SV2414 and vrp2113 Energy Storage Options in Sao Vicente Note: This RMD contains setpoint calculation, along with question 5 of 'Storage Capacity Effects on Capacity Factor' section (which uses setpoints).

```
## Loading required package: plyr
## Loading required package: ggplot2
```

REFINING SYSTEM SETPOINTS

1. Propose a reasonable set of setpoints for wind farm generation and baseload generation. How do these values affect the curtailment and capacity factor?

```
#Average demand in the evenings
avgeved=summary(ad$demand[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=17 & (as.POSIXlt
(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=21])[4]
#Average demand in the day
avgdayd=summary(ad$demand[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=6 & (as.POSIXlt(
ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=16])[4]
#Average demand at late nights
avglnd=summary(ad$demand[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=22 | (as.POSIXlt(
ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=05])[4]

#Average windgen in the evenings
avgevegen=summary(ad$windgen[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=17 & (as.POSI
Xlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=21])[4]
#Average windgen in the day
avgdaygen=summary(ad$windgen[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=6 & (as.POSIX
lt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=16])[4]
#Average windgen at late nights
avglngen=summary(ad$windgen[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=22 | (as.POSIX
lt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=05])[4]

#Average deficit in the evenings, day and late nights
avgevedef=avgeved-avgevegen
avgdaydef=avgdayd-avgdaygen
avglndef=avglnd-avglngen

#Assign setpoints for baseload
for (i in 1:nrow(ad)){
  if((as.POSIXlt(ad$datetime[i],format="%Y-%m-%d %H:%M:%S"))$hour>=17 & (as.POSIXlt(ad$datetime[i],fo
rmat="%Y-%m-%d %H:%M:%S"))$hour<=21){
    ad$blsp[i]=avgevedef
    }
  if((as.POSIXlt(ad$datetime[i],format="%Y-%m-%d %H:%M:%S"))$hour>=6 & (as.POSIXlt(ad$datetime[i],for
mat="%Y-%m-%d %H:%M:%S"))$hour<=16){
    ad$blsp[i]=avgdaydef
    }
```

```
  if((as.POSIXlt(ad$datetime[i],format="%Y-%m-%d %H:%M:%S"))$hour>=22 | (as.POSIXlt(ad$datetime[i],fo
rmat="%Y-%m-%d %H:%M:%S"))$hour<=05){
    ad$blsp[i]=avglndef
  }
  #Find gap to be filled above baseload
  ad$gap[i]=max(ad$demand[i]-ad$blsp[i],0.0)
}

#Find average gap to be filled in evenings, days and late nights, and take appropriate fraction
avgevegap=0.76*summary(ad$gap[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=17 & (as.POS
IXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=21])[4]
avgdaygap=0.76*summary(ad$gap[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=6 & (as.POSI
Xlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=16])[4]
avglngap=0.76*summary(ad$gap[(as.POSIXlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour>=22 | (as.POSI
Xlt(ad$datetime,format="%Y-%m-%d %H:%M:%S"))$hour<=05])[4]

#Calculate setpoints for generation
for (i in 1:nrow(ad)){
   if((as.POSIXlt(ad$datetime[i],format="%Y-%m-%d %H:%M:%S"))$hour>=17 & (as.POSIXlt(ad$datetime[i],f
ormat="%Y-%m-%d %H:%M:%S"))$hour<=21){
    ad$gensp[i]=avgevegap
    }
  if((as.POSIXlt(ad$datetime[i],format="%Y-%m-%d %H:%M:%S"))$hour>=6 & (as.POSIXlt(ad$datetime[i],for
mat="%Y-%m-%d %H:%M:%S"))$hour<=16){
    ad$gensp[i]=avgdaygap
    }
  if((as.POSIXlt(ad$datetime[i],format="%Y-%m-%d %H:%M:%S"))$hour>=22 | (as.POSIXlt(ad$datetime[i],fo
rmat="%Y-%m-%d %H:%M:%S"))$hour<=05){
    ad$gensp[i]=avglngap
  }
  #Update generation values based on the setpoints
  ad$newwindgen[i]=min(ad$windgen[i],ad$gensp[i])
  #Find total supply
  ad$totalsupply[i]=ad$newwindgen[i]+ad$blsp[i]
  #Find total delivered power
  ad$sputilized[i]=min(ad$demand[i],ad$totalsupply[i])
}

#Calculate curtailment
ad$spcurtailment=ad$totalsupply-ad$sputilized
#Calculate deficit
ad$spdeficit=ad$demand-ad$sputilized

#Print curtailment
sprintf("The total curtailment over the year, using setpoints, is %.2f kWh",sum(ad$spcurtailment))
```

```
## [1] "The total curtailment over the year, using setpoints, is 1282269.17 kWh"
```

```
#Calculate curtailed capacity factor
sum=0.0
for (i in 1:nrow(ad)){
sum=sum+max(ad$sputilized[i]-ad$blsp[i],0.0)
}
cf_c_sp=sum*100/(850*8760*7)
sprintf("Using setpoints for baseload and wind generation, curtailed CF is %.2f percent",cf_c_sp)
```

```
## [1] "Using setpoints for baseload and wind generation, curtailed CF is 28.92 percent"
```

STORAGE CAPACITY EFFECTS ON CAPACITY FACTOR

5. Finally, perform the same calculations for your proposed storage capacity and set point values. How much additional energy is now recoverable via storage?

```
#Calculate state of  storage at each hour
ad$storage[1]=min(0.8*ad$spcurtailment[1],10000.0)
for (i in 2:nrow(ad)){
  if (ad$spdeficit[i]==0){
    ad$storage[i]=min((ad$storage[i-1]+0.8*ad$spcurtailment[i]),10000.0)
    }
  #With deficit
  else if (ad$spcurtailment[i]==0){
    ad$storage[i]=max(ad$storage[i-1]-((ad$spdeficit[i])/0.8),0.0)
    }
}

#Calculate net WE used in each hour
ad$we_used[1]=max(ad$sputilized[1]-ad$blsp[1],0.0)
#Find total wind energy supplied (including from storage) at each hour
for (i in 2:nrow(ad)){
  if (ad$spdeficit[i]==0){
    ad$we_used[i]=max(ad$sputilized[i]-ad$blsp[i],0.0)
    }
  else if (ad$spcurtailment[i]==0){
  ad$we_used[i]=max(ad$sputilized[i]-ad$blsp[i],0.0)+(ad$storage[i-1]-ad$storage[i])*0.8
  }
}


#Print previous useful WE
sprintf("Without storage, net useful wind energy is %.2f kWh",sum)
```

```
## [1] "Without storage, net useful wind energy is 15075644.35 kWh"
```

```
#Print new useful WE
sprintf("With storage, net useful wind energy is % .2fkWh",sum(ad$we_used))
```

```
## [1] "With storage, net useful wind energy is  15729264.50kWh"
```

```
#Print additional useful WE
sprintf("Therefore additional useful wind energy recoverable from storage is %.2f kWh",sum(ad$we_used
)-sum)
```

```
## [1] "Therefore additional useful wind energy recoverable from storage is 653620.15 kWh"
```

```
#Print fraction of previous curtailment saved
sprintf("This is %.2f percent of the curtailment that would have occured without storage, %.2f kWh",(
sum(ad$we_used)-sum)*100/sum(ad$spcurtailment),sum(ad$spcurtailment))
```

```
## [1] "This is 50.97 percent of the curtailment that would have occured without storage, 1282269.17
kWh"
```

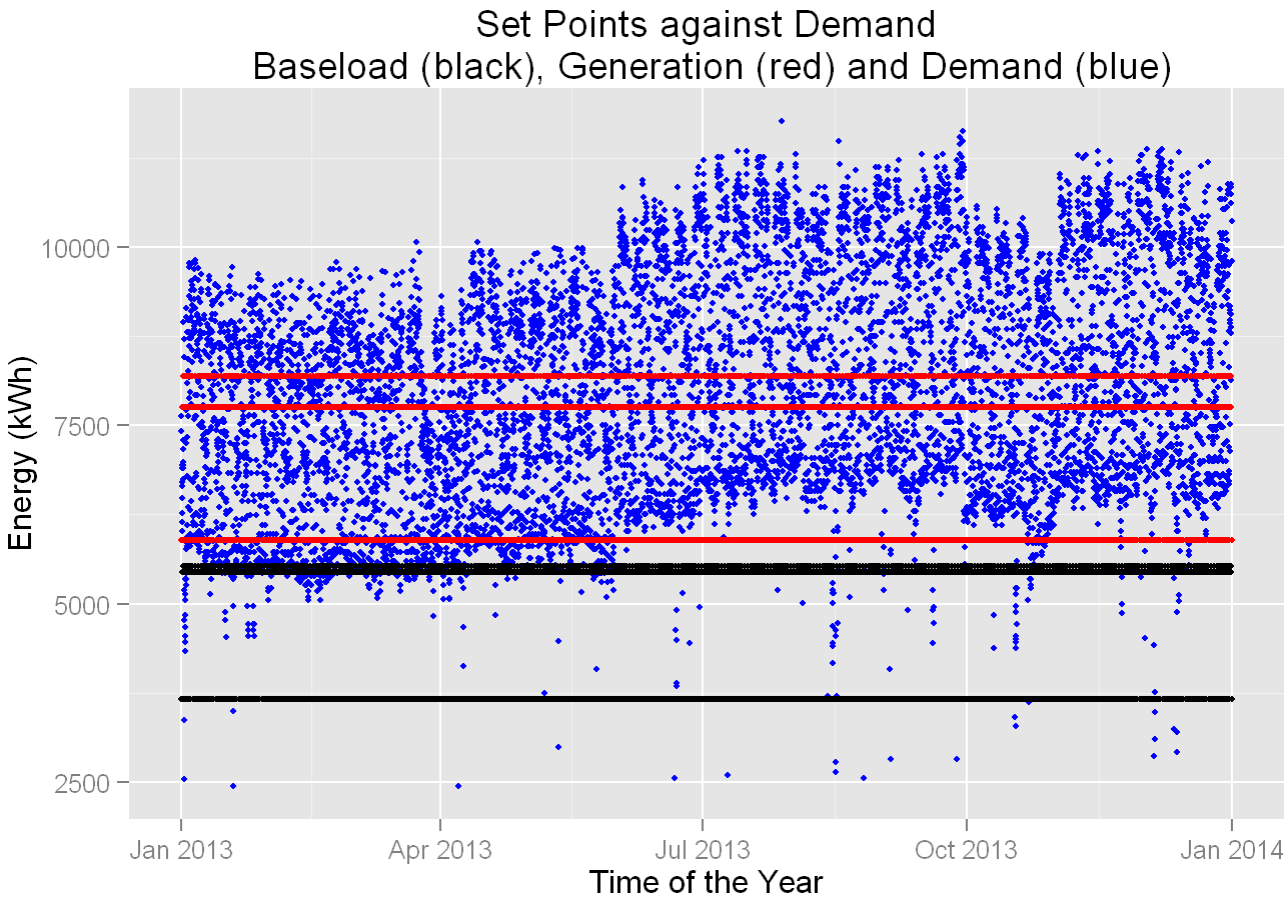
```
#Print fraction of previous unmet demand now met
sprintf("Therefore, %.2f kWh (%.2f percent) of non-baseload energy not met by the wind farm earlier,
%.2f kWh, can be met by adding storage",sum(ad$we_used)-sum,(sum(ad$we_used)-sum)*100/sum(ad$spdefici
t),sum(ad$spdeficit))
```

```
## [1] "Therefore, 653620.15 kWh (5.39 percent) of non-baseload energy not met by the wind farm earli
er, 12135497.65 kWh, can be met by adding storage"
```

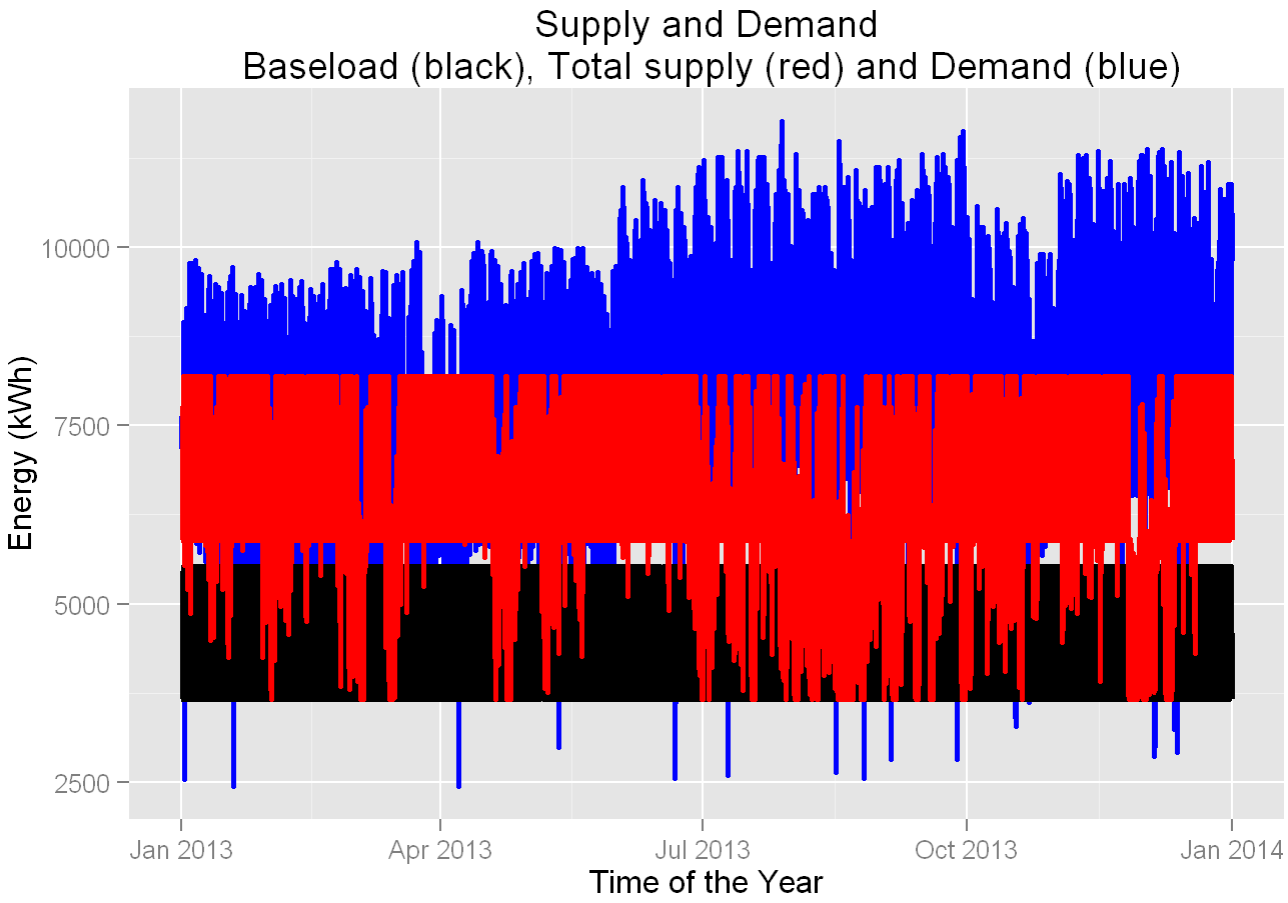
```
#Print new capacity factor
cf_c_bl_st_sp=sum(ad$we_used)*100/(850*8760*7)
sprintf("Capacity factor with storage is %.2f percent",cf_c_bl_st_sp)
```

```
## [1] "Capacity factor with storage is 30.18 percent"
```

```
plot3<-ggplot(ad, aes(x=ad$datetime))
plot3+geom_point(aes(y=ad$demand),colour="blue",size=1)+geom_point(aes(y=ad$blsp),colour="black",size
=1)+geom_point(aes(y=ad$blsp+ad$gensp),colour="red",size=1)+ylab("Energy (kWh)")+xlab("Time of the Ye
ar")+ggtitle("Set Points against Demand\n Baseload (black), Generation (red) and Demand (blue)")
```




```
plot4<-ggplot(ad, aes(x=ad$datetime))
plot4+geom_line(aes(y=ad$demand),colour="blue",size=1)+geom_line(aes(y=ad$blsp),colour="black",size=1
)+geom_line(aes(y=ad$totalsupply),colour="red",size=1)+ylab("Energy (kWh)")+xlab("Time of the Year")+
ggtitle("Supply and Demand\n Baseload (black), Total supply (red) and Demand (blue)")
```


Supply and Demand
Baseload (black), Total supply (red) and Demand (blue)
Energy (kWh)
10000
7500
5000
2500
Jan 2013
Apr 2013
Jul 2013
Oct 2013
Jan 2014
Time of the Year