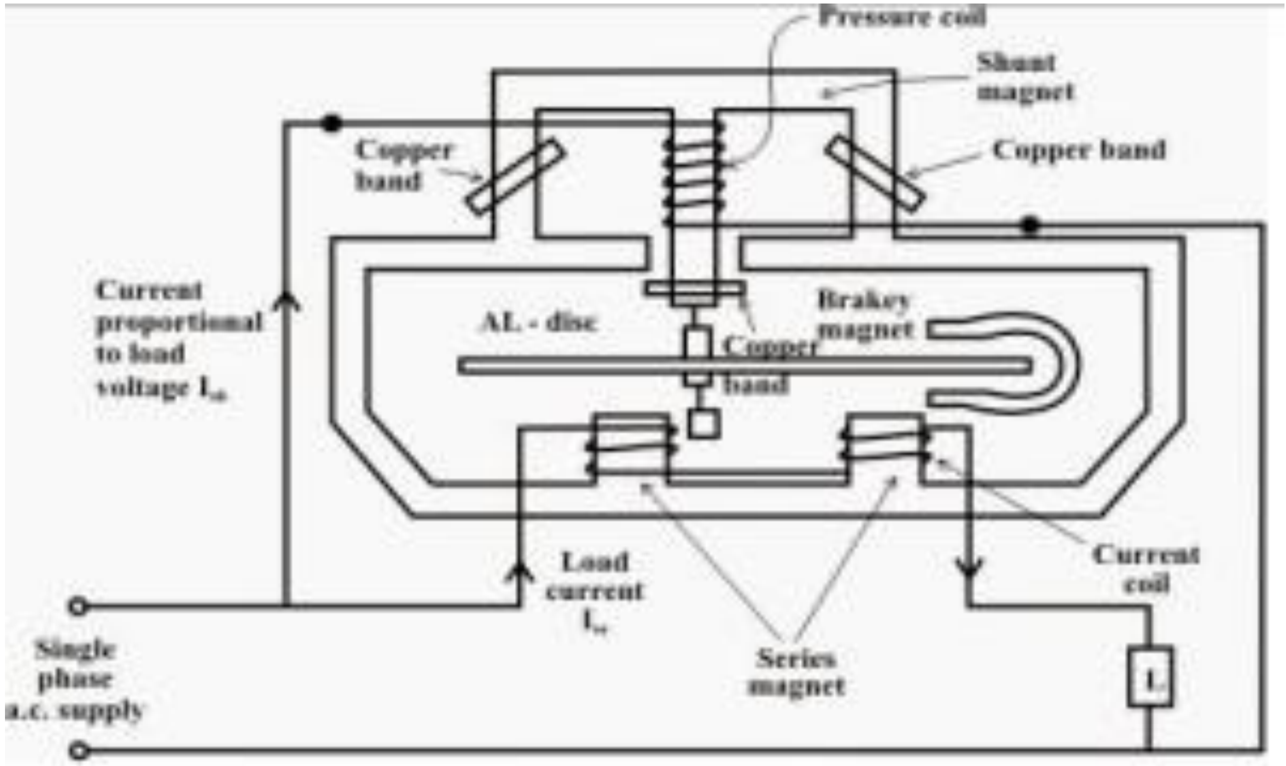
Energy Meter

- An electric meter is a device that measures the amount of electric energy consumed by a residence, a business or electrically powered devices.
- Electric utilities install meter at the customer premises to measure electric energy delivered to their customers for billing purpose.
- They are calibrated in billing units and the most popular and accepted unit is measured in kilo watt hour (KWH).

Types of energy meter

- It is classified in accordance with several factors such as
  - Types of display - Analog or digital
  - Type of metering point – Grid, primary / secondary transmission and local distribution.
  - End applications - Domestic, commercial industrial
  - Technical application – 3 phase, single phase, LT, HT and accuracy class meter.

Energy Meter



Problem statement.

- Our objective is to : -
  - To find clusters of high, low, medium consumers on daily basis. (weekdays / weekends)
  - To forecast what is going to be consumption for next 7 days and/or next month.
  - What should be the demand forecast? (Identify the shortage day and provide back up)
  - Identify spike. (outlier detection)
  - Able to satisfy the demand.

R Script

Graphs

Concluding Statement

Design Thinking

Ask the participants what kind of problems related to their industry can be solved using this concept.

Question & Answers

THANK YOU