ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

# ETM 510 Energy Demand Forecasting

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# Contents

## Introduction

Energy load forecasting is a major business problem in the electric power industry. A lot of effort is put in this field by the researchers and industry experts to estimate load. In the recent times, technological development, renewable integration requirements and aging infrastructure has made the energy forecasting more and more important to energy system operations and its planning [1] This project is based on participation in worldwide energy forecasting competition GEFCom for 2017. With the growing need of load forecasting, this competition is an effort to bring together the very advanced and sophisticated techniques and methodologies to predict the demand of energy using hierarchical probabilistic energy forecasting and has participants from various countries. This report explains the learning process and the entire journey of participation in this competition. This process involves understanding the concepts of R as R was chosen as the analysis tool. It also includes understanding the concepts of Forecasting and specific to weather forecasting. Competition was designed in a way to raise the level of participants every week. Every 2 weeks, there was a submission and then there was good amount of time to look back and analyze the results and improve on it [2] [1] To provide a brief description of the competition, it had a bi level setup i.e. a 2 month qualifying match with 2 tracks and a 1 month final match on a large scale problem [2]

The qualifying match included two tracks which included forecasting the total and zonal loads of ISO New England. The 2 tracks are [2][1]

1) Defined Data Track – This track restricts the contestant's n what data to be used. The data is available from the ISO New England's website and we were not allowed to go beyond the demand and temperature data (DryBulb and DewPnt) in the files. Another data that could be use was of the federal holidays and infer days of week to identify the demand correlation between different days of the week.
2) Open Data Track – This track allows contestants to explore various channels to gather more information including weather channels, economy information, and the penetration of solar PV published by US government websites.

The final match has only one forecasting track with more real world data and open to top teams from the qualifying matches

This report discusses in detail the different phases of learning and analysis done during the course. How the perspective, level of understanding and skillset of performing demand forecasting went from beginner to an intermediary level. Models used to analyze the data with different parameters are discussed in detail in the following sections. Analysis helps in learning that there is never a 100% correct prediction. There is always a chance of 10% or more error. Different parameters play a critical role in analyzing data and brings up interesting results.

## Literature Review

With the emerging technologies like electric vehicles, micro grids, rooftop solar panels etc. are bringing a lot of uncertainty to the demand of energy at these times. Therefore, it is very important area of research in the current environment. Loa forecasting is important not only or the electrical companies but also by other business entities like regulatory commissions, big industrial companies, banks etc. Forecasting process can be grouped in 4 categories and are different in the term used for forecasting [3]

1) Very Short term load forecasting
2) Short term load forecasting
3) Medium term load forecasting
4) Long term load forecasting

Very short term forecasting process is to forecast for next hours, short term is for next day, Medium term forecasting talks about 2-3 weeks and long term load forecasting focuses on forecasting for 1 or more years [3].

Probabilistic Load forecasting (PLFs) can be used for various cases like stochastic unit commitment, planning the power supply, forecasting price, equipment failure prediction etc.

Load forecasting techniques are generally classified in 2 groups 1) Statistical Techniques 2) Artificial Intelligence Techniques. Statistical techniques include MLR models, autoregressive and moving average (ARMA) models, semi-parametric additive models and exponential smoothing models [3]

Exponential Smoothing model assigns weights to the past observations in time series. These weights decrease exponentially over time. Holtwinters model is an example of triple exponential smoothing model. This model was the first model to be used for this project and on further study realized that exponential smoothing is not the best model to consider as per various researchers as it has lower data requirements as compared to other models. The reason being that load forecasting id heavily affected by the weather conditions. Since this techniques does not use meteorological forecasts, load forecasting becomes challenging due to the volatile nature of weather changes [3].

Autoregressive moving average model (ARIMA) provides as "parsimonious description of a stationary stochastic process in terms of two polynomials, one an auto regression and the other a moving average. Since the hourly electricity demand series is well-known to be nonstationary, ARIMA models, which are a generalization of ARMA models, are often used for load forecasting purposes. ARMA models can also be generalized to include exogenous variables, giving ARMAX models." [3] Therefore, ARIMA model was the next model that was used for load forecasting.

Artificial Neural Networks model is the most widely used model for load forecasting across the industries. In this model, the forecaster does not have to specify the input and output variables. Rather, by reading the past data, and learning the patterns from historical data, the input variables and demand are constructed [3] It also provide the advantage of handling nonlinear data and is often able to provide very accurate results. However, there are some challenges with this model too. It lacks interpretability and there is also an overfitting issue associate with it [4]. Although it is a strong tool but due to these limitations and due to the limitation of me not having strong coding background, I decided to rule out as an option.

Next level of challenge in this competition is to forecast the hourly demand of load. For most short and medium term load forecasting the major question is when and how much the demand will be. To understand that, it is important to understand that what are the parameters impacting load. When is the consumption highest, and what is changing the pattern. Further research states that statistical approaches are preferred by the researchers and industry experts due to the accuracy and interpretability [4] Time series approach has been expensively used while performing short term load forecasting [4]

Multiple regression is used to model the load with linear function of various independent variables. For example, the multiple regression is used to understand if the load forecasting depends on the hour of the day or the weather of the day as well or not. If it does depend on either of these, what is the dependency?

## Methodology

Forecasting is not a straight forward series of steps to be executed. It is a collection of various steps. There is no exact correct or wrong forecast. It depends on what variables are considered while forecasting. The approach in this project was to start with something simple to get accustomed to using R [5] [6] [7] [8][9] and understanding the basic concepts of forecasting. Knowledge has evolved since then. Different approaches and models were adopted and then tested to see if the results were better from last time. Below are the various models adopted and we will discuss them in detail in this report.

## Approach 1 (Holtwinters model)

Energy demand data is available for various years in a time series format. Time series means that data is progressing after each point. I figured that my data is a perfect example of time series. Further, Holtwinters model is an advanced version of Naïve Method, Simple Average, Moving average and weighted moving average. This model is also known as Triple Exponential Smoothing model which can be used to forecast data points which are in time series which means that data is seasonal and repetitive over some period. [10][11]. TO start with the forecast, I took demand data of March for last 3 years 2014, 2015 and 2016. The data was arranged in the rows which mean that row number 1 to 24 were for March 1st 2014 and next 24 rows would be March 2nd and so on. The trial here was to predict first 200 rows i.e. around 8 days. Below is the code for this simplest model that I worked on [11].

```
demandseriesforecast <- HoltWinters(Serialanddemand,beta=FALSE,gamma=FALSE)
> demandseriesforecast
plot(demandseriesforecast)
> demandseriesforecast2 <-forecast.HoltWinters(demandseriesforecast,h=200)
> plot.forecast(demandseriesforecast2)
> demandseriesforecast2
```

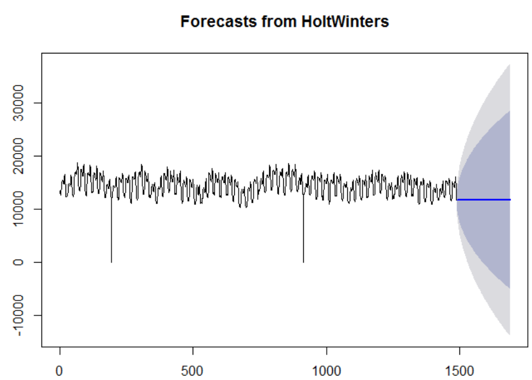


**FIGURE 1 HOLTWINTERS MODEL**

Challenge: The results for first 200 rows of prediction from this model were not convincing as they result ed in same values for all rows and only difference was in the alpha values for low 80, high 80, low 95 and high 95. Also, the challenges as described in the earlier section led to the realization that it is not the bes t approach for load forecasting. For more detailed data result, refer Table 1 in Exhibits

Hence, this was not a correct approach and further research led me to another forecasting model as discussed in next points

## Approach 2 (ARIMA Function)

Autoregressive Integrated Moving Average (ARIMA) model as explained in the earlier section was chosen as the second approach for forecasting load. The function used in R for the same is called as " Auto.arima()" and qnorm() function is being used for the quantile forecast from 10 % to 90% [11]. Similar to the first approach, this approach changes the model from Holtwinters (Exponential Smoothing model) to the ARIMA model. However, the dataset was of Rhode Island for all months for 3 years 2014, 2015 and 2016. It was assumed that data can be forecasted for Jan2017 to March 2017. Therefore, number of points/ rows to be forecasted i.e. "h"= 2160.

Sum(Days in Jan 2017+Feb 2017+March 2017)*24 hours

(31+28+31)*24 = 2160

This function forms a matrix with 9 columns and 2160 rows for forecasted values. Below is the code for forecasting [11] [9]

```
View(RIdata3years)
fitRI<-auto.arima(RIdata3years)
fcRI<-forecast(fitRI,h=2160,level=95)


qfRI<-matrix(0,nrow=9,ncol=2160)
mRI<-fcRI$mean
sRI<-(fcRI$upper-fcRI$lower)/1.96/2
for(h in 1:2160)
+ qfRI[,h]<-
qnorm((seq(from=10,to=90,by=10))/100,mRI[h],
sRI[h])
plot(fcRI)
qfRIt<-t(qfRI)
qfRIt
write.csv(qfRIt,"qfRIt.csv")
```

Challenge: It was realized that this forecasting method considered all the hours of the day as equal and therefore the demand forecast assigned equal values to all the hours of the day and for the entire month of march too. So, when plotted in a graph, the values of March 2017, came out to be a straight line

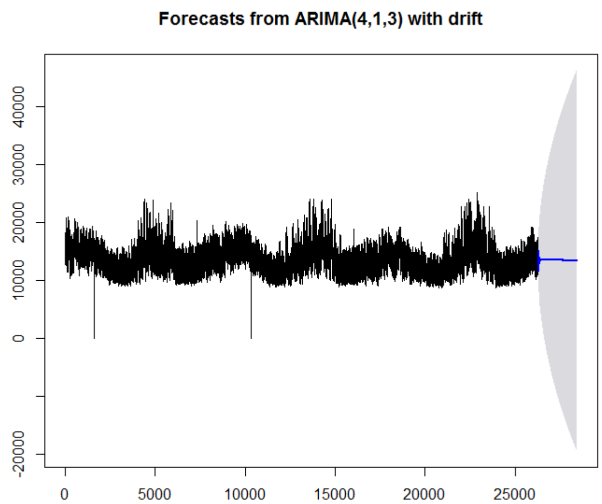


**FIGURE 2: ARIMA MODEL CHART**

In addition, quantile values appeared to me negative for some regions. Refer Exhibit 2 for complete data for March [Table 2] in Exhibit. Another interesting thing to note was that all the quantile values were not negative and that too not for all the regions. The values came negative for 10% to 30% of quantiles in some cases. Logically forecast values should be non-negative and therefore further study was required to figure out why the values were coming out negative.

So, I tried to do more research but there is not much literature on the quantiles. However, below figure explains what quantile means. Since normal distribution divides a graph in 2equal parts. Half students do better than the median and half will do bad then the median[12]. Similarly, quantile divides the graph into equal parts. So, 10% quantile divides the graph into 10 equal parts.

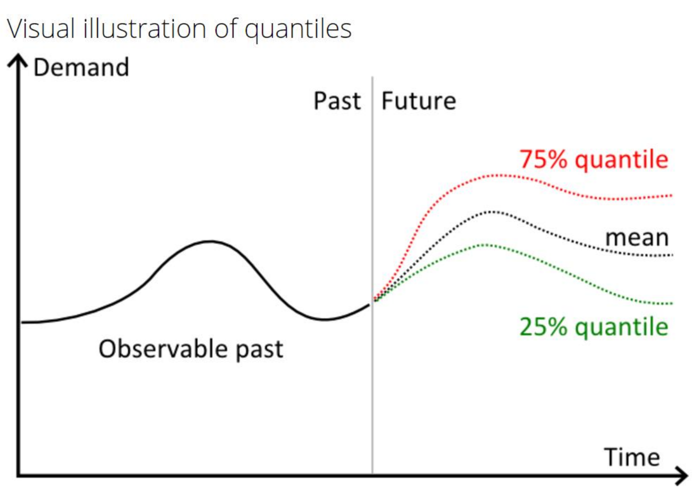


**FIGURE 3 WHAT IS QUANTILE [13]**

## Approach 3 (ARIMA Matrix)

On further literature review about correlation between different independent variables [4], I realized that it is important for me to see what is the correlation between the days, hours, and months in previous years? I realized that there is a need to understand data better.

Assumption: I initially assumed that Feb, March and April are more of winter months and therefore should have similar temperature.

So, to confirm my understanding, I took data for 6 years 2011-2016 for Feb –April. The data was divided in 2 different ways:

1) Chose 4 days Feb 10th, March 1st, March 25th and April 20th to see the energy demand on these 4 days for all 24 hours of the day. Plotted 4 different graphs for each day with hours of the day on x axis and respective demand on the y axis

2) Chose 4 hours of a day i.e. 3 AM, 9AM, 3 PM and 9PM to see how the energy demand varies at these times for all days from February to April for 6 years. Plotted 4 different graphs with total 89 days of each year in the x axis and demand on the y axis. I also discarded the data of 29th February for leap year 2012 and 2016.

Objective of this exercise was to see if it is correct to include data of Feb to April for all the years to predict demand for March and April 2017. The rationale is that if the demand is similar for all times in these months, then it will be logical to use the entire data. However, if the hypothesis is proven wrong, an alternative approach need to be figured out. Below are the graphs

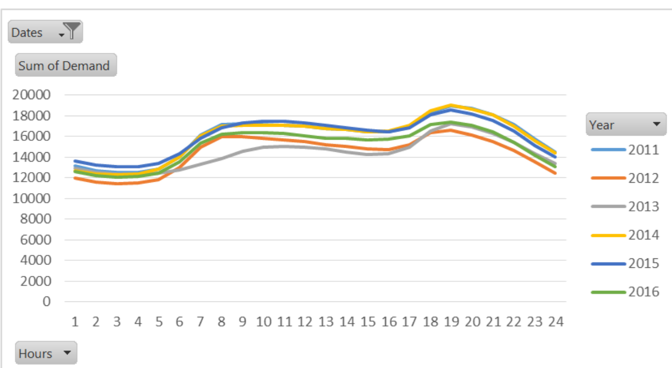


**FIGURE 4 FEBRUARY 10TH : LOAD DEMAND GRAPH FOR FEB 2011 TO 2016**

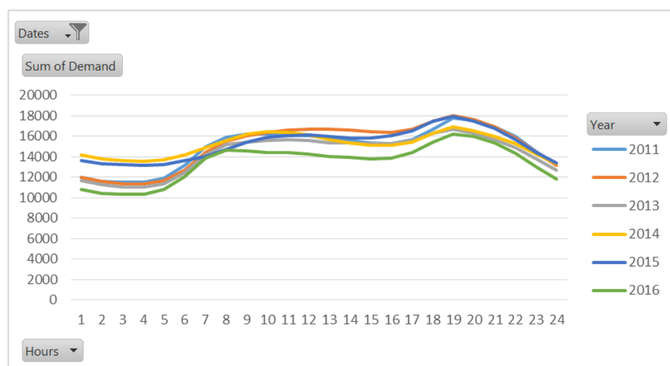


**FIGURE 5: MARCH 1ST LOAD DEMAND GRAPH FOR MARCH 2011 TO 2016**

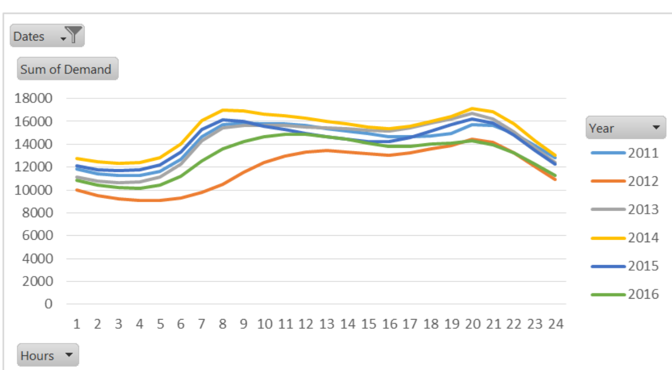


**FIGURE 6: MARCH 21ST LOAD DEMAND GRAPH FOR MARCH 2011 TO 2016**

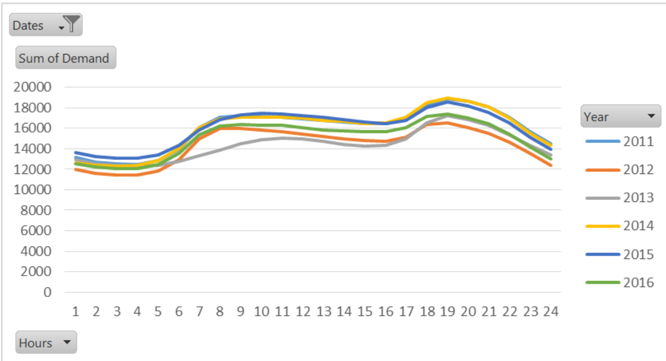


FIGURE 7:APRIL 20TH LOAD DEMAND GRAPH FOR APRIL 2011 TO 2016

From the 4 graphs of random days between February and April, it became clear that the demand is different in each month. Demand is higher in February and then gradually decreases in March. Hen from March to April it is again varying between different years. So, it proves that temperature plays a major role in electricity demand. And also, demand is higher in winters when heating is used in homes while less in the transition time between winter and summer. Another important point that comes out of these graphs is that the graph pattern is similar for all days of these months. i.e. demand is lowest in late nights and maximum during 8 AM-9AM and 7 PM -8PM all days.

So, it is incorrect to forecast electricity demand of March using any other month and for that matter even the days of March will not be able to forecast correct values of demand. Therefore, it is important to forecast the value of each day of March using the respective day's demand in past years. This will help get more correct forecast values.

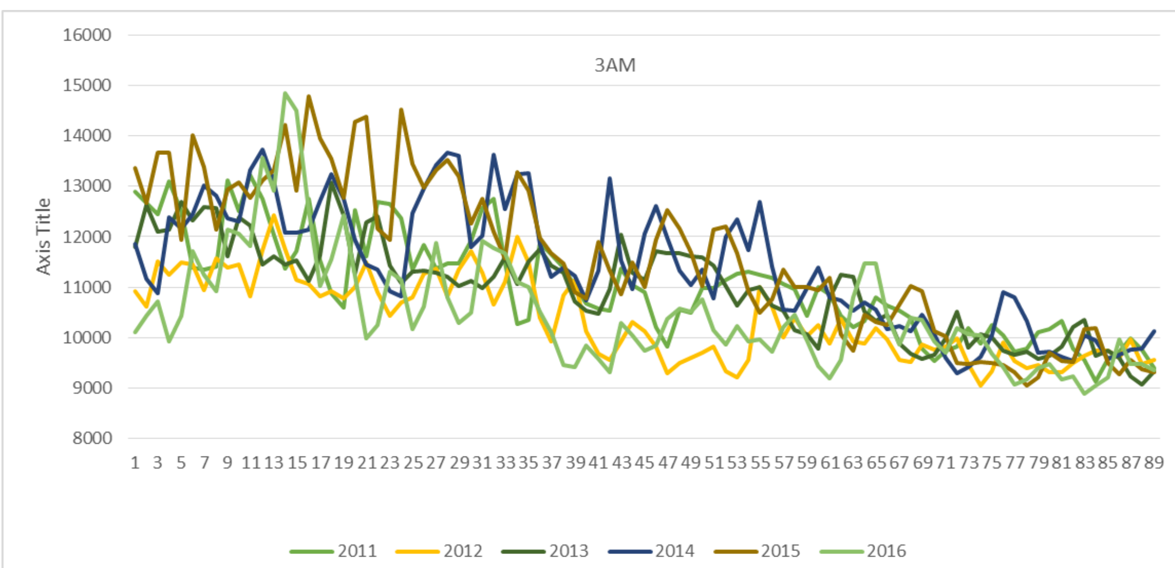


FIGURE 8: 3 AM DEMAND GRAPH FOR FEB, MARCH AND APRIL FOR 2011 TO 2016

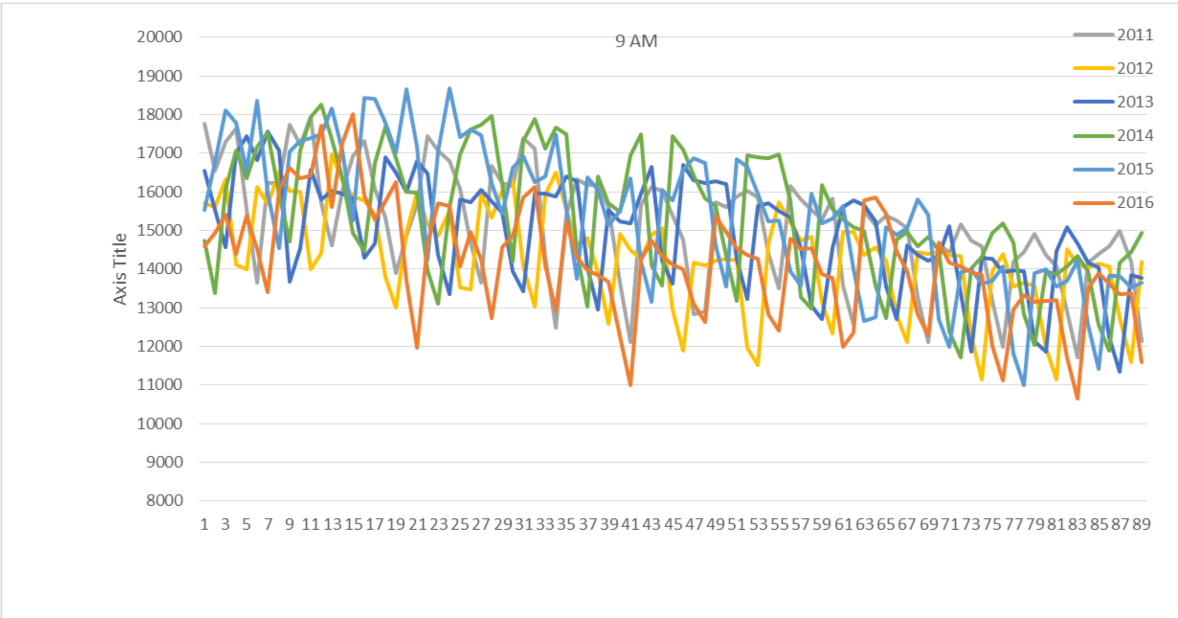


**FIGURE 9: 9 AM DEMAND GRAPH FOR FEB, MARCH AND APRIL FOR 2011 TO 2016**

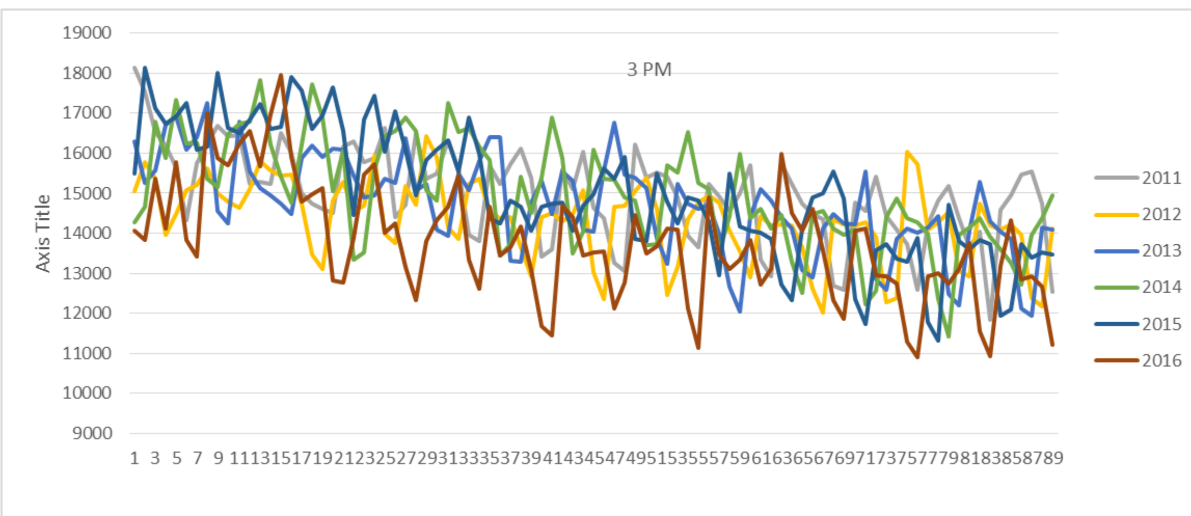


**FIGURE 10: 3 PM DEMAND GRAPH FOR FEB, MARCH AND APRIL FOR 2011 TO 2016**

From these graphs, it is clear that the demand of electricity goes down from each month even though it is at the same time. Therefore, it is clear from the above graphs, which are simpler way of understanding the data better instead of using correlation. Therefore the initial assumption has been proven wrong.

From the above analysis it is clear that it would be better to use only March data to predict load from March. Also, according to me, it would e further better to use past data of March 1 to predict data of March 1. Also, the next approach is based on using the 12 AM data of March 1 from last 6 years to predict

1 AM March 2017 demand. Similarly time series will compare the demand of each date with the same date demand for last 6 years and that too at the same time. Refer the below code [11][9]

```
# Converting the list form into vector
df <- data.frame(matrix(unlist(march6years), nrow=4464, byrow=T),stringsAsFactors=FALSE)
invisible(sapply(df,c))

dataFull <- matrix(0.0, nrow=186, ncol=24)

for (day in 1:186){
  for (hour in 1:24){
    dataFull[day, hour] <- df[24*(day-1)+ hour,1]
}}

library(forecast)

meanfc <- matrix(0.0, nrow=31, ncol=24)
sfc <- matrix(0.0, nrow=31, ncol=24)

for (i in 1:24){
  fit <- auto.arima(dataFull[,i])
  fc <- forecast(fit, h=31, level=95)
  m <- fc$mean
  s <- (fc$upper-fc$lower)/1.96/2
  meanfc[,i] <- m
  sfc[,i] <- s
}
```

```
# Quantile forecast at 10 %, 20 %, ....90 %

qf <- matrix(0, nrow=9, ncol=31*24)
qfTemp <- matrix(0, nrow=9, ncol=1)
for (i in 1:31){
  for(j in 1:24){
  qfTemp[,1] <-qnorm((seq(from=10,to=90,by=10))/100,meanfc[i,j],sfc[i,j])
  qf[,(i-1)*24 +j] <- qfTemp[,1]
}}

qft <- t(qf)
```

The Above code first coverts the entire data of March for 6 years with 24 rows for each day i.e. total 4464 rows into 186 rows and 24 columns. Which means that each day will be in 1 row and each row will have 24 columns. So, a matrix is formed for this data. Now, once the matrix is created, there will be 189 rows for each day of March and column of 1 AM will be used to predict the demand value of March 1st, 2017. And this loop will be repeated for all the 24 values of hours i.e. "I" in the code. H=31 to forecast 31 values using the past data. Similar qnorm() function is used to forecast the quantiles from 10& to 90%. Please refer the Table 3 excel file in Exhibit for complete data.

# Analysis and Conclusion

Approach 3 is the final method used for forecasting load for each of the states. This method has given better results as compared to the other methods and prove to be closely in line with the actual data pattern. We did not see any negative values in the analysis and also, all the values seem to vary as per the pattern found out in earlier analysis. To check the assumption, a graph was plotted for March 1st 2017 load forecasted values to see how the values very in the entire day for all the quantile values.

The below graph shows the exact same pattern for electricity consumption in the entire day where consumption peaks around 7- 8 AM and 7-9 PM amongst the 24 ours of a day. Refer figure 11

Therefore, this approach was considered the closest for analysis until date and in the interest of time there were limited options that could be evaluated. Learning from the entire process of forecasting has helped me learn that it is very important to understand data before applying any models for forecasting. It is important to understand how data varies due to several independent variables. Also, what should be used as a parameter to forecast? As in this it was realized that temperature is playing a major role in demand of electricity and therefore, it is not fair to predict load for March using any other data than March.

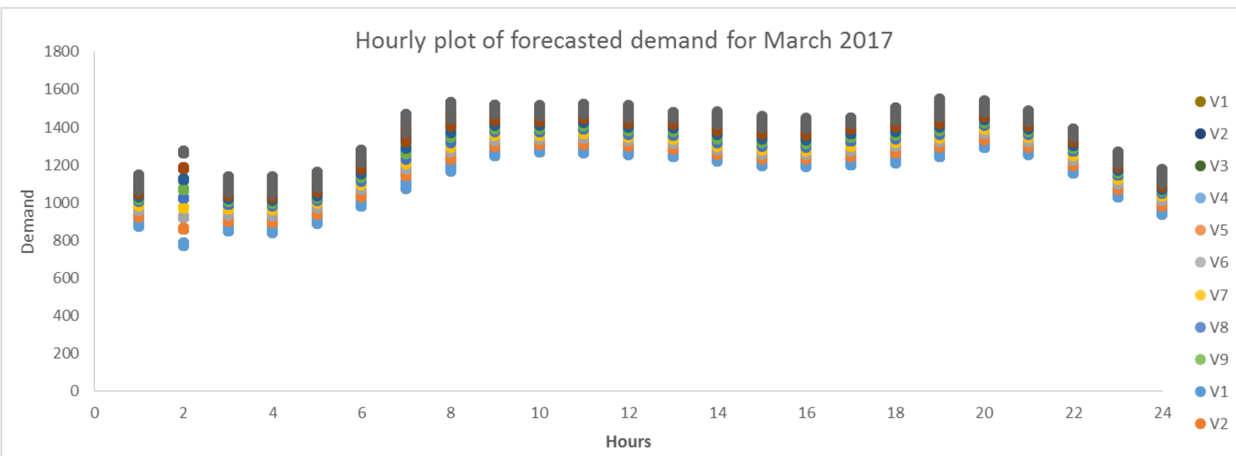


**Figure 11: Hourly graph of frorecasted load for March 1st 2017**

# Next Steps

Due to limited time I have not been able to explore the possibility of using federal holidays as one of the data points. However given more time I would like to understand from the past years how the demand changed in certain months on the federal holidays and accordingly forecast for year 2017

I would also like to build up skillset in using R as the tool for forecasting. Artificial Neural Networks is one of the models being widely used and taking data from various sources. This would be very important model to try out and I am sure there would be more possible ways and models of forecasting using R. However due to limited visibility and being very new to R, it acted as a limitation. I would like to improve more on that in future.

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# Exhibit

### TABLE 1: HOLTWINTERS MODEL RESULTS

| | Point Forecast | Lo 80 | Hi 80 | Lo 95 | Hi 95 |
|---|---|---|---|---|---|
| 1489 | 11688.08 | 10506.767990 | 12869.40 | 9881.4180 | 13494.75 |
| 1490 | 11688.08 | 10017.507430 | 13358.66 | 9133.1586 | 14243.01 |
| 1491 | 11688.08 | 9642.077104 | 13734.09 | 8558.9875 | 14817.18 |
| 1492 | 11688.08 | 9325.572171 | 14050.59 | 8074.9349 | 15301.23 |
| 1493 | 11688.08 | 9046.724516 | 14329.44 | 7648.4742 | 15727.69 |
| 1494 | 11688.08 | 8794.626274 | 14581.54 | 7262.9233 | 16113.24 |
| 1495 | 11688.08 | 8562.797577 | 14813.37 | 6908.3719 | 16467.79 |
| 1496 | 11688.08 | 8347.016389 | 15029.15 | 6578.3630 | 16797.80 |
| 1497 | 11688.08 | 8144.350054 | 15231.81 | 6268.4116 | 17107.75 |
| 1498 | 11688.08 | 7952.663308 | 15423.50 | 5975.2520 | 17400.91 |
| 1499 | 11688.08 | 7770.344195 | 15605.82 | 5696.4190 | 17679.75 |
| 1500 | 11688.08 | 7596.140381 | 15780.02 | 5429.9973 | 17946.17 |
| 1501 | 11688.08 | 7429.055947 | 15947.11 | 5174.4637 | 18201.70 |
| 1502 | 11688.08 | 7268.283405 | 16107.88 | 4928.5833 | 18447.58 |
| 1503 | 11688.08 | 7113.157265 | 16263.01 | 4691.3383 | 18684.83 |
| 1504 | 11688.08 | 6963.121361 | 16413.04 | 4461.8782 | 18914.29 |
| 1505 | 11688.08 | 6817.705243 | 16558.46 | 4239.4834 | 19136.68 |
| 1506 | 11688.08 | 6676.506752 | 16699.66 | 4023.5390 | 19352.63 |
| 1507 | 11688.08 | 6539.178895 | 16836.99 | 3813.5142 | 19562.65 |
| 1508 | 11688.08 | 6405.419802 | 16970.74 | 3608.9473 | 19767.22 |
| 1509 | 11688.08 | 6274.964911 | 17101.20 | 3409.4337 | 19966.73 |
| 1510 | 11688.08 | 6147.580819 | 17228.58 | 3214.6166 | 20161.55 |
| 1511 | 11688.08 | 6023.060371 | 17353.10 | 3024.1790 | 20351.99 |
| 1512 | 11688.08 | 5901.218707 | 17474.95 | 2837.8382 | 20538.33 |
| 1513 | 11688.08 | 5781.890038 | 17594.27 | 2655.3408 | 20720.82 |
| 1514 | 11688.08 | 5664.925002 | 17711.24 | 2476.4582 | 20899.71 |
| 1515 | 11688.08 | 5550.188474 | 17825.98 | 2300.9838 | 21075.18 |
| 1516 | 11688.08 | 5437.557729 | 17938.61 | 2128.7300 | 21247.43 |
| 1517 | 11688.08 | 5326.920912 | 18049.24 | 1959.5256 | 21416.64 |
| 1518 | 11688.08 | 5218.175732 | 18157.99 | 1793.2142 | 21582.95 |
| 1519 | 11688.08 | 5111.228357 | 18264.94 | 1629.6523 | 21746.51 |
| 1520 | 11688.08 | 5005.992464 | 18370.17 | 1468.7079 | 21907.46 |
| 1521 | 11688.08 | 4902.388425 | 18473.78 | 1310.2591 | 22065.91 |
| 1522 | 11688.08 | 4800.342602 | 18575.82 | 1154.1935 | 22221.97 |
| 1523 | 11688.08 | 4699.786733 | 18676.38 | 1000.4066 | 22375.76 |
| 1524 | 11688.08 | 4600.657399 | 18775.51 | 848.8014 | 22527.36 |
| 1525 | 11688.08 | 4502.895559 | 18873.27 | 699.2875 | 22676.88 |
| 1526 | 11688.08 | 4406.446131 | 18969.72 | 551.7809 | 22824.38 |
| 1527 | 11688.08 | 4311.257639 | 19064.91 | 406.2026 | 22969.96 |
| 1528 | 11688.08 | 4217.281883 | 19158.88 | 262.4791 | 23113.69 |
| 1529 | 11688.08 | 4124.473661 | 19251.69 | 120.5412 | 23255.62 |
| 1530 | 11688.08 | 4032.790507 | 19343.37 | -19.6761 | 23395.84 |
| 1531 | 11688.08 | 3942.192473 | 19433.97 | -158.2338 | 23534.40 |
| 1532 | 11688.08 | 3852.641917 | 19523.52 | -295.1896 | 23671.35 |
| 1533 | 11688.08 | 3764.103326 | 19612.06 | -430.5977 | 23806.76 |
| 1534 | 11688.08 | 3676.543149 | 19699.62 | -564.5094 | 23940.67 |
| 1535 | 11688.08 | 3589.929649 | 19786.23 | -696.9733 | 24073.14 |
| 1536 | 11688.08 | 3504.232770 | 19871.93 | -828.0354 | 24204.20 |
| 1537 | 11688.08 | 3419.424010 | 19956.74 | -957.7392 | 24333.90 |
| 1538 | 11688.08 | 3335.476317 | 20040.69 | -1086.1261 | 24462.29 |
| 1539 | 11688.08 | 3252.363985 | 20123.80 | -1213.2355 | 24589.40 |
| 1540 | 11688.08 | 3170.062561 | 20206.10 | -1339.1046 | 24715.27 |

| | | | | | |
|---|---|---|---|---|---|
| 1541 | 11688.08 | 3088.548763 | 20287.62 | -1463.7692 | 24839.93 |
| 1542 | 11688.08 | 3007.800402 | 20368.36 | -1587.2632 | 24963.43 |
| 1543 | 11688.08 | 2927.796311 | 20448.37 | -1709.6189 | 25085.78 |
| 1544 | 11688.08 | 2848.516282 | 20527.65 | -1830.8672 | 25207.03 |
| 1545 | 11688.08 | 2769.941004 | 20606.22 | -1951.0378 | 25327.20 |
| 1546 | 11688.08 | 2692.052011 | 20684.11 | -2070.1587 | 25446.32 |
| 1547 | 11688.08 | 2614.831629 | 20761.33 | -2188.2571 | 25564.42 |
| 1548 | 11688.08 | 2538.262929 | 20837.90 | -2305.3588 | 25681.52 |
| 1549 | 11688.08 | 2462.329686 | 20913.83 | -2421.4887 | 25797.65 |
| 1550 | 11688.08 | 2387.016336 | 20989.15 | -2536.6705 | 25912.83 |
| 1551 | 11688.08 | 2312.307940 | 21063.86 | -2650.9271 | 26027.09 |
| 1552 | 11688.08 | 2238.190151 | 21137.97 | -2764.2805 | 26140.44 |
| 1553 | 11688.08 | 2164.649179 | 21211.52 | -2876.7517 | 26252.92 |
| 1554 | 11688.08 | 2091.671763 | 21284.49 | -2988.3610 | 26364.53 |
| 1555 | 11688.08 | 2019.245143 | 21356.92 | -3099.1280 | 26475.29 |
| 1556 | 11688.08 | 1947.357032 | 21428.81 | -3209.0714 | 26585.24 |
| 1557 | 11688.08 | 1875.995594 | 21500.17 | -3318.2093 | 26694.37 |
| 1558 | 11688.08 | 1805.149420 | 21571.01 | -3426.5591 | 26802.72 |
| 1559 | 11688.08 | 1734.807508 | 21641.36 | -3534.1378 | 26910.30 |
| 1560 | 11688.08 | 1664.959240 | 21711.21 | -3640.9615 | 27017.13 |
| 1561 | 11688.08 | 1595.594369 | 21780.57 | -3747.0459 | 27123.21 |
| 1562 | 11688.08 | 1526.702993 | 21849.46 | -3852.4062 | 27228.57 |
| 1563 | 11688.08 | 1458.275547 | 21917.89 | -3957.0570 | 27333.22 |
| 1564 | 11688.08 | 1390.302783 | 21985.86 | -4061.0123 | 27437.18 |
| 1565 | 11688.08 | 1322.775756 | 22053.39 | -4164.2860 | 27540.45 |
| 1566 | 11688.08 | 1255.685809 | 22120.48 | -4266.8912 | 27643.06 |
| 1567 | 11688.08 | 1189.024565 | 22187.14 | -4368.8408 | 27745.01 |
| 1568 | 11688.08 | 1122.783909 | 22253.38 | -4470.1471 | 27846.31 |
| 1569 | 11688.08 | 1056.955978 | 22319.21 | -4570.8223 | 27946.99 |
| 1570 | 11688.08 | 991.533153 | 22384.63 | -4670.8778 | 28047.04 |
| 1571 | 11688.08 | 926.508046 | 22449.66 | -4770.3252 | 28146.49 |
| 1572 | 11688.08 | 861.873490 | 22514.29 | -4869.1752 | 28245.34 |
| 1573 | 11688.08 | 797.622531 | 22578.54 | -4967.4386 | 28343.60 |
| 1574 | 11688.08 | 733.748420 | 22642.42 | -5065.1256 | 28441.29 |
| 1575 | 11688.08 | 670.244602 | 22705.92 | -5162.2463 | 28538.41 |
| 1576 | 11688.08 | 607.104712 | 22769.06 | -5258.8104 | 28634.97 |
| 1577 | 11688.08 | 544.322563 | 22831.84 | -5354.8274 | 28730.99 |
| 1578 | 11688.08 | 481.892142 | 22894.27 | -5450.3065 | 28826.47 |
| 1579 | 11688.08 | 419.807603 | 22956.36 | -5545.2566 | 28921.42 |
| 1580 | 11688.08 | 358.063262 | 23018.10 | -5639.6864 | 29015.85 |
| 1581 | 11688.08 | 296.653584 | 23079.51 | -5733.6044 | 29109.77 |
| 1582 | 11688.08 | 235.573188 | 23140.59 | -5827.0188 | 29203.18 |
| 1583 | 11688.08 | 174.816832 | 23201.35 | -5919.9377 | 29296.10 |
| 1584 | 11688.08 | 114.379413 | 23261.78 | -6012.3687 | 29388.53 |
| 1585 | 11688.08 | 54.255961 | 23321.91 | -6104.3196 | 29480.48 |
| 1586 | 11688.08 | -5.558368 | 23381.72 | -6195.7977 | 29571.96 |
| 1587 | 11688.08 | -65.068292 | 23441.23 | -6286.8103 | 29662.97 |
| 1588 | 11688.08 | -124.278413 | 23500.44 | -6377.3644 | 29753.53 |
| 1589 | 11688.08 | -183.193217 | 23559.36 | -6467.4668 | 29843.63 |
| 1590 | 11688.08 | -241.817078 | 23617.98 | -6557.1243 | 29933.29 |
| 1591 | 11688.08 | -300.154265 | 23676.32 | -6646.3433 | 30022.51 |
| 1592 | 11688.08 | -358.208943 | 23734.37 | -6735.1303 | 30111.29 |
| 1593 | 11688.08 | -415.985177 | 23792.15 | -6823.4914 | 30199.66 |
| 1594 | 11688.08 | -473.486936 | 23849.65 | -6911.4327 | 30287.60 |
| 1595 | 11688.08 | -530.718093 | 23906.88 | -6998.9602 | 30375.12 |
| 1596 | 11688.08 | -587.682435 | 23963.85 | -7086.0797 | 30462.24 |
| 1597 | 11688.08 | -644.383658 | 24020.55 | -7172.7967 | 30548.96 |

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1598        11688.08  -700.825375 24076.99  -7259.1169 30635.28
1599        11688.08  -757.011116 24133.18  -7345.0455 30721.21
1600        11688.08  -812.944335 24189.11  -7430.5880 30806.75
1601        11688.08  -868.628404 24244.79  -7515.7495 30891.91
1602        11688.08  -924.066624 24300.23  -7600.5349 30976.70
1603        11688.08  -979.262222 24355.43  -7684.9493 31061.11
1604        11688.08 -1034.218357 24410.38  -7768.9974 31145.16
1605        11688.08 -1088.938119 24465.10  -7852.6841 31228.85
1606        11688.08 -1143.424531 24519.59  -7936.0139 31312.18
1607        11688.08 -1197.680554 24573.84  -8018.9913 31395.16
1608        11688.08 -1251.709086 24627.87  -8101.6208 31477.79
1609        11688.08 -1305.512964 24681.68  -8183.9067 31560.07
1610        11688.08 -1359.094968 24735.26  -8265.8533 31642.02
1611        11688.08 -1412.457820 24788.62  -8347.4648 31723.63
1612        11688.08 -1465.604187 24841.77  -8428.7451 31804.91
1613        11688.08 -1518.536684 24894.70  -8509.6984 31885.86
1614        11688.08 -1571.257871 24947.42  -8590.3285 31966.49
1615        11688.08 -1623.770258 24999.93  -8670.6393 32046.80
1616        11688.08 -1676.076308 25052.24  -8750.6345 32126.80
1617        11688.08 -1728.178434 25104.34  -8830.3178 32206.48
1618        11688.08 -1780.079002 25156.24  -8909.6929 32285.86
1619        11688.08 -1831.780333 25207.94  -8988.7632 32364.93
1620        11688.08 -1883.284706 25259.45  -9067.5324 32443.70
1621        11688.08 -1934.594352 25310.76  -9146.0037 32522.17
1622        11688.08 -1985.711466 25361.88  -9224.1806 32600.34
1623        11688.08 -2036.638197 25412.80  -9302.0663 32678.23
1624        11688.08 -2087.376658 25463.54  -9379.6641 32755.83
1625        11688.08 -2137.928920 25514.09  -9456.9771 32833.14
1626        11688.08 -2188.297020 25564.46  -9534.0084 32910.17
1627        11688.08 -2238.482955 25614.65  -9610.7612 32986.93
1628        11688.08 -2288.488688 25664.65  -9687.2384 33063.40
1629        11688.08 -2338.316146 25714.48  -9763.4429 33139.61
1630        11688.08 -2387.967221 25764.13  -9839.3777 33215.54
1631        11688.08 -2437.443775 25813.61  -9915.0455 33291.21
1632        11688.08 -2486.747635 25862.91  -9990.4493 33366.61
1633        11688.08 -2535.880595 25912.04 -10065.5916 33441.76
1634        11688.08 -2584.844422 25961.01 -10140.4754 33516.64
1635        11688.08 -2633.640850 26009.81 -10215.1031 33591.27
```

### TABLE 2: ARIMA MODEL RESULT

| Date | Hour | Q10 | Q20 | Q30 | Q40 | Q50 | Q60 | Q70 | Q80 | Q90 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/1/2017 | 1 | -2253.281 | -1189.59 | -422.6 | 232.77 | 845.32 | 1457.88 | 2113.25 | 2880.2 | 3943.9 |
| 3/1/2017 | 2 | -2254.354 | -1190.3 | -423.039 | 232.56 | 845.32 | 1458.09 | 2113.69 | 2880.9 | 3945 |
| 3/1/2017 | 3 | -2255.426 | -1191 | -423.477 | 232.34 | 845.32 | 1458.31 | 2114.13 | 2881.7 | 3946.1 |
| 3/1/2017 | 4 | -2256.497 | -1191.71 | -423.916 | 232.13 | 845.32 | 1458.52 | 2114.57 | 2882.4 | 3947.1 |
| 3/1/2017 | 5 | -2257.569 | -1192.41 | -424.354 | 231.92 | 845.32 | 1458.73 | 2115 | 2883.1 | 3948.2 |
| 3/1/2017 | 6 | -2258.64 | -1193.11 | -424.792 | 231.71 | 845.32 | 1458.94 | 2115.44 | 2883.8 | 3949.3 |
| 3/1/2017 | 7 | -2259.71 | -1193.82 | -425.23 | 231.5 | 845.32 | 1459.15 | 2115.88 | 2884.5 | 3950.4 |
| 3/1/2017 | 8 | -2260.781 | -1194.52 | -425.668 | 231.29 | 845.32 | 1459.36 | 2116.32 | 2885.2 | 3951.4 |
| 3/1/2017 | 9 | -2261.85 | -1195.22 | -426.106 | 231.07 | 845.32 | 1459.58 | 2116.76 | 2885.9 | 3952.5 |
| 3/1/2017 | 10 | -2262.92 | -1195.92 | -426.544 | 230.86 | 845.32 | 1459.79 | 2117.19 | 2886.6 | 3953.6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/1/2017 | 11 | -2263.989 | -1196.63 | -426.981 | 230.65 | 845.32 | 1460 | 2117.63 | 2887.3 | 3954.6 |
| 3/1/2017 | 12 | -2265.058 | -1197.33 | -427.419 | 230.44 | 845.32 | 1460.21 | 2118.07 | 2888 | 3955.7 |
| 3/1/2017 | 13 | -2266.126 | -1198.03 | -427.856 | 230.23 | 845.32 | 1460.42 | 2118.51 | 2888.7 | 3956.8 |
| 3/1/2017 | 14 | -2267.194 | -1198.73 | -428.293 | 230.02 | 845.32 | 1460.63 | 2118.94 | 2889.4 | 3957.8 |
| 3/1/2017 | 15 | -2268.262 | -1199.43 | -428.73 | 229.81 | 845.32 | 1460.84 | 2119.38 | 2890.1 | 3958.9 |
| 3/1/2017 | 16 | -2269.329 | -1200.13 | -429.166 | 229.6 | 845.32 | 1461.05 | 2119.82 | 2890.8 | 3960 |
| 3/1/2017 | 17 | -2270.396 | -1200.83 | -429.603 | 229.38 | 845.32 | 1461.26 | 2120.25 | 2891.5 | 3961 |
| 3/1/2017 | 18 | -2271.463 | -1201.53 | -430.039 | 229.17 | 845.32 | 1461.48 | 2120.69 | 2892.2 | 3962.1 |
| 3/1/2017 | 19 | -2272.529 | -1202.23 | -430.476 | 228.96 | 845.32 | 1461.69 | 2121.13 | 2892.9 | 3963.2 |
| 3/1/2017 | 20 | -2273.595 | -1202.93 | -430.912 | 228.75 | 845.32 | 1461.9 | 2121.56 | 2893.6 | 3964.2 |
| 3/1/2017 | 21 | -2274.66 | -1203.63 | -431.348 | 228.54 | 845.32 | 1462.11 | 2122 | 2894.3 | 3965.3 |
| 3/1/2017 | 22 | -2275.725 | -1204.33 | -431.784 | 228.33 | 845.32 | 1462.32 | 2122.43 | 2895 | 3966.4 |
| 3/1/2017 | 23 | -2276.79 | -1205.03 | -432.219 | 228.12 | 845.32 | 1462.53 | 2122.87 | 2895.7 | 3967.4 |
| 3/1/2017 | 24 | -2277.855 | -1205.73 | -432.655 | 227.91 | 845.32 | 1462.74 | 2123.3 | 2896.4 | 3968.5 |
| 3/2/2017 | 1 | -2278.919 | -1206.43 | -433.09 | 227.7 | 845.32 | 1462.95 | 2123.74 | 2897.1 | 3969.6 |
| 3/2/2017 | 2 | -2279.982 | -1207.13 | -433.526 | 227.49 | 845.32 | 1463.16 | 2124.17 | 2897.8 | 3970.6 |
| 3/2/2017 | 3 | -2281.046 | -1207.83 | -433.961 | 227.28 | 845.32 | 1463.37 | 2124.61 | 2898.5 | 3971.7 |
| 3/2/2017 | 4 | -2282.108 | -1208.52 | -434.396 | 227.07 | 845.32 | 1463.58 | 2125.04 | 2899.2 | 3972.8 |
| 3/2/2017 | 5 | -2283.171 | -1209.22 | -434.83 | 226.86 | 845.32 | 1463.79 | 2125.48 | 2899.9 | 3973.8 |
| 3/2/2017 | 6 | -2284.233 | -1209.92 | -435.265 | 226.65 | 845.32 | 1464 | 2125.91 | 2900.6 | 3974.9 |
| 3/2/2017 | 7 | -2285.295 | -1210.62 | -435.7 | 226.44 | 845.32 | 1464.21 | 2126.35 | 2901.3 | 3975.9 |
| 3/2/2017 | 8 | -2286.357 | -1211.31 | -436.134 | 226.23 | 845.32 | 1464.42 | 2126.78 | 2902 | 3977 |
| 3/2/2017 | 9 | -2287.418 | -1212.01 | -436.568 | 226.02 | 845.32 | 1464.63 | 2127.22 | 2902.7 | 3978.1 |
| 3/2/2017 | 10 | -2288.479 | -1212.71 | -437.002 | 225.81 | 845.32 | 1464.84 | 2127.65 | 2903.4 | 3979.1 |
| 3/2/2017 | 11 | -2289.539 | -1213.4 | -437.436 | 225.6 | 845.32 | 1465.05 | 2128.09 | 2904.1 | 3980.2 |
| 3/2/2017 | 12 | -2290.599 | -1214.1 | -437.87 | 225.39 | 845.32 | 1465.26 | 2128.52 | 2904.8 | 3981.2 |
| 3/2/2017 | 13 | -2291.659 | -1214.8 | -438.304 | 225.18 | 845.32 | 1465.47 | 2128.95 | 2905.4 | 3982.3 |
| 3/2/2017 | 14 | -2292.718 | -1215.49 | -438.737 | 224.97 | 845.32 | 1465.68 | 2129.39 | 2906.1 | 3983.4 |
| 3/2/2017 | 15 | -2293.777 | -1216.19 | -439.17 | 224.76 | 845.32 | 1465.89 | 2129.82 | 2906.8 | 3984.4 |
| 3/2/2017 | 16 | -2294.836 | -1216.88 | -439.603 | 224.55 | 845.32 | 1466.1 | 2130.25 | 2907.5 | 3985.5 |
| 3/2/2017 | 17 | -2295.894 | -1217.58 | -440.037 | 224.34 | 845.32 | 1466.31 | 2130.69 | 2908.2 | 3986.5 |
| 3/2/2017 | 18 | -2296.952 | -1218.27 | -440.469 | 224.13 | 845.32 | 1466.51 | 2131.12 | 2908.9 | 3987.6 |
| 3/2/2017 | 19 | -2298.009 | -1218.97 | -440.902 | 223.93 | 845.32 | 1466.72 | 2131.55 | 2909.6 | 3988.7 |
| 3/2/2017 | 20 | -2299.067 | -1219.66 | -441.335 | 223.72 | 845.32 | 1466.93 | 2131.98 | 2910.3 | 3989.7 |
| 3/2/2017 | 21 | -2300.123 | -1220.36 | -441.767 | 223.51 | 845.32 | 1467.14 | 2132.42 | 2911 | 3990.8 |
| 3/2/2017 | 22 | -2301.18 | -1221.05 | -442.2 | 223.3 | 845.32 | 1467.35 | 2132.85 | 2911.7 | 3991.8 |
| 3/2/2017 | 23 | -2302.236 | -1221.74 | -442.632 | 223.09 | 845.32 | 1467.56 | 2133.28 | 2912.4 | 3992.9 |
| 3/2/2017 | 24 | -2303.292 | -1222.44 | -443.064 | 222.88 | 845.32 | 1467.77 | 2133.71 | 2913.1 | 3993.9 |
| 3/3/2017 | 1 | -2304.347 | -1223.13 | -443.496 | 222.67 | 845.32 | 1467.98 | 2134.14 | 2913.8 | 3995 |
| 3/3/2017 | 2 | -2305.402 | -1223.82 | -443.927 | 222.46 | 845.32 | 1468.18 | 2134.58 | 2914.5 | 3996.1 |
| 3/3/2017 | 3 | -2306.457 | -1224.52 | -444.359 | 222.26 | 845.32 | 1468.39 | 2135.01 | 2915.2 | 3997.1 |
| 3/3/2017 | 4 | -2307.512 | -1225.21 | -444.79 | 222.05 | 845.32 | 1468.6 | 2135.44 | 2915.9 | 3998.2 |
| 3/3/2017 | 5 | -2308.566 | -1225.9 | -445.222 | 221.84 | 845.32 | 1468.81 | 2135.87 | 2916.5 | 3999.2 |
| 3/3/2017 | 6 | -2309.619 | -1226.59 | -445.653 | 221.63 | 845.32 | 1469.02 | 2136.3 | 2917.2 | 4000.3 |
| 3/3/2017 | 7 | -2310.673 | -1227.28 | -446.084 | 221.42 | 845.32 | 1469.23 | 2136.73 | 2917.9 | 4001.3 |
| 3/3/2017 | 8 | -2311.726 | -1227.98 | -446.515 | 221.21 | 845.32 | 1469.43 | 2137.16 | 2918.6 | 4002.4 |
| 3/3/2017 | 9 | -2312.778 | -1228.67 | -446.945 | 221.01 | 845.32 | 1469.64 | 2137.59 | 2919.3 | 4003.4 |
| 3/3/2017 | 10 | -2313.83 | -1229.36 | -447.376 | 220.8 | 845.32 | 1469.85 | 2138.03 | 2920 | 4004.5 |
| 3/3/2017 | 11 | -2314.882 | -1230.05 | -447.806 | 220.59 | 845.32 | 1470.06 | 2138.46 | 2920.7 | 4005.5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/3/2017 | 12 | -2315.934 | -1230.74 | -448.237 | 220.38 | 845.32 | 1470.27 | 2138.89 | 2921.4 | 4006.6 |
| 3/3/2017 | 13 | -2316.985 | -1231.43 | -448.667 | 220.17 | 845.32 | 1470.47 | 2139.32 | 2922.1 | 4007.6 |
| 3/3/2017 | 14 | -2318.036 | -1232.12 | -449.097 | 219.97 | 845.32 | 1470.68 | 2139.75 | 2922.8 | 4008.7 |
| 3/3/2017 | 15 | -2319.086 | -1232.81 | -449.527 | 219.76 | 845.32 | 1470.89 | 2140.18 | 2923.5 | 4009.7 |

### TABLE 3 : FINAL DATA FOR APRIL 2017

D5-Apeksha Gupta.xls

March 2017

D6-Apeksha Gupta.xls

April 2017