

# ENERGY CONSUMPTION PREDICTION

Rebeca Estrada, Víctor Asanza, Danny Torres, Adrian Bazuerto, Irving Valeriano

- Main Code: <https://github.com/vasanza/EnergyConsumptionPrediction>
- SRC: [https://github.com/vasanza/Matlab\\_Code](https://github.com/vasanza/Matlab_Code)
- DataPort: <https://dx.doi.org/10.21227/x6jw-m015>
- Reference: [10.1109/SAS51076.2021.9530151](https://doi.org/10.1109/SAS51076.2021.9530151)
- Sampling Rate=1Hz
- Date = '2021-05-06 00:00:00' AND '2021-11-22 22:04:21'



## 1- Load Raw Data

```
clear;clc;%clear all
%Prepare the raw dataset
addpath(genpath('./src'))%functions folders
datapath = fullfile('./data/');%data folder
filenames = FindCSV(datapath);%List All CSV files
allData=[];
for i=1:length(filenames)% Through all files
    data=readtable(fullfile(datapath,filenames(i).name));%Select i CSV file
    %The first 3 columns are deleted: topic, server date, esp32 date, and esp32 date.
    data=[data(:,2) data(:,5:end)];
    dataNew=table2array(data);% Array Double
    dataNew(isnan(dataNew)) = 0;%Remove NAN numbers
    allData=[allData;dataNew];
end
clear data dataNew;
```

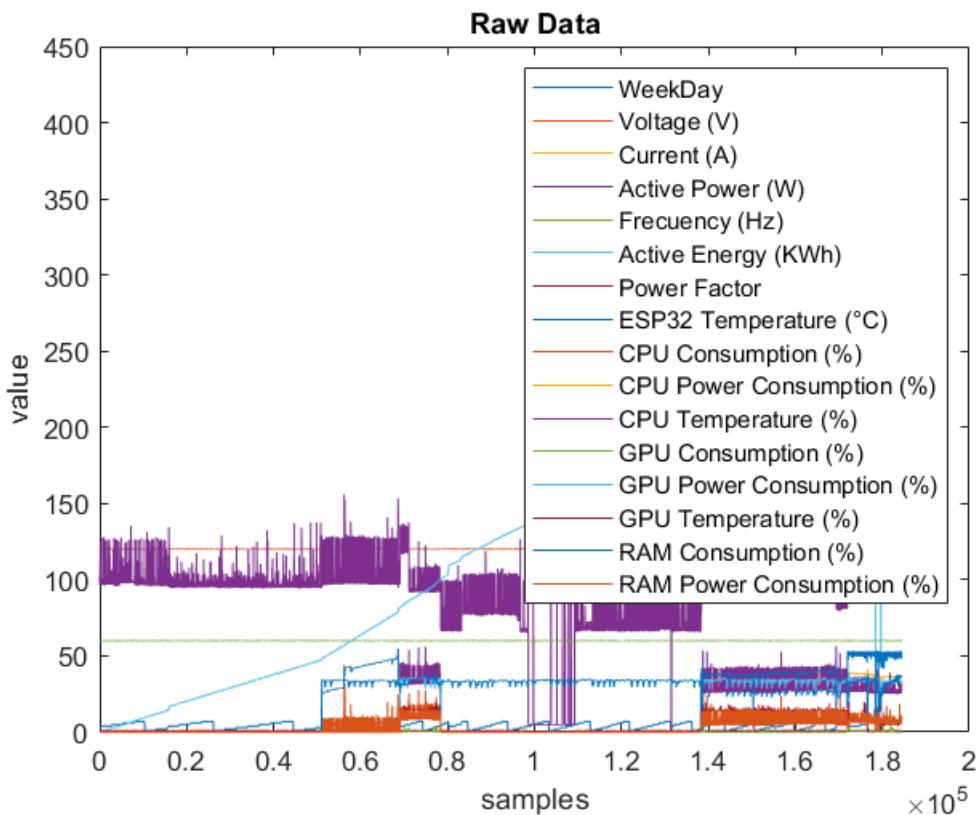
## 2- Every 60 samples the value of 1 minute is averaged

```
win=60;% 1 minute
```

```
%It takes time to iterate the number of samples / time window.
allDataMean = fData_MeanWin(allData,win);
%save(fullfile(datapath,'allData.mat'),'allData');%No es posible para datos
%mayores a 2GB
save(fullfile(datapath,'allDataMean.mat'),'allDataMean');
clear allData win
```

### 3- Plot Raw Data (Dataset)

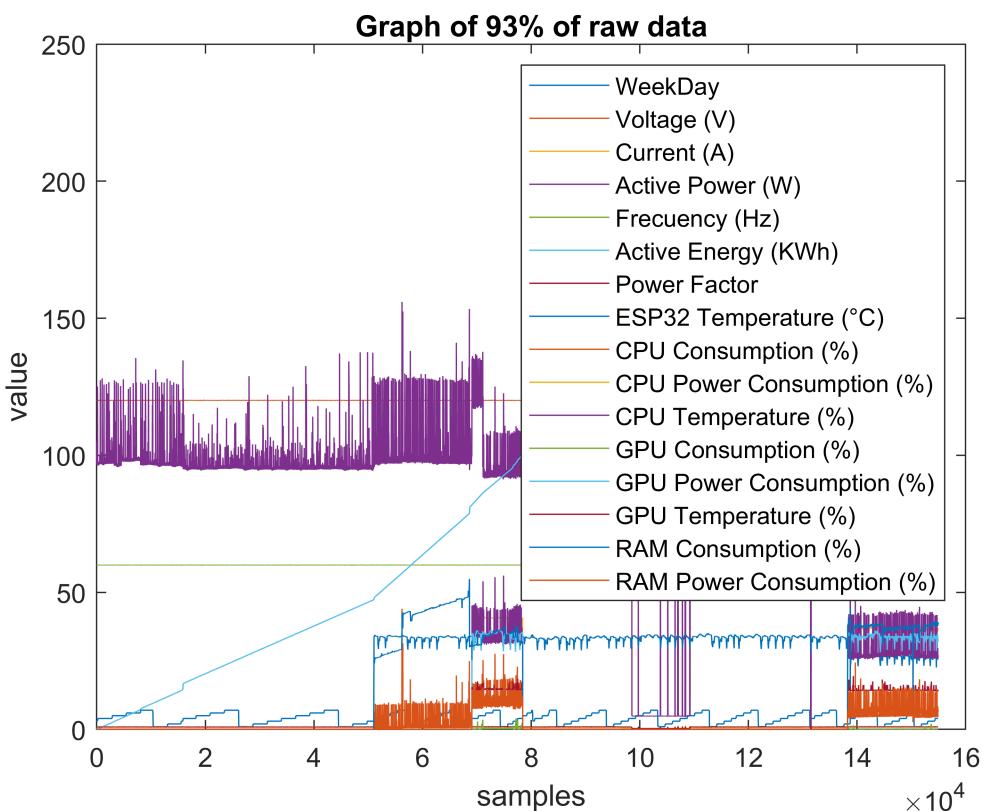
```
figure
plot(allDataMean);title('Raw Data');xlabel('samples');ylabel('value');
legend('WeekDay','Voltage (V)', 'Current (A)', 'Active Power (W)', 'Frecuency (Hz)', 'Active Energy (KWh)', 'Power Factor', 'ESP32 Temperature (°C)', 'CPU Consumption (%)', 'CPU Power Consumption (%)', 'CPU Temperature (%)', 'GPU Consumption (%)', 'GPU Power Consumption (%)', 'GPU Temperature (%)', 'RAM Consumption (%)', 'RAM Power Consumption (%)')
```



### [4] - Feature Extraction (Please set TimeStep per time window)

```
clear;clc;%clear all
%Prepare the raw dataset
addpath(genpath('./src'))%functions folders
datapath = fullfile('./data/');%data folder
allDataMean = load(fullfile(datapath,'allDataMean.mat'));%List All CSV files
allDataMean=allDataMean.allDataMean;
allDataMean=allDataMean(1:round(size(allDataMean,1)*.84),:);%Eliminates the final 16% with noise
figure
plot(allDataMean);title('Graph of 93% of raw data');xlabel('samples');ylabel('value');
```

```
legend('WeekDay','Voltage (V)', 'Current (A)', 'Active Power (W)', 'Frecuency (Hz)', 'Active Energy (KWh)', 'Power Factor', 'ESP32 Temperature (°C)', 'CPU Consumption (%)', 'CPU Power Consumption (%)', 'GPU Consumption (%)', 'GPU Power Consumption (%)', 'GPU Temperature (%)', 'RAM Consumption (%)', 'RAM Power Consumption (%)')
```



```
AEds = datastats(allDataMean(:,6))%Active Energy Statistics with cumulative values
```

```
AEds = struct with fields:
  num: 154918
  max: 222.2872
  min: 0.0062
  mean: 97.2140
  median: 97.7100
  range: 222.2810
  std: 63.5079
```

```
%<----- Please select only one TimeStep
n = input(['Please select only one number (minute = 1, ' ...
  ' hour = 2, day = 3, week = 4, month = 5),: '']);

switch n
  case 1
    Timestep = 1;% one minute
    disp('Timestep selected is minute')
  case 2
    Timestep = 60;% one hour in minutes
    disp('Timestep selected is hour')
  case 3
    Timestep = 1440;% one day in minutes (ok)
    disp('Timestep selected is day')
  case 4
```

```

TimeStep =10080;% one week in minutes (ok)
disp('TimeStep selected is week')
case 5
TimeStep =40320;% one month in minutes (only 8 monthss) (ok)
disp('TimeStep selected is month')
otherwise
disp('other value')
end

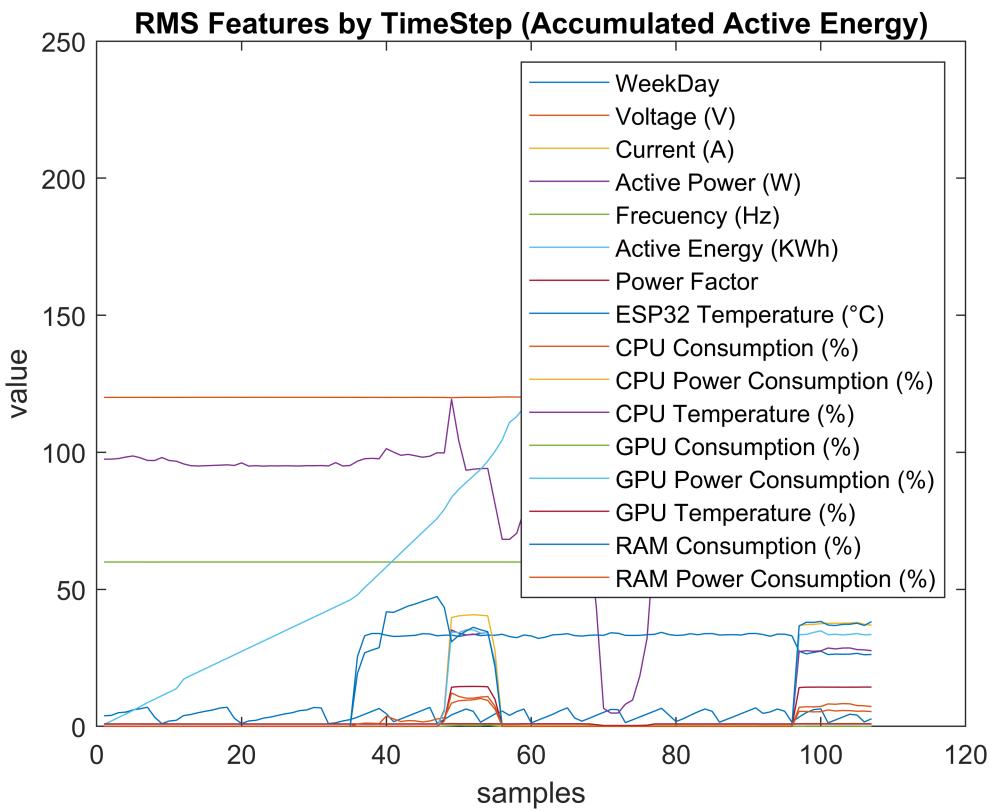
```

TimeStep selected is day

```

figure; DataFeatures = frms_features_v2(allDataMean,TimeStep);
plot(DataFeatures);title('RMS Features by TimeStep (Accumulated Active Energy)');xlabel('samples');
legend('WeekDay','Voltage (V)', 'Current (A)', 'Active Power (W)', 'Frecuency (Hz)', 'Active Energy (KWh)', 'Power Factor', 'ESP32 Temperature (°C)', 'CPU Consumption (%)', 'CPU Power Consumption (%)', 'GPU Consumption (%)', 'GPU Power Consumption (%)', 'GPU Temperature (%)', 'RAM Consumption (%)', 'RAM Power Consumption (%)');

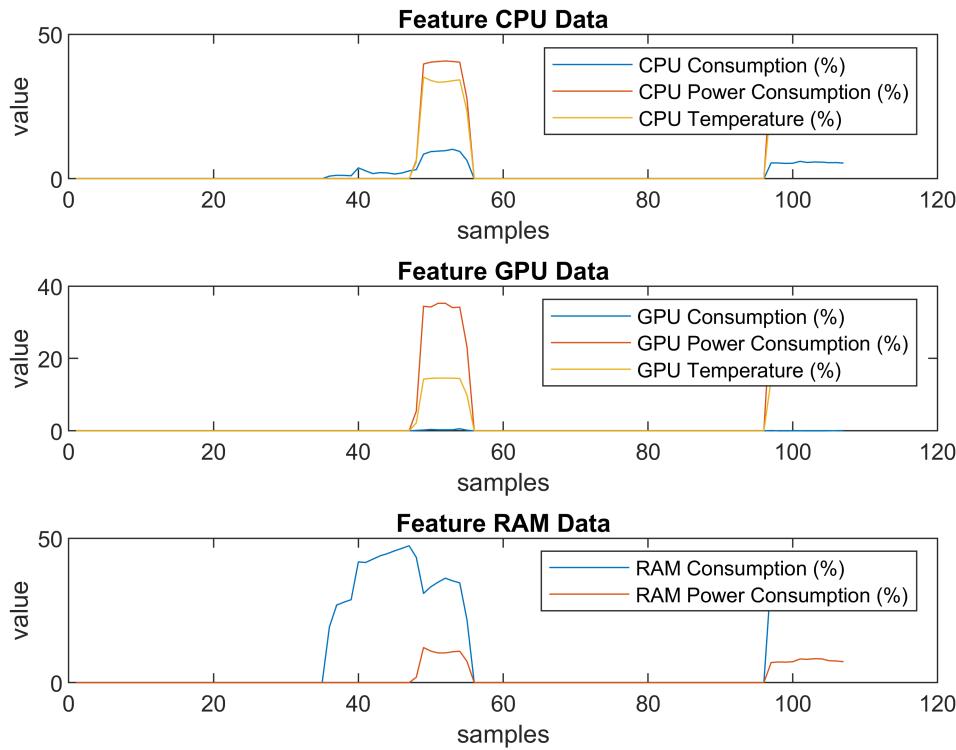
```



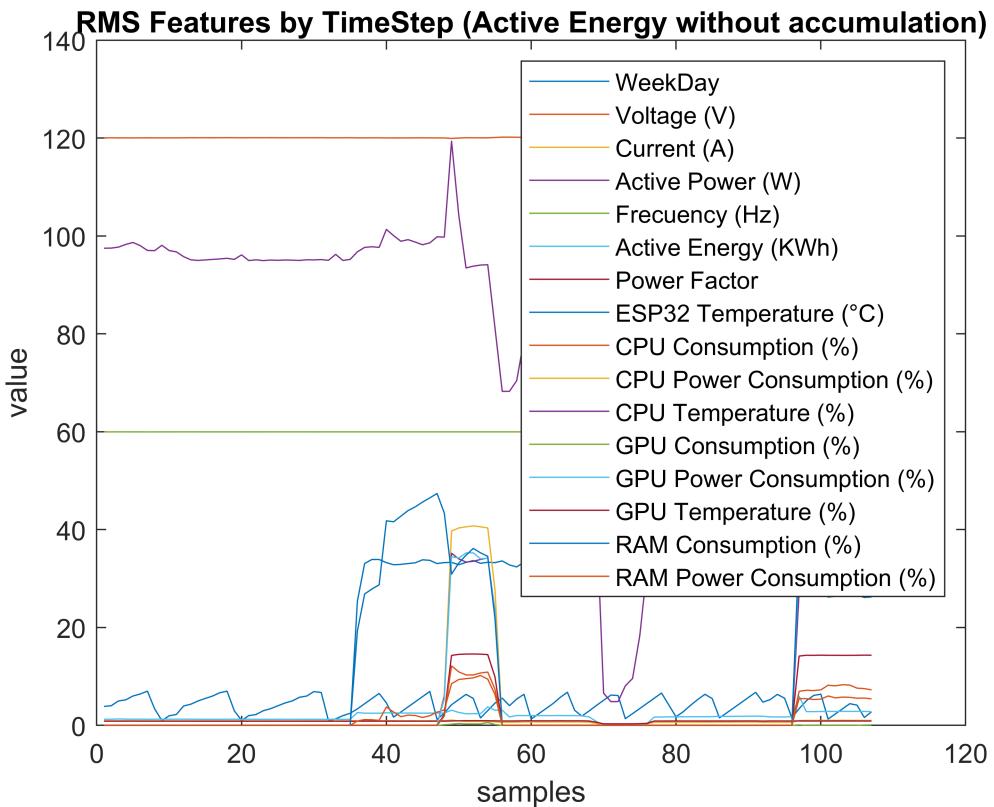
```

figure; subplot(3,1,1)
plot(DataFeatures(:,9:11));title('Feature CPU Data');xlabel('samples');ylabel('value');
legend('CPU Consumption (%)', 'CPU Power Consumption (%)', 'CPU Temperature (%)');
subplot(3,1,2)
plot(DataFeatures(:,12:14));title('Feature GPU Data');xlabel('samples');ylabel('value');
legend('GPU Consumption (%)', 'GPU Power Consumption (%)', 'GPU Temperature (%)');
subplot(3,1,3)
plot(DataFeatures(:,15:16));title('Feature RAM Data');xlabel('samples');ylabel('value');
legend('RAM Consumption (%)', 'RAM Power Consumption (%)');

```



```
figure; DataFeatures(:,6)= fmax_features(allDataMean(:,6),TimeStep);
DataFeatures(:,6)=hampel(DataFeatures(:,6));
plot(DataFeatures);title('RMS Features by TimeStep (Active Energy without accumulation)'); xlabel('TimeStep');
legend('WeekDay','Voltage (V)', 'Current (A)', 'Active Power (W)', 'Frequency (Hz)', 'Active Energy (Wh)', 'Power Factor', 'ESP32 Temperature (°C)', 'CPU Consumption (%)', 'CPU Power Consumption (%)', 'GPU Consumption (%)', 'GPU Power Consumption (%)', 'GPU Temperature (%)', 'RAM Consumption (%)');
```

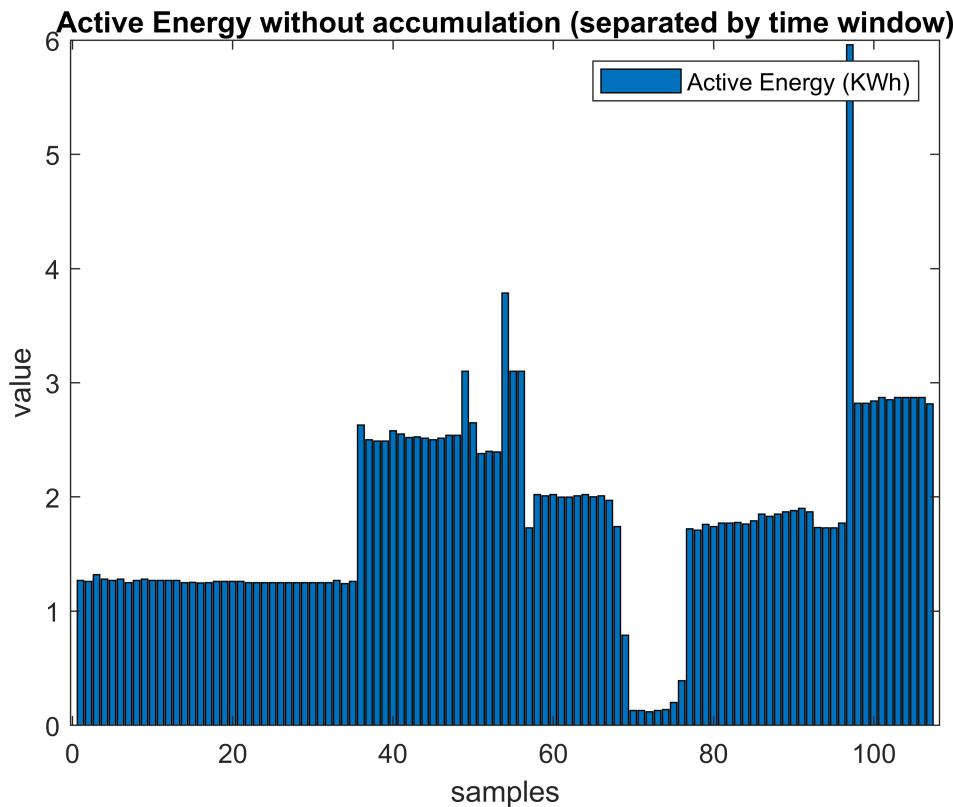


```
AEds = datastats(DataFeatures(:,6))%Active Energy (KWh), without accumulation (separated by time window)
```

```
AEds = struct with fields:
```

```
num: 107
max: 5.9600
min: 0.1200
mean: 1.8294
median: 1.7700
range: 5.8400
std: 0.8477
```

```
figure; bar(DataFeatures(:,6));title('Active Energy without accumulation (separated by time window)'); legend('Active Energy (KWh)');
```



```
clear allDataMean TimeStep
```

## 5- Statital Features Information

```
%'WeekDay', 'Voltage (V)'
[wds,vds] = datastats(DataFeatures(:,1),DataFeatures(:,2))
```

```
wds = struct with fields:
  num: 107
  max: 7
  min: 1
  mean: 4.1818
  median: 4.3336
  range: 6
  std: 1.7573
vds = struct with fields:
  num: 107
  max: 120.4916
  min: 119.9211
  mean: 120.0953
  median: 120.0544
  range: 0.5704
  std: 0.1254
```

```
%'Current (A)', 'Active Power (W)'
[cds,pds] = datastats(DataFeatures(:,3),DataFeatures(:,4))
```

```
cds = struct with fields:
  num: 107
  max: 1.0957
  min: 0.1300
```

```

    mean: 0.7993
    median: 0.9232
    range: 0.9657
    std: 0.2216
pds = struct with fields:
    num: 107
    max: 119.3349
    min: 4.8674
    mean: 84.6613
    median: 95.0447
    range: 114.4675
    std: 24.0662

```

```
%'Frecuency (Hz)', 'Active Energy (KWh)'
[fdss,eds] = datastats(DataFeatures(:,5),DataFeatures(:,6))
```

```

fds = struct with fields:
    num: 107
    max: 59.9695
    min: 59.9599
    mean: 59.9648
    median: 59.9647
    range: 0.0097
    std: 0.0021
eds = struct with fields:
    num: 107
    max: 5.9600
    min: 0.1200
    mean: 1.8294
    median: 1.7700
    range: 5.8400
    std: 0.8477

```

```
%'Power Factor', 'ESP32 Temperature (°C)'
[pfds,tds] = datastats(DataFeatures(:,7),DataFeatures(:,8))
```

```

pfds = struct with fields:
    num: 107
    max: 0.9620
    min: 0.3201
    mean: 0.8507
    median: 0.8687
    range: 0.6418
    std: 0.1406
tds = struct with fields:
    num: 107
    max: 34.3069
    min: 0
    mean: 21.6780
    median: 32.8821
    range: 34.3069
    std: 15.3350

```

```
%'CPU Consumption (%)', 'CPU Power Consumption (%)'
[cpuds, cpupds] = datastats(DataFeatures(:,9),DataFeatures(:,10))
```

```

cpuds = struct with fields:
    num: 107
    max: 10.1948
    min: 0
    mean: 1.4073
    median: 0

```

```
range: 10.1948
std: 2.6973
cpupds = struct with fields:
  num: 107
  max: 40.7520
  min: 0
  mean: 6.4272
  median: 0
  range: 40.7520
  std: 14.2619
```

```
%'CPU Temperature (%)',%'GPU Consumption (%)'
[cputds,gpuds] = datastats(DataFeatures(:,11),DataFeatures(:,12))
```

```
cputds = struct with fields:
  num: 107
  max: 35.1698
  min: 0
  mean: 5.0551
  median: 0
  range: 35.1698
  std: 11.2423
gpuds = struct with fields:
  num: 107
  max: 0.5909
  min: 0
  mean: 0.0266
  median: 0
  range: 0.5909
  std: 0.0896
```

```
%'GPU Power Consumption (%)', 'GPU Temperature (%)'
[gpupds,gputds] = datastats(DataFeatures(:,13),DataFeatures(:,14))
```

```
gpupds = struct with fields:
  num: 107
  max: 35.2516
  min: 0
  mean: 5.6730
  median: 0
  range: 35.2516
  std: 12.5917
gputds = struct with fields:
  num: 107
  max: 14.5880
  min: 0
  mean: 2.3977
  median: 0
  range: 14.5880
  std: 5.3226
```

```
%'RAM Consumption (%)', 'RAM Power Consumption (%)'
[ramds,rampds] = datastats(DataFeatures(:,15),DataFeatures(:,16))
```

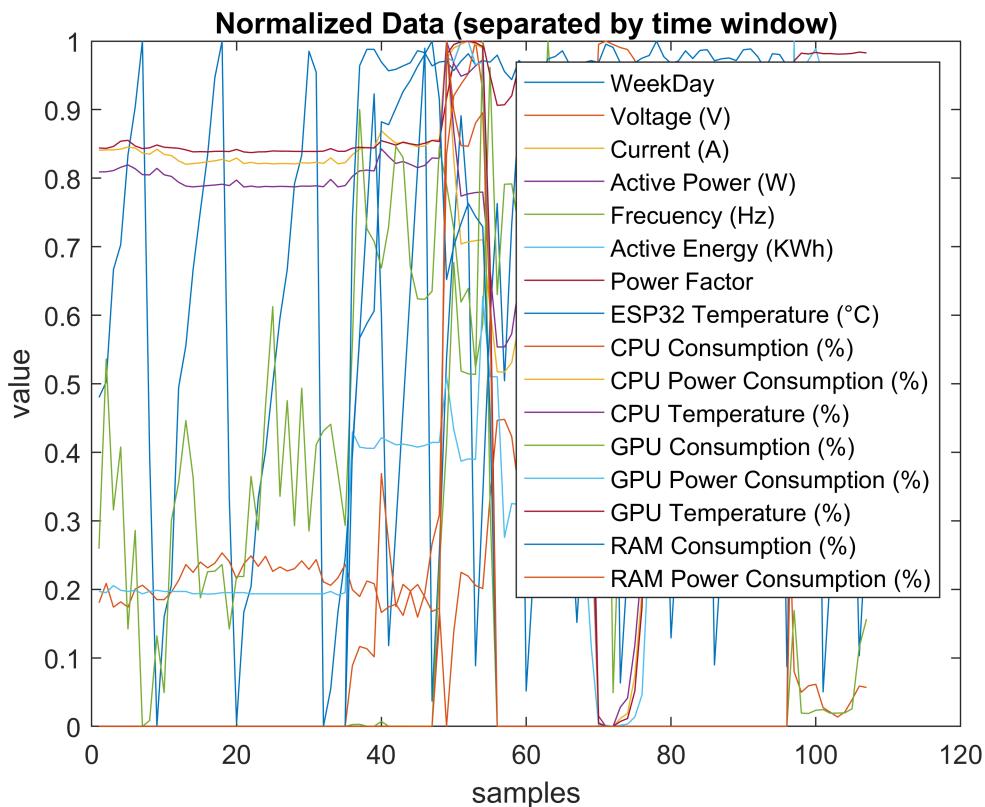
```
ramds = struct with fields:
  num: 107
  max: 47.3799
  min: 0
  mean: 10.6423
  median: 0
  range: 47.3799
  std: 17.1225
```

```
rampds = struct with fields:
  num: 107
  max: 12.1653
  min: 0
  mean: 1.4798
  median: 0
  range: 12.1653
  std: 3.3328
```

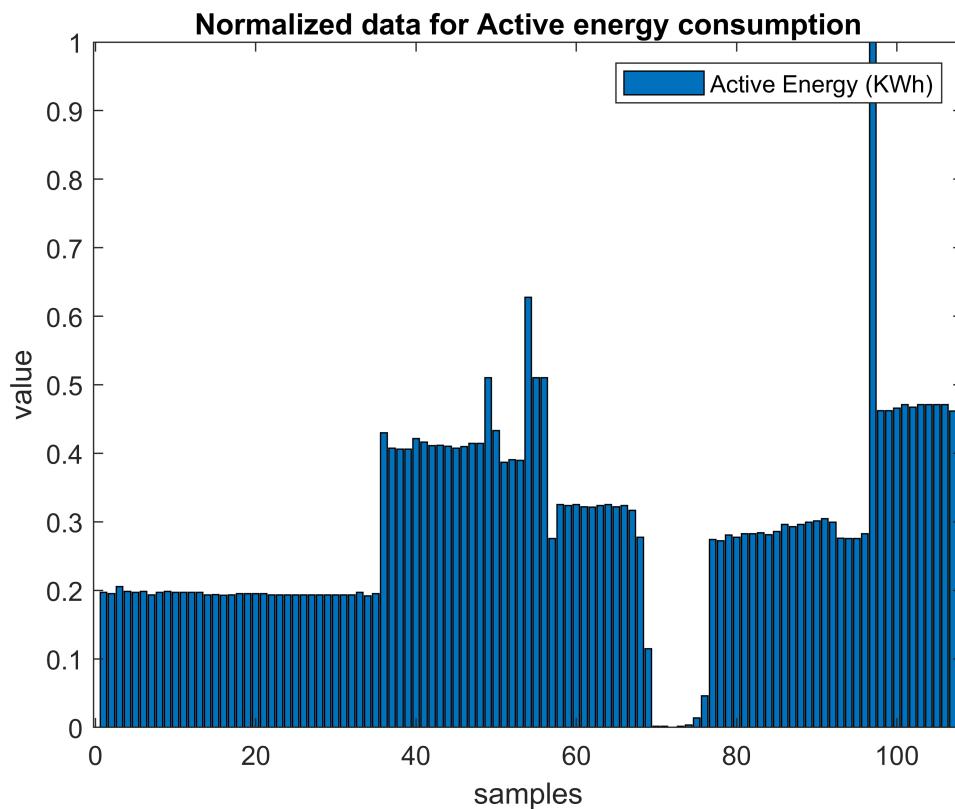
```
clear wds vds cds pds fds eds pfds tds cpuds cpupds cputds gpuds gpupds gputds ramds rampds
```

## 6- Feature Normalization and Plot

```
allFeatureNorm = fNormalization(DataFeatures);%Normalization
figure; plot(allFeatureNorm);title('Normalized Data (separated by time window)'); xlabel('sample');
legend('WeekDay','Voltage (V)', 'Current (A)', 'Active Power (W)', 'Frecuency (Hz)', 'Active Energy (KWh)', 'Power Factor', 'ESP32 Temperature (°C)', 'CPU Consumption (%)', 'CPU Power Consumption (%)', 'GPU Consumption (%)', 'GPU Power Consumption (%)', 'GPU Temperature (%)', 'RAM Consumption (%)', 'RAM Power Consumption (%)');
```



```
figure; bar(allFeatureNorm(:,6));title('Normalized data for Active energy consumption'); xlabel('sample');
legend('Active Energy (KWh)');
```

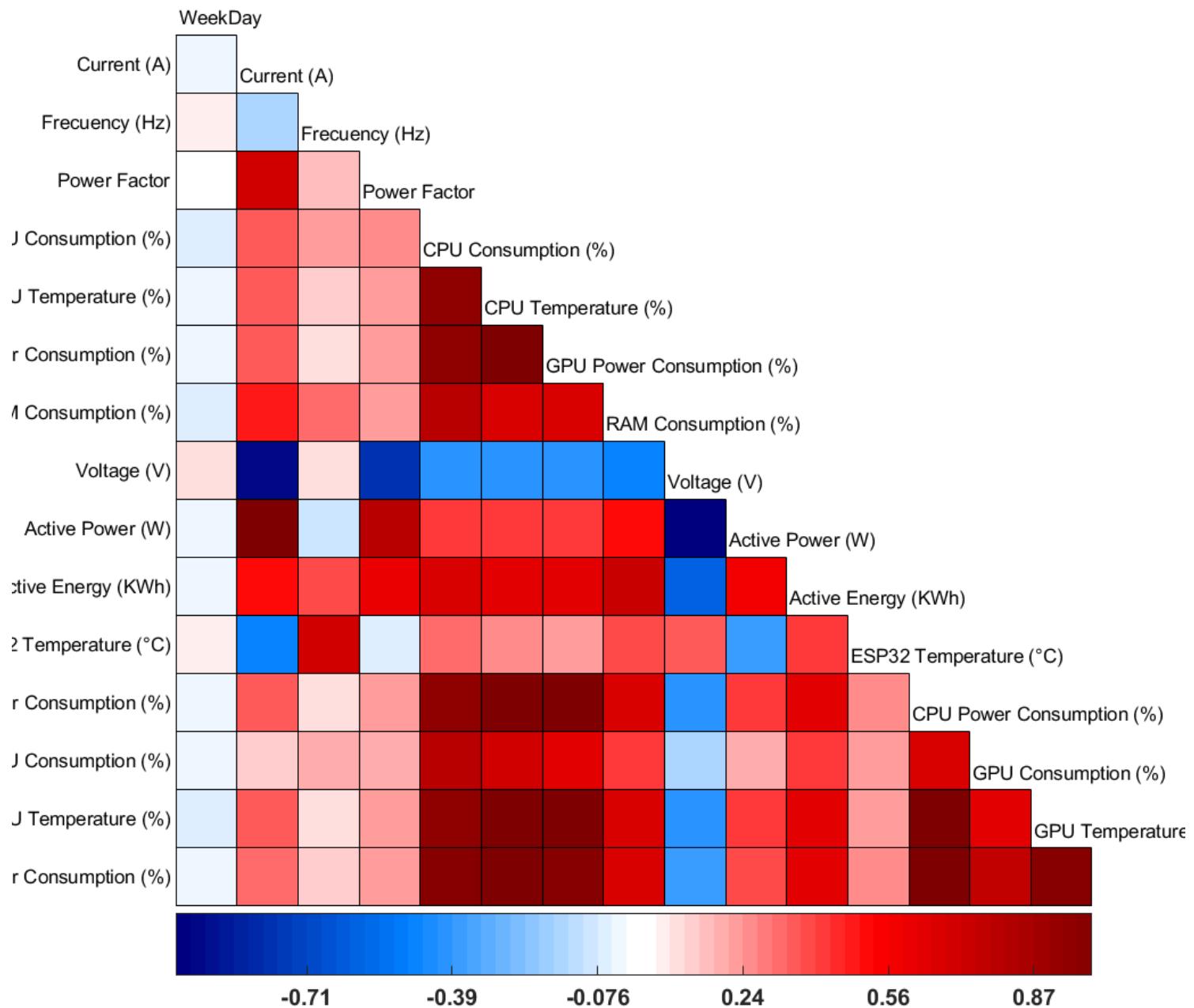


```
clear DataFeatures
```

## 7 - Feature Selection (Please set the maximum correlation value allowed.)

```
threshold = 0.75;%75<-----Maximum correlation value allowed
% Labels:
FeaturesLabels = {'WeekDay','Voltage (V)','Current (A)','Active Power (W)','Frecuency (Hz)','Ad
    'ESP32 Temperature (°C)','CPU Consumption (%)','CPU Power Consumption (%)','CPU Temperature (%)'
    , 'GPU Power Consumption (%)','GPU Temperature (%)','RAM Consumption (%)','RAM Power Consumption (%)'
    [NewDataFeatures,NewFeaturesLabels,LabelsRemove] = Feature_Selection(allFeatureNorm,FeaturesLabels)
```

### Electrical Consumption Parameters



LabelsRemove(:)

```
ans = 9x1 cell
'Active Power (W)'
'Power Factor'
'CPU Power Consumption (%)'
'CPU Temperature (%)'
'GPU Consumption (%)'
'GPU Power Consumption (%)'
'GPU Temperature (%)'
'RAM Consumption (%)'
'RAM Power Consumption (%)'
```

```
clear threshold LabelsRemove ans allFeatureNorm FeaturesLabels
```

## 8 - Regression Learner (Input output Data)

```

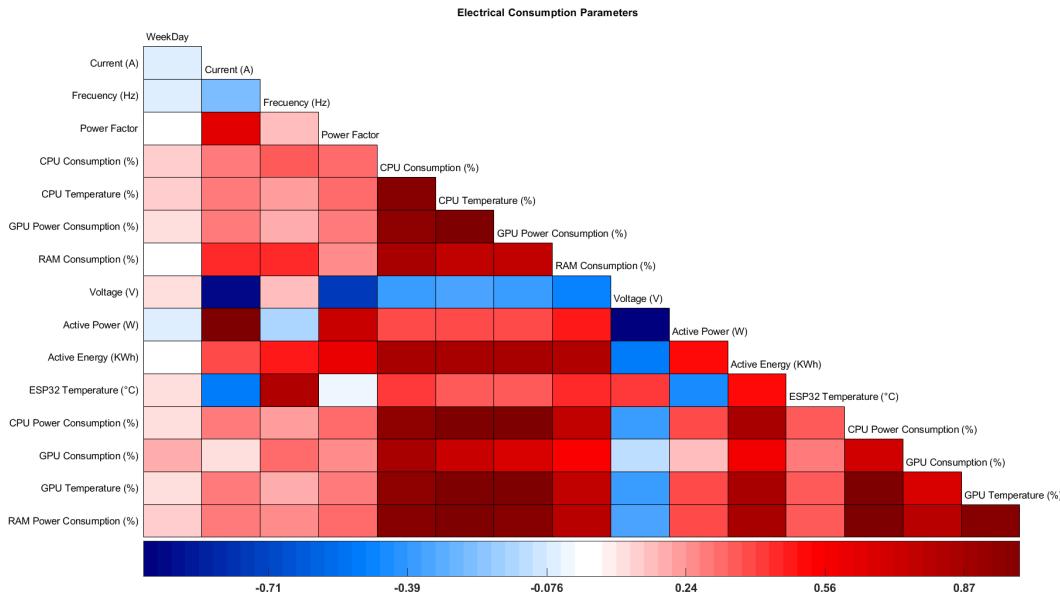
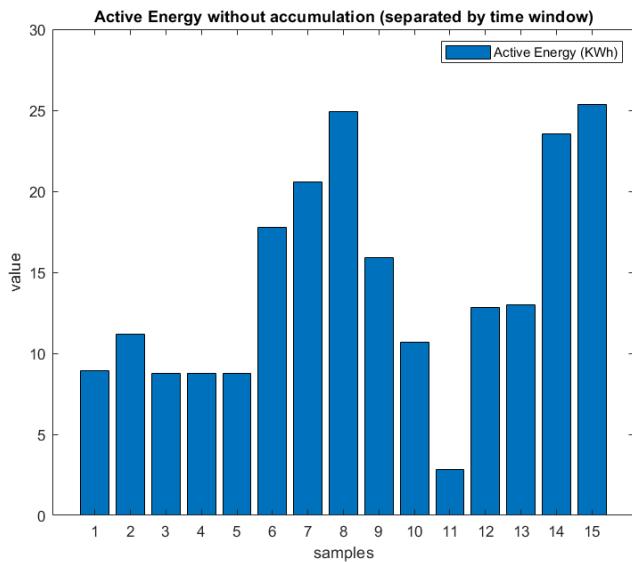
training_size=0.85; %70 Training, 15% Validation
Cell_Active_Energy=strfind(NewFeaturesLabels, 'Active Energy (Kwh)');
ind_Active_Energy = find(not(cellfun('isempty',Cell_Active_Energy)));

% -----inputs: All previously selected features-----
input_train=NewDataFeatures(1:round(size(NewDataFeatures,1)*training_size)-1,:);

% -----output: Energy in the next time step-----
output_train=NewDataFeatures(1+1:round(size(NewDataFeatures,1)*training_size),...
    ind_Active_Energy);%Active Energy index 5
%regressionLearner
clear Cell_Active_Energy Features_labels

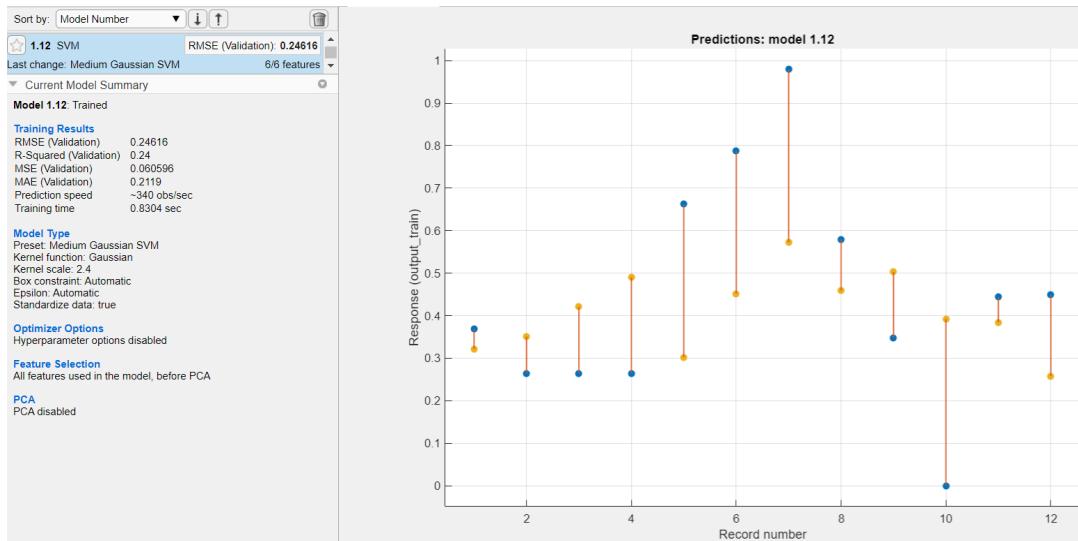
```

RMSE (Validation): 1 Week [threshold = 0.750;training\_size=0.85;]



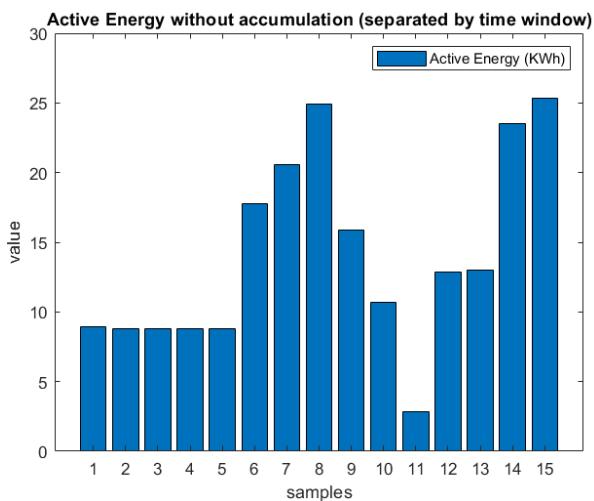
```
LabelsRemove(:)
```

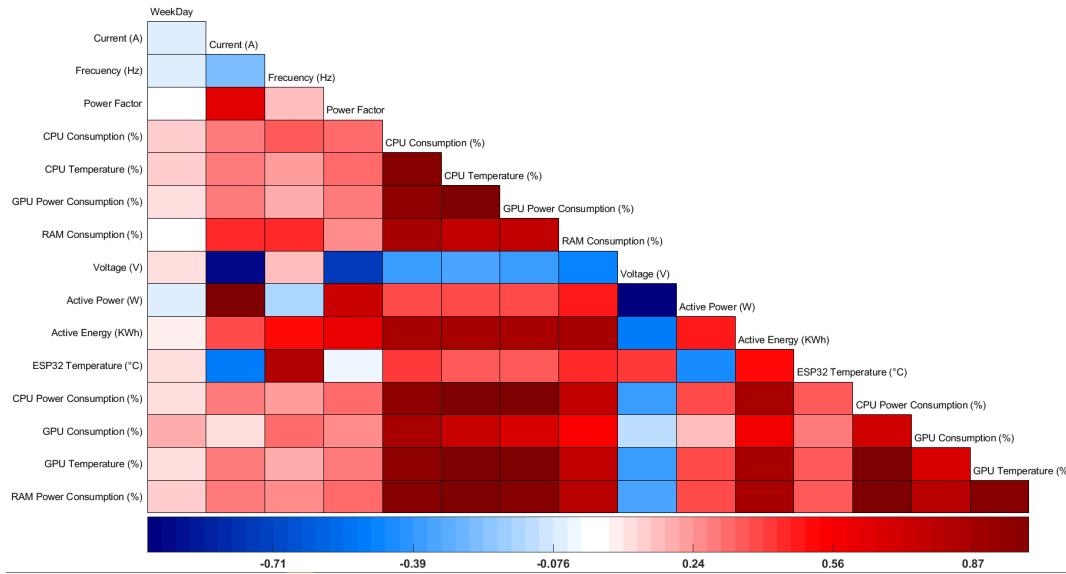
```
ans = 10x1 cell
'Active Power (W)'
'ESP32 Temperature (°C)'
'CPU Consumption (%)'
'CPU Power Consumption (%)'
'CPU Temperature (%)'
'GPU Consumption (%)'
'GPU Power Consumption (%)'
'GPU Temperature (%)'
'RAM Consumption (%)'
'RAM Power Consumption (%)'
```



<b>1.1</b> Linear Regression Last change: Linear	RMSE (Validation): 0.56341 6/6 features	<b>1.13</b> SVM Last change: Coarse Gaussian SVM	RMSE (Validation): 0.28654 6/6 features
<b>1.2</b> Linear Regression Last change: Interactions Linear	RMSE (Validation): 1.8826 6/6 features	<b>1.14</b> Ensemble Last change: Boosted Trees	RMSE (Validation): 0.28127 6/6 features
<b>1.3</b> Linear Regression Last change: Robust Linear	RMSE (Validation): 0.56232 6/6 features	<b>1.15</b> Ensemble Last change: Bagged Trees	RMSE (Validation): 0.27993 6/6 features
<b>1.4</b> Stepwise Linear Regression Last change: Stepwise Linear	RMSE (Validation): 0.76271 6/6 features	<b>1.16</b> Gaussian Process Regr... Last change: Squared Exponential GPR	RMSE (Validation): 0.29956 6/6 features
<b>1.5</b> Tree Last change: Fine Tree	RMSE (Validation): 0.29072 6/6 features	<b>1.17</b> Gaussian Process Regr... Last change: Matern 5/2 GPR	RMSE (Validation): 0.29579 6/6 features
<b>1.6</b> Tree Last change: Medium Tree	RMSE (Validation): 0.28153 6/6 features	<b>1.18</b> Gaussian Process Regr... Last change: Exponential GPR	RMSE (Validation): 0.28644 6/6 features
<b>1.7</b> Tree Last change: Coarse Tree	RMSE (Validation): 0.28153 6/6 features	<b>1.19</b> Gaussian Process Regr... Last change: Rational Quadratic GPR	RMSE (Validation): 0.29909 6/6 features
<b>1.8</b> SVM Last change: Linear SVM	RMSE (Validation): 0.37074 6/6 features	<b>1.20</b> Neural Network Last change: Narrow Neural Network	RMSE (Validation): 0.48629 6/6 features
<b>1.9</b> SVM Last change: Quadratic SVM	RMSE (Validation): 1.1921 6/6 features	<b>1.21</b> Neural Network Last change: Medium Neural Network	RMSE (Validation): 1.089 6/6 features
<b>1.10</b> SVM Last change: Cubic SVM	RMSE (Validation): 2.0938 6/6 features	<b>1.22</b> Neural Network Last change: Wide Neural Network	RMSE (Validation): 0.65337 6/6 features
<b>1.11</b> SVM Last change: Fine Gaussian SVM	RMSE (Validation): 0.27641 6/6 features	<b>1.23</b> Neural Network Last change: Bilayered Neural Network	RMSE (Validation): 1.2374 6/6 features
<b>1.12</b> SVM Last change: Medium Gaussian SVM	RMSE (Validation): <b>0.24616</b> 6/6 features	<b>1.24</b> Neural Network Last change: Trilayered Neural Network	RMSE (Validation): 0.4058 6/6 features

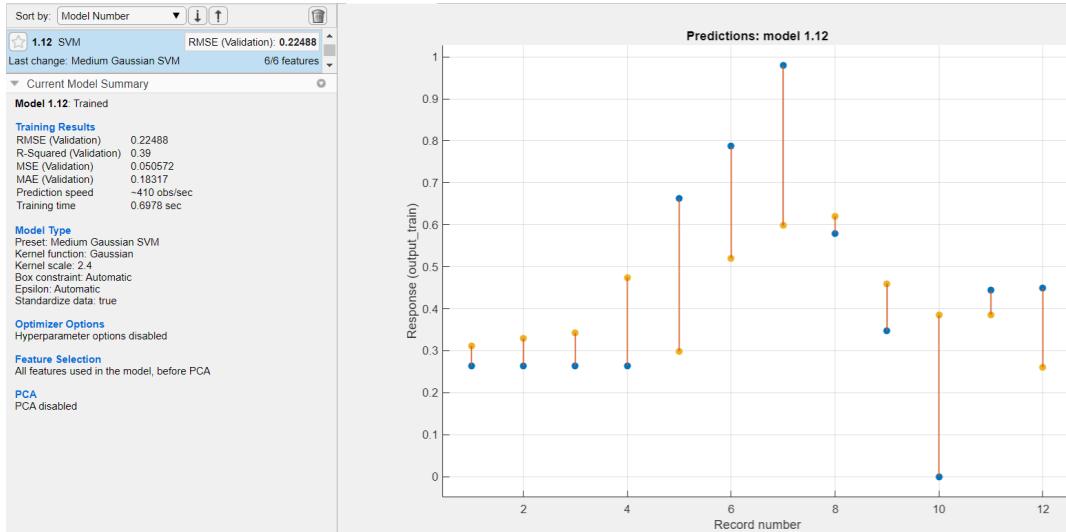
RMSE (Validation - Filtrado): 1 Week [threshold = 0.750; training\_size=0.85;]





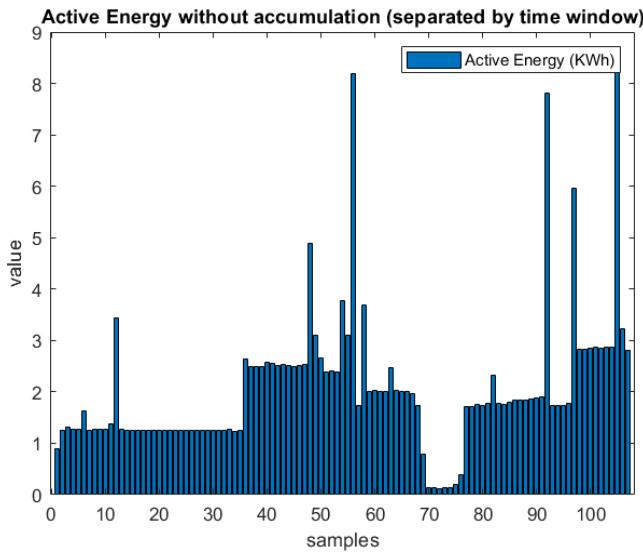
## LabelsRemove(:)

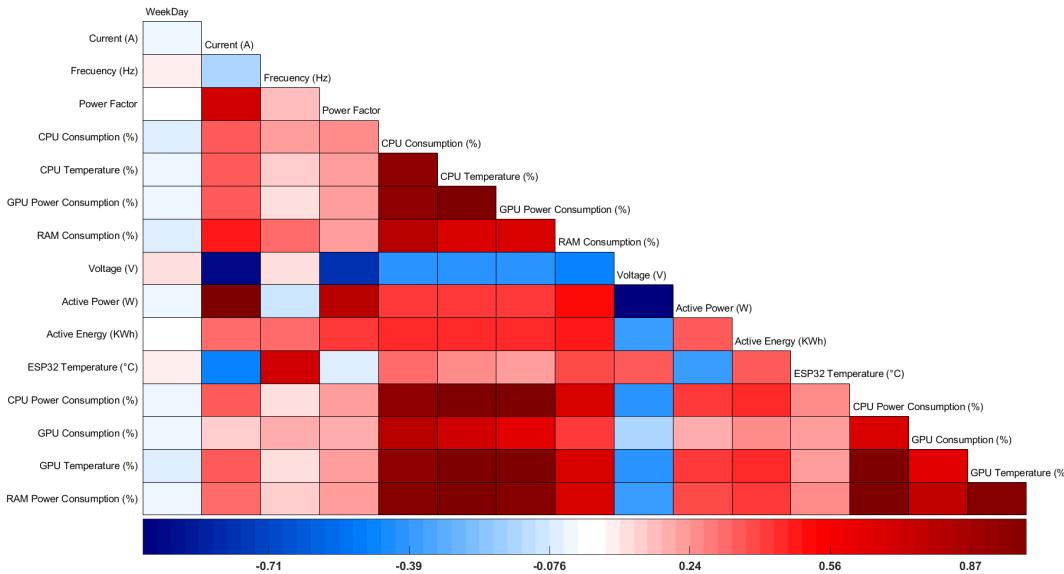
```
ans = 10×1 cell
'Active Power (W)'
'ESP32 Temperature (°C)'
'CPU Consumption (%)'
'CPU Power Consumption (%)'
'CPU Temperature (%)'
'GPU Consumption (%)'
'GPU Power Consumption (%)'
'GPU Temperature (%)'
'RAM Consumption (%)'
'RAM Power Consumption (%)'
```



<b>1.1</b> Linear Regression Last change: Linear	RMSE (Validation): 0.727 6/6 features	<b>1.13</b> SVM Last change: Coarse Gaussian SVM	RMSE (Validation): 0.30214 6/6 features
<b>1.2</b> Linear Regression Last change: Interactions Linear	RMSE (Validation): 4.6396 6/6 features	<b>1.14</b> Ensemble Last change: Boosted Trees	RMSE (Validation): 0.2863 6/6 features
<b>1.3</b> Linear Regression Last change: Robust Linear	RMSE (Validation): 0.72291 6/6 features	<b>1.15</b> Ensemble Last change: Bagged Trees	RMSE (Validation): 0.28161 6/6 features
<b>1.4</b> Stepwise Linear Regression Last change: Stepwise Linear	RMSE (Validation): 0.48081 6/6 features	<b>1.16</b> Gaussian Process Regr... Last change: Squared Exponential GPR	RMSE (Validation): 0.29835 6/6 features
<b>1.5</b> Tree Last change: Fine Tree	RMSE (Validation): 0.2672 6/6 features	<b>1.17</b> Gaussian Process Regr... Last change: Matern 5/2 GPR	RMSE (Validation): 0.29169 6/6 features
<b>1.6</b> Tree Last change: Medium Tree	RMSE (Validation): 0.28699 6/6 features	<b>1.18</b> Gaussian Process Regr... Last change: Exponential GPR	RMSE (Validation): 0.28464 6/6 features
<b>1.7</b> Tree Last change: Coarse Tree	RMSE (Validation): 0.28699 6/6 features	<b>1.19</b> Gaussian Process Regr... Last change: Rational Quadratic GPR	RMSE (Validation): 0.29585 6/6 features
<b>1.8</b> SVM Last change: Linear SVM	RMSE (Validation): 0.43255 6/6 features	<b>1.20</b> Neural Network Last change: Narrow Neural Network	RMSE (Validation): 0.46098 6/6 features
<b>1.9</b> SVM Last change: Quadratic SVM	RMSE (Validation): 1.5042 6/6 features	<b>1.21</b> Neural Network Last change: Medium Neural Network	RMSE (Validation): 1.3558 6/6 features
<b>1.10</b> SVM Last change: Cubic SVM	RMSE (Validation): 2.3677 6/6 features	<b>1.22</b> Neural Network Last change: Wide Neural Network	RMSE (Validation): 1.0426 6/6 features
<b>1.11</b> SVM Last change: Fine Gaussian SVM	RMSE (Validation): 0.26992 6/6 features	<b>1.23</b> Neural Network Last change: Bilayered Neural Network	RMSE (Validation): 0.62734 6/6 features
<b>1.12</b> SVM Last change: Medium Gaussian SVM	RMSE (Validation): <b>0.22488</b> 6/6 features	<b>1.24</b> Neural Network Last change: Trilayered Neural Network	RMSE (Validation): 0.69259 6/6 features

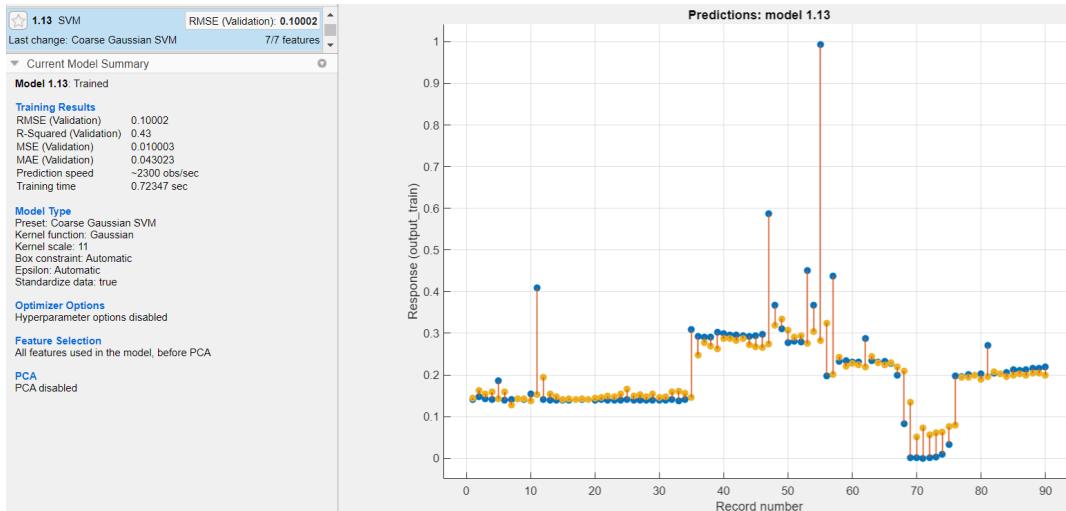
RMSE (Validation): 1 day [threshold = 0.750;training\_size=0.85;]





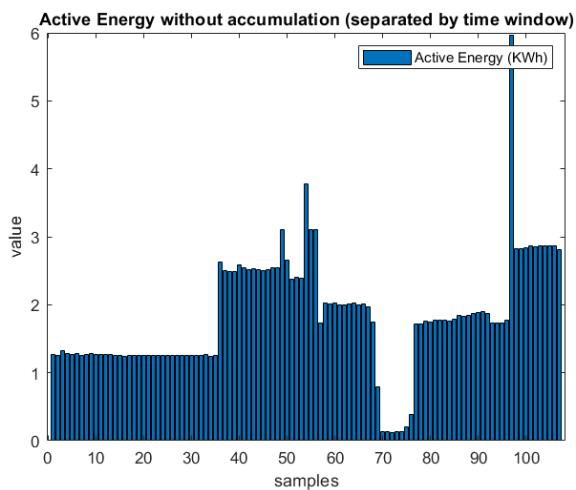
LabelsRemove(:)

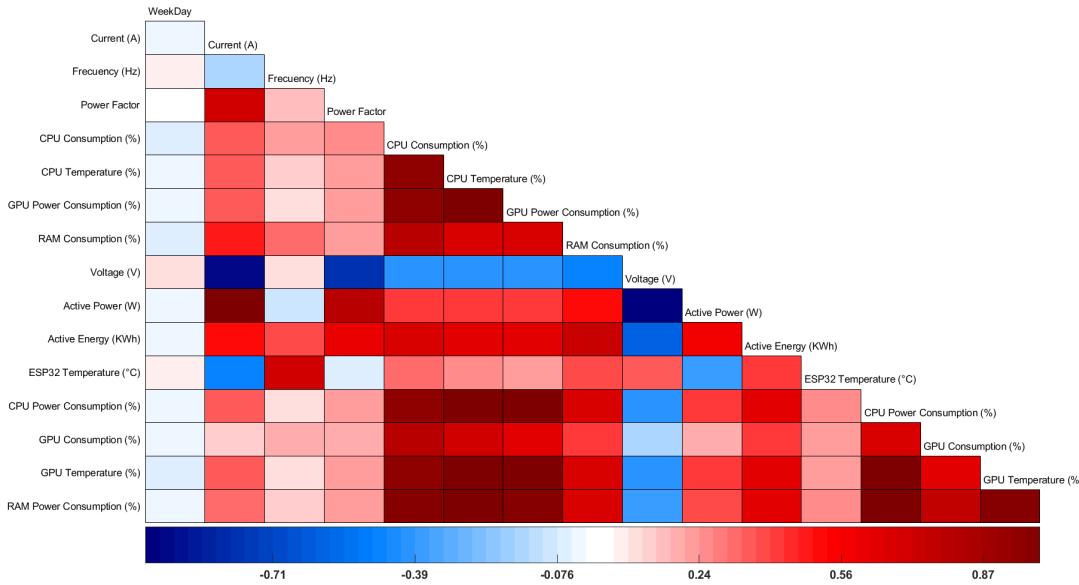
```
ans = 9x1 cell
'Active Power (W)'
'Power Factor'
'CPU Power Consumption (%)'
'CPU Temperature (%)'
'GPU Consumption (%)'
'GPU Power Consumption (%)'
'GPU Temperature (%)'
'RAM Consumption (%)'
'RAM Power Consumption (%)'
```



<b>1.1</b> Linear Regression Last change: Linear	RMSE (Validation): 0.10927 7/7 features	<b>1.13</b> SVM Last change: Coarse Gaussian SVM	RMSE (Validation): <b>0.10002</b> 7/7 features
<b>1.2</b> Linear Regression Last change: Interactions Linear	RMSE (Validation): 0.28661 7/7 features	<b>1.14</b> Ensemble Last change: Boosted Trees	RMSE (Validation): 0.11074 7/7 features
<b>1.3</b> Linear Regression Last change: Robust Linear	RMSE (Validation): 0.10504 7/7 features	<b>1.15</b> Ensemble Last change: Bagged Trees	RMSE (Validation): 0.10413 7/7 features
<b>1.4</b> Stepwise Linear Regression Last change: Stepwise Linear	RMSE (Validation): 0.12136 7/7 features	<b>1.16</b> Gaussian Process Regr... Last change: Squared Exponential GPR	RMSE (Validation): 0.10806 7/7 features
<b>1.5</b> Tree Last change: Fine Tree	RMSE (Validation): 0.11459 7/7 features	<b>1.17</b> Gaussian Process Regr... Last change: Matern 5/2 GPR	RMSE (Validation): 0.10651 7/7 features
<b>1.6</b> Tree Last change: Medium Tree	RMSE (Validation): 0.10754 7/7 features	<b>1.18</b> Gaussian Process Regre... Last change: Exponential GPR	RMSE (Validation): 0.1039 7/7 features
<b>1.7</b> Tree Last change: Coarse Tree	RMSE (Validation): 0.11394 7/7 features	<b>1.19</b> Gaussian Process Regr... Last change: Rational Quadratic GPR	RMSE (Validation): 0.10822 7/7 features
<b>1.8</b> SVM Last change: Linear SVM	RMSE (Validation): 0.1016 7/7 features	<b>1.20</b> Neural Network Last change: Narrow Neural Network	RMSE (Validation): 0.2737 7/7 features
<b>1.9</b> SVM Last change: Quadratic SVM	RMSE (Validation): 0.15565 7/7 features	<b>1.21</b> Neural Network Last change: Medium Neural Network	RMSE (Validation): 0.29608 7/7 features
<b>1.10</b> SVM Last change: Cubic SVM	RMSE (Validation): 0.14093 7/7 features	<b>1.22</b> Neural Network Last change: Wide Neural Network	RMSE (Validation): 0.20877 7/7 features
<b>1.11</b> SVM Last change: Fine Gaussian SVM	RMSE (Validation): 0.12321 7/7 features	<b>1.23</b> Neural Network Last change: Bilayered Neural Network	RMSE (Validation): 0.16103 7/7 features
<b>1.12</b> SVM Last change: Medium Gaussian SVM	RMSE (Validation): 0.10185 7/7 features	<b>1.24</b> Neural Network Last change: Trilayered Neural Network	RMSE (Validation): 0.1634 7/7 features

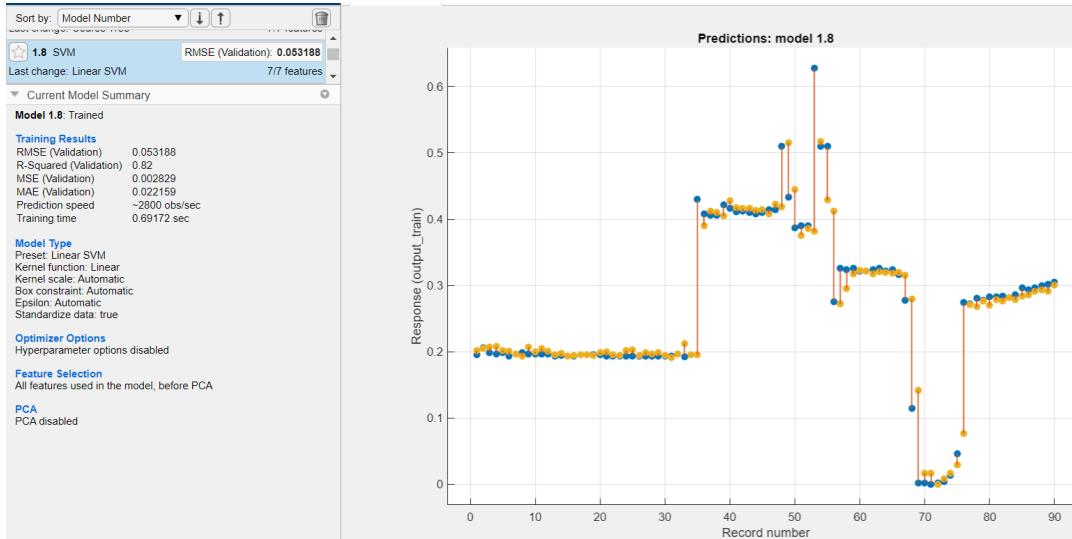
RMSE (Validation - Filtrado): 1 day [threshold = 0.750; training\_size=0.85;]





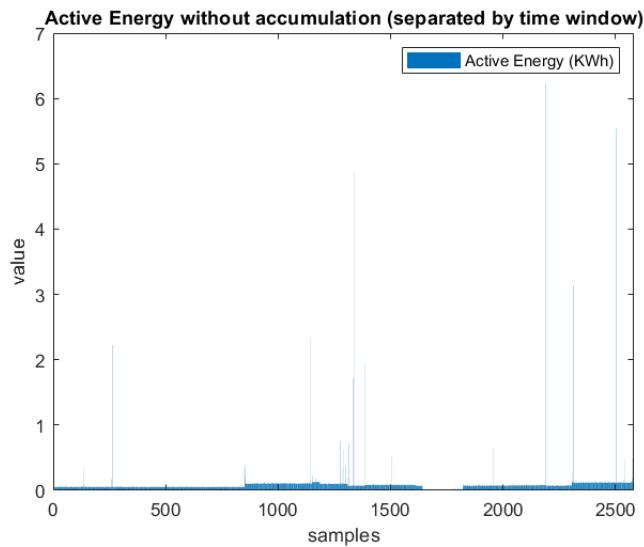
### LabelsRemove(:)

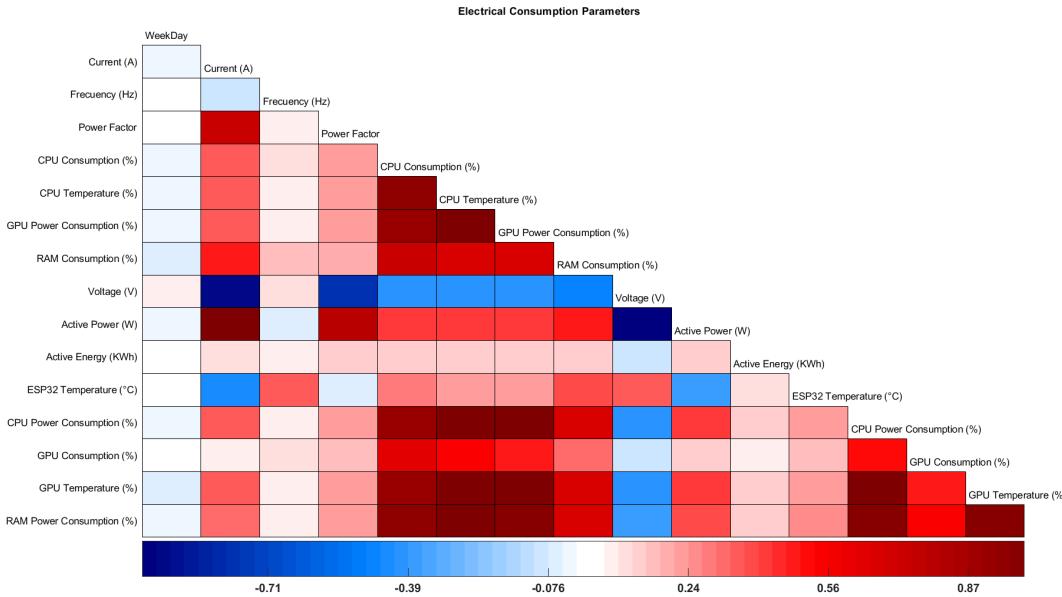
```
ans = 9x1 cell
'Active Power (W)'
'Power Factor'
'CPU Power Consumption (%)'
'CPU Temperature (%)'
'GPU Consumption (%)'
'GPU Power Consumption (%)'
'GPU Temperature (%)'
'RAM Consumption (%)'
'RAM Power Consumption (%)'
```



<b>1.1</b> Linear Regression Last change: Linear	RMSE (Validation): 0.056596 7/7 features	<b>1.13</b> SVM Last change: Coarse Gaussian SVM 7/7 features	RMSE (Validation): 0.059634 7/7 features
<b>1.2</b> Linear Regression Last change: Interactions Linear	RMSE (Validation): 0.17343 7/7 features	<b>1.14</b> Ensemble Last change: Boosted Trees	RMSE (Validation): 0.063349 7/7 features
<b>1.3</b> Linear Regression Last change: Robust Linear	RMSE (Validation): 0.055551 7/7 features	<b>1.15</b> Ensemble Last change: Bagged Trees	RMSE (Validation): 0.061139 7/7 features
<b>1.4</b> Stepwise Linear Regres... Last change: Stepwise Linear	RMSE (Validation): 0.066606 7/7 features	<b>1.16</b> Gaussian Process Reg... Last change: Squared Exponential GPR	RMSE (Validation): 0.061162 7/7 features
<b>1.5</b> Tree Last change: Fine Tree	RMSE (Validation): 0.067534 7/7 features	<b>1.17</b> Gaussian Process Reg... Last change: Matern 5/2 GPR	RMSE (Validation): 0.059668 7/7 features
<b>1.6</b> Tree Last change: Medium Tree	RMSE (Validation): 0.071774 7/7 features	<b>1.18</b> Gaussian Process Reg... Last change: Exponential GPR	RMSE (Validation): 0.057895 7/7 features
<b>1.7</b> Tree Last change: Coarse Tree	RMSE (Validation): 0.087256 7/7 features	<b>1.19</b> Gaussian Process Reg... Last change: Rational Quadratic GPR	RMSE (Validation): 0.061105 7/7 features
<b>1.8</b> SVM Last change: Linear SVM	RMSE (Validation): <b>0.053188</b> 7/7 features	<b>1.20</b> Neural Network Last change: Narrow Neural Network	RMSE (Validation): 0.11429 7/7 features
<b>1.9</b> SVM Last change: Quadratic SVM	RMSE (Validation): 0.065746 7/7 features	<b>1.21</b> Neural Network Last change: Medium Neural Network	RMSE (Validation): 0.17723 7/7 features
<b>1.10</b> SVM Last change: Cubic SVM	RMSE (Validation): 0.077658 7/7 features	<b>1.22</b> Neural Network Last change: Wide Neural Network	RMSE (Validation): 0.14771 7/7 features
<b>1.11</b> SVM Last change: Fine Gaussian SVM	RMSE (Validation): 0.10159 7/7 features	<b>1.23</b> Neural Network Last change: Bilayered Neural Network	RMSE (Validation): 0.13804 7/7 features
<b>1.12</b> SVM Last change: Medium Gaussian SVM	RMSE (Validation): 0.066788 7/7 features	<b>1.24</b> Neural Network Last change: Trilayered Neural Network	RMSE (Validation): 0.14041 7/7 features

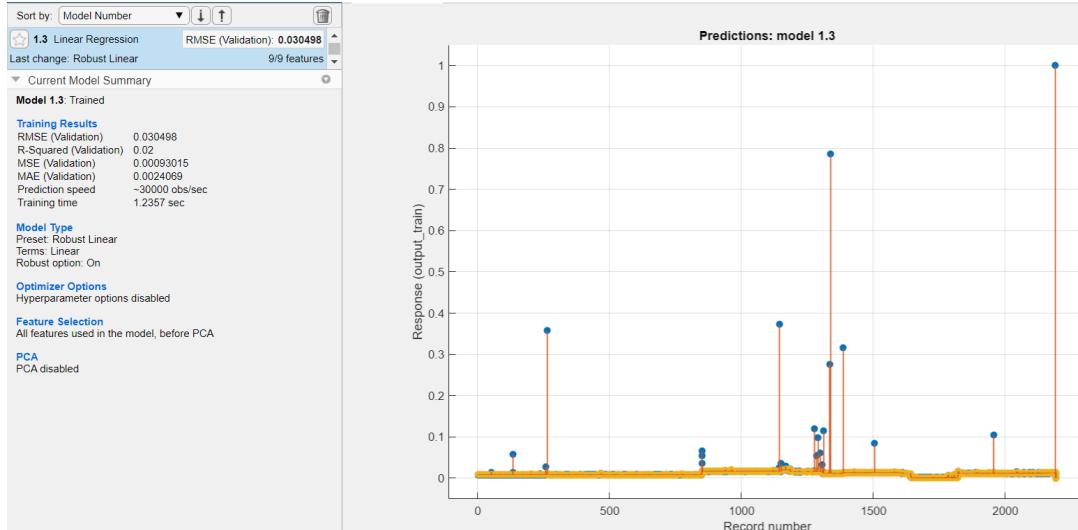
RMSE (Validation): 1 hour [threshold = 0.750;training\_size=0.85;]





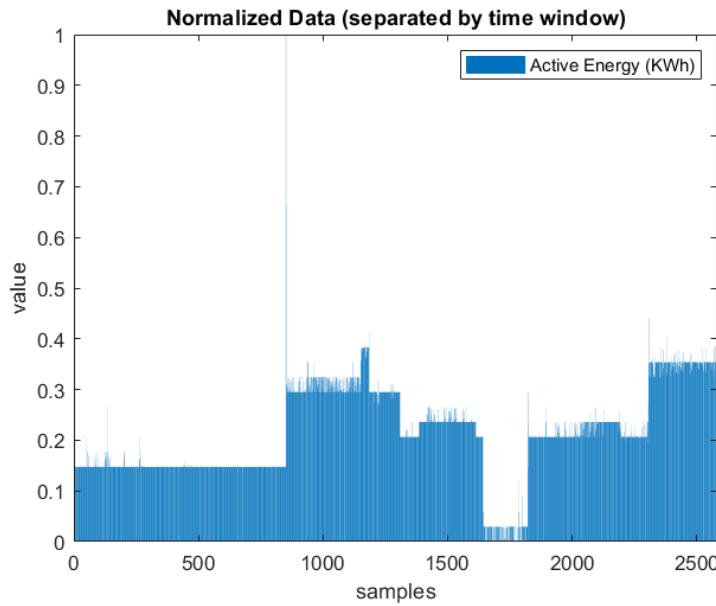
LabelsRemove(:)

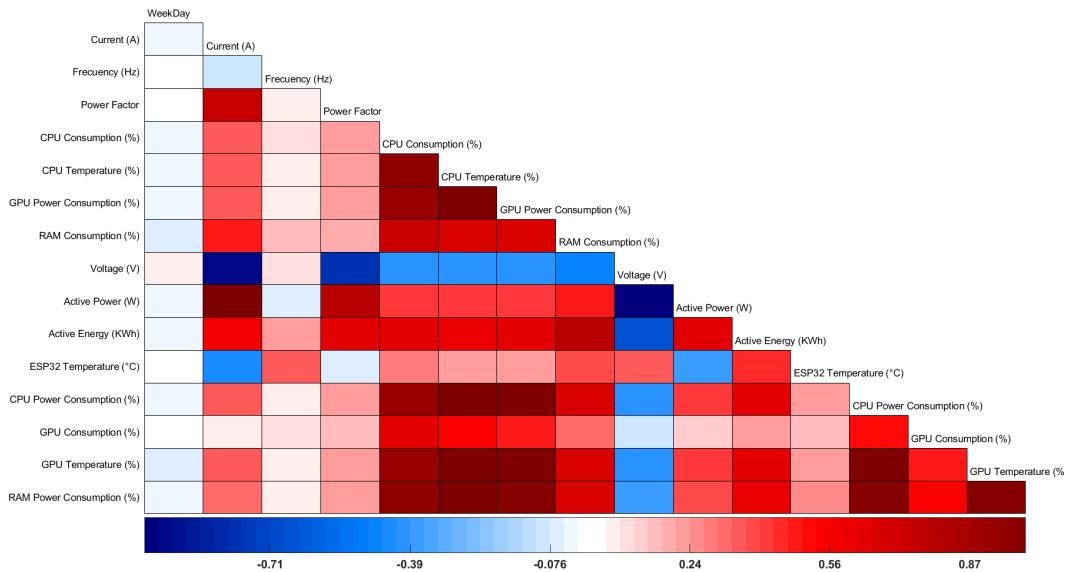
```
ans = 7x1 cell
'Active Power (W)'
'Power Factor'
'CPU Power Consumption (%)'
'CPU Temperature (%)'
'GPU Power Consumption (%)'
'GPU Temperature (%)'
'RAM Power Consumption (%)'
```



<b>1.1</b> Linear Regression Last change: Linear	RMSE (Validation): 0.030546 9/9 features	<b>1.13</b> SVM Last change: Coarse Gaussian SVM 9/9 features	RMSE (Validation): 0.030531 9/9 features
<b>1.2</b> Linear Regression Last change: Interactions Linear	RMSE (Validation): 0.032596 9/9 features	<b>1.14</b> Ensemble Last change: Boosted Trees 9/9 features	RMSE (Validation): 0.031279 9/9 features
<b>1.3</b> Linear Regression Last change: Robust Linear	RMSE (Validation): <b>0.030498</b> 9/9 features	<b>1.15</b> Ensemble Last change: Bagged Trees 9/9 features	RMSE (Validation): 0.030754 9/9 features
<b>1.4</b> Stepwise Linear Regres... Last change: Stepwise Linear	RMSE (Validation): 0.030556 9/9 features	<b>1.16</b> Gaussian Process Reg... Last change: Squared Exponential GPR	RMSE (Validation): 0.030544 9/9 features
<b>1.5</b> Tree Last change: Fine Tree	RMSE (Validation): 0.036725 9/9 features	<b>1.17</b> Gaussian Process Reg... Last change: Matern 5/2 GPR	RMSE (Validation): 0.030542 9/9 features
<b>1.6</b> Tree Last change: Medium Tree	RMSE (Validation): 0.031552 9/9 features	<b>1.18</b> Gaussian Process Reg... Last change: Exponential GPR	RMSE (Validation): 0.030543 9/9 features
<b>1.7</b> Tree Last change: Coarse Tree	RMSE (Validation): 0.030947 9/9 features	<b>1.19</b> Gaussian Process Reg... Last change: Rational Quadratic GPR	RMSE (Validation): 0.030545 9/9 features
<b>1.8</b> SVM Last change: Linear SVM	RMSE (Validation): 0.030519 9/9 features	<b>1.20</b> Neural Network Last change: Narrow Neural Network	RMSE (Validation): 0.031267 9/9 features
<b>1.9</b> SVM Last change: Quadratic SVM	RMSE (Validation): 0.030502 9/9 features	<b>1.21</b> Neural Network Last change: Medium Neural Network	RMSE (Validation): 0.032977 9/9 features
<b>1.10</b> SVM Last change: Cubic SVM	RMSE (Validation): 0.54047 9/9 features	<b>1.22</b> Neural Network Last change: Wide Neural Network	RMSE (Validation): 0.036425 9/9 features
<b>1.11</b> SVM Last change: Fine Gaussian SVM	RMSE (Validation): 0.030551 9/9 features	<b>1.23</b> Neural Network Last change: Bilayered Neural Network	RMSE (Validation): 0.10341 9/9 features
<b>1.12</b> SVM Last change: Medium Gaussian SVM	RMSE (Validation): 0.030515 9/9 features	<b>1.24</b> Neural Network Last change: Trilayered Neural Network	RMSE (Validation): 0.31326 9/9 features

RMSE (Validation - Filtrado): 1 hour [threshold = 0.750; training\_size=0.85;]





### LabelsRemove(:)

```
ans = 8×1 cell
'Active Power (W)'
'Power Factor'
'CPU Power Consumption (%)'
'CPU Temperature (%)'
'GPU Power Consumption (%)'
'GPU Temperature (%)'
'RAM Consumption (%)'
'RAM Power Consumption (%)'
```

Sort by: Model Number ▼ ↴ ↵

**1.15 Ensemble** RMSE (Validation): 0.023141

Last change: Bagged Trees 8/8 features

Current Model Summary

**Model 1.15:** Trained

**Training Results**

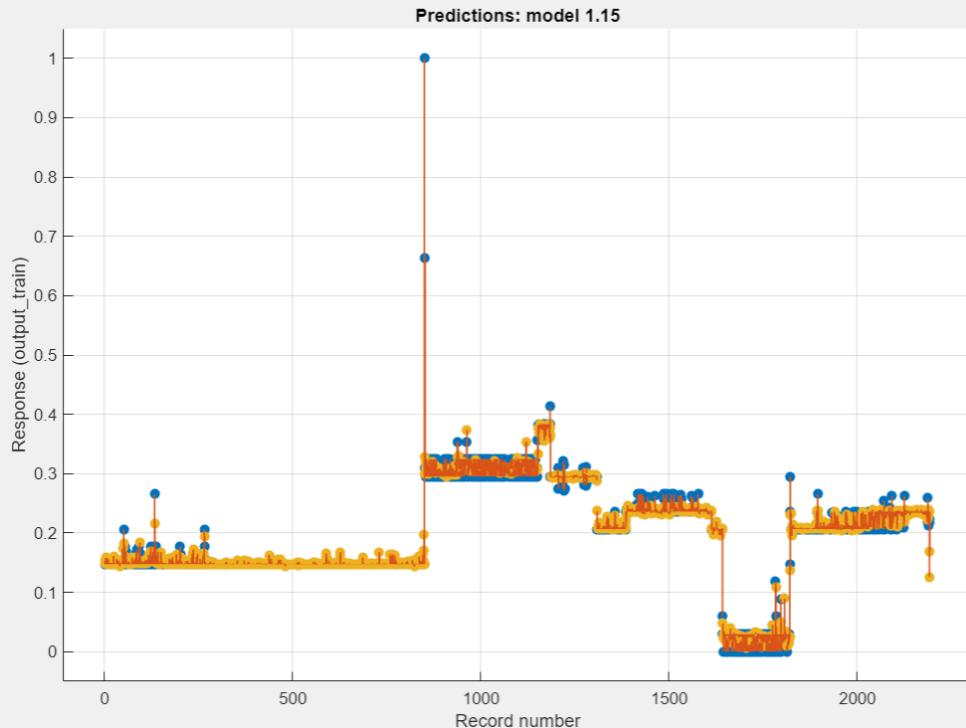
RMSE (Validation)	0.023141
R-Squared (Validation)	0.92
MSE (Validation)	0.00053552
MAE (Validation)	0.0067041
Prediction speed	~15000 obs/sec
Training time	3.6419 sec

**Model Type**  
Preset: Bagged Trees  
Minimum leaf size: 8  
Number of learners: 30

**Optimizer Options**  
Hyperparameter options disabled

**Feature Selection**  
All features used in the model, before PCA

**PCA**  
PCA disabled



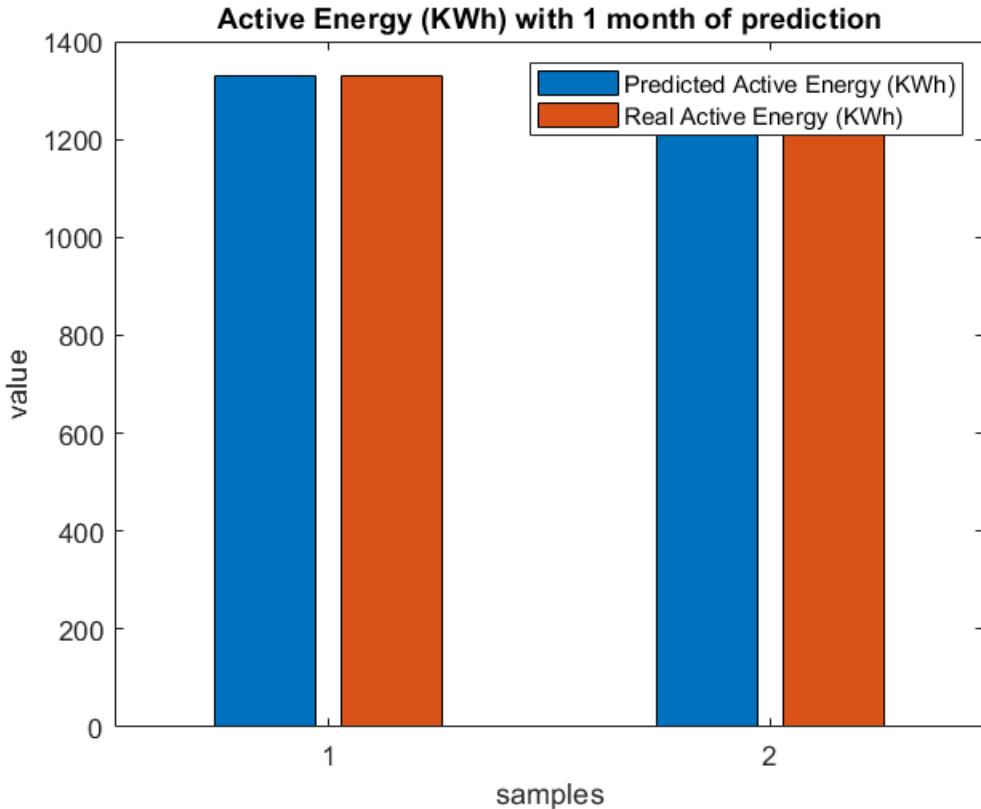
<b>1.1</b> Linear Regression Last change: Linear	RMSE (Validation): 0.02474 8/8 features	<b>1.13</b> SVM Last change: Coarse Gaussian SVM	RMSE (Validation): 0.024284 8/8 features
<b>1.2</b> Linear Regression Last change: Interactions Linear	RMSE (Validation): 0.024048 8/8 features	<b>1.14</b> Ensemble Last change: Boosted Trees	RMSE (Validation): 0.025261 8/8 features
<b>1.3</b> Linear Regression Last change: Robust Linear	RMSE (Validation): 0.029663 8/8 features	<b>1.15</b> Ensemble Last change: Bagged Trees	RMSE (Validation): <b>0.023141</b> 8/8 features
<b>1.4</b> Stepwise Linear Regres... Last change: Stepwise Linear	RMSE (Validation): 0.024424 8/8 features	<b>1.16</b> Gaussian Process Reg... Last change: Squared Exponential GPR	RMSE (Validation): 0.024063 8/8 features
<b>1.5</b> Tree Last change: Fine Tree	RMSE (Validation): 0.025318 8/8 features	<b>1.17</b> Gaussian Process Reg... Last change: Matern 5/2 GPR	RMSE (Validation): 0.024005 8/8 features
<b>1.6</b> Tree Last change: Medium Tree	RMSE (Validation): 0.024457 8/8 features	<b>1.18</b> Gaussian Process Reg... Last change: Exponential GPR	RMSE (Validation): 0.023871 8/8 features
<b>1.7</b> Tree Last change: Coarse Tree	RMSE (Validation): 0.023801 8/8 features	<b>1.19</b> Gaussian Process Reg... Last change: Rational Quadratic GPR	RMSE (Validation): 0.024064 8/8 features
<b>1.8</b> SVM Last change: Linear SVM	RMSE (Validation): 0.024776 8/8 features	<b>1.20</b> Neural Network Last change: Narrow Neural Network	RMSE (Validation): 0.023815 8/8 features
<b>1.9</b> SVM Last change: Quadratic SVM	RMSE (Validation): 0.024175 8/8 features	<b>1.21</b> Neural Network Last change: Medium Neural Network	RMSE (Validation): 0.025071 8/8 features
<b>1.10</b> SVM Last change: Cubic SVM	RMSE (Validation): 0.13562 8/8 features	<b>1.22</b> Neural Network Last change: Wide Neural Network	RMSE (Validation): 0.027654 8/8 features
<b>1.11</b> SVM Last change: Fine Gaussian SVM	RMSE (Validation): 0.030088 8/8 features	<b>1.23</b> Neural Network Last change: Bilayered Neural Network	RMSE (Validation): 0.023992 8/8 features
<b>1.12</b> SVM Last change: Medium Gaussian SVM	RMSE (Validation): 0.024639 8/8 features	<b>1.24</b> Neural Network Last change: Trilayered Neural Network	RMSE (Validation): 0.025289 8/8 features

RMSE (Testing): 1 month [threshold = 0.750;training\_size=0.85;]

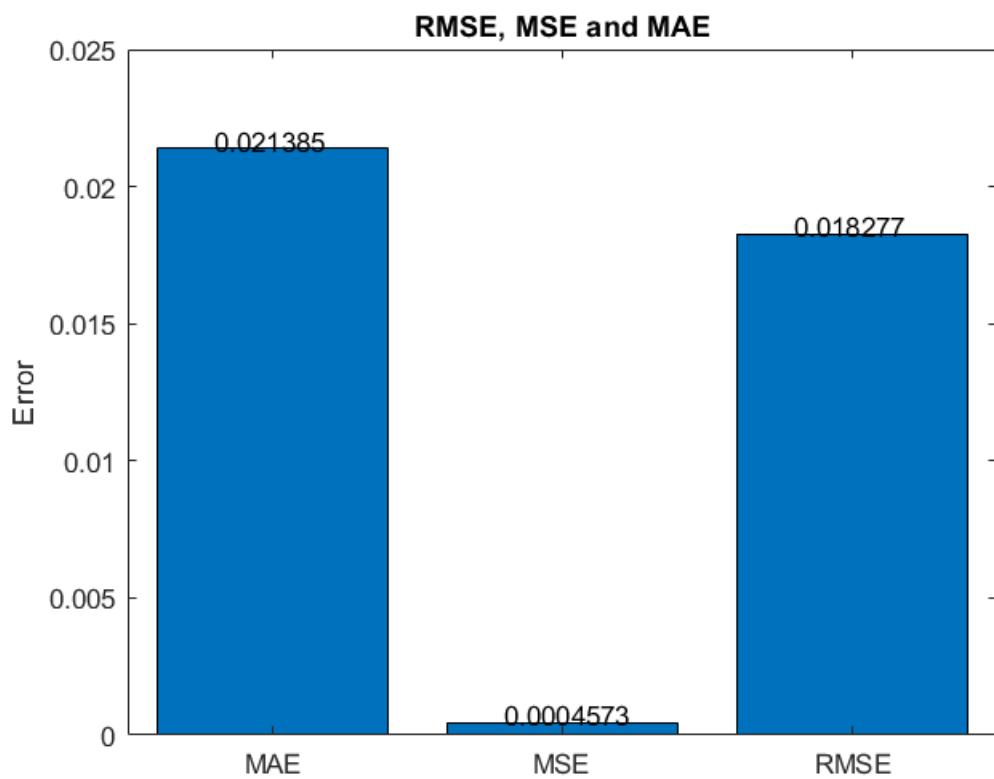
```
training_size=0.40;
% input: Energy
input_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size):size(NewDataFeatures,1));
% output: Energy in the next time step
output_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size)+1:size(NewDataFeatures,
    ,ind_Active_Energy));%Active Energy index 5
% Generate model
[model_month, RMSE_month] = trainRegressionModel_month(input_train, output_train);
RMSE_month
```

RMSE\_month = 0.9105

```
estimate_month=model_month.predictFcn(input_val);
estimate_month=fDenormalize(estimate_month,AEds.max,AEds.min);
output_month=fDenormalize(output_val,AEds.max,AEds.min);
figure; bar([estimate_month,output_month]); xlabel('samples'); ylabel('value');
legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
title('Active Energy (KWh) with 1 month of prediction');
```



```
[rmse_month,mse_month,mae_month]=fBar_RmseMseMae(estimate_month,output_month);
```



```
save(fullfile(datapath,'rmse_month.mat'),'rmse_month');
```

```

save(fullfile(datapath,'mse_month.mat'),'mse_month');
save(fullfile(datapath,'mae_month.mat'),'mae_month');

%figure; plot([estimate_month,output_month]); xlabel('samples'); ylabel('value');
%legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
%title('Active Energy (KWh) with 1 month of prediction');
clear model_month output_month estimate_month rmse_month mse_month mae_month RMSE_month

```

RMSE (Testing): 1 week [threshold = 0.750; training\_size=0.85;]

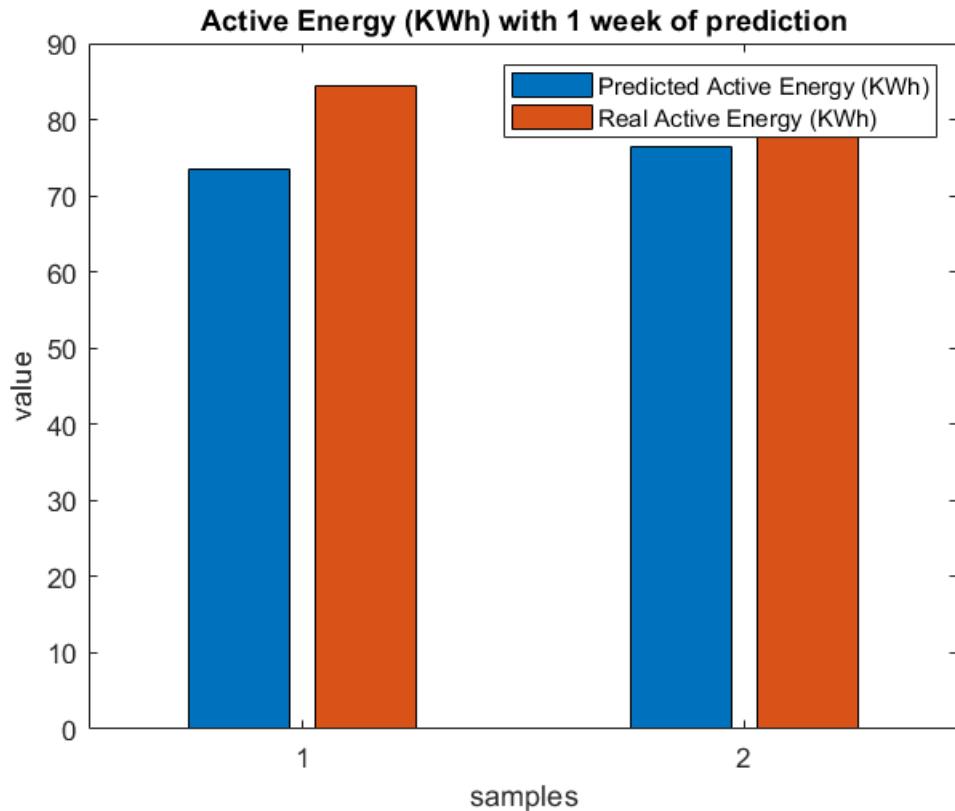
```

% input: Energy
input_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size):size(NewDataFeatures,1));
% output: Energy in the next time step
output_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size)+1:size(NewDataFeatures,
    ,ind_Active_Energy));%Active Energy index 5
% Generate model
%[model_week, RMSE_week] = trainRegressionModel_week(input_train, output_train);
[model_week, RMSE_week] = trainRegressionModel_week_filtered(input_train, output_train);
RMSE_week

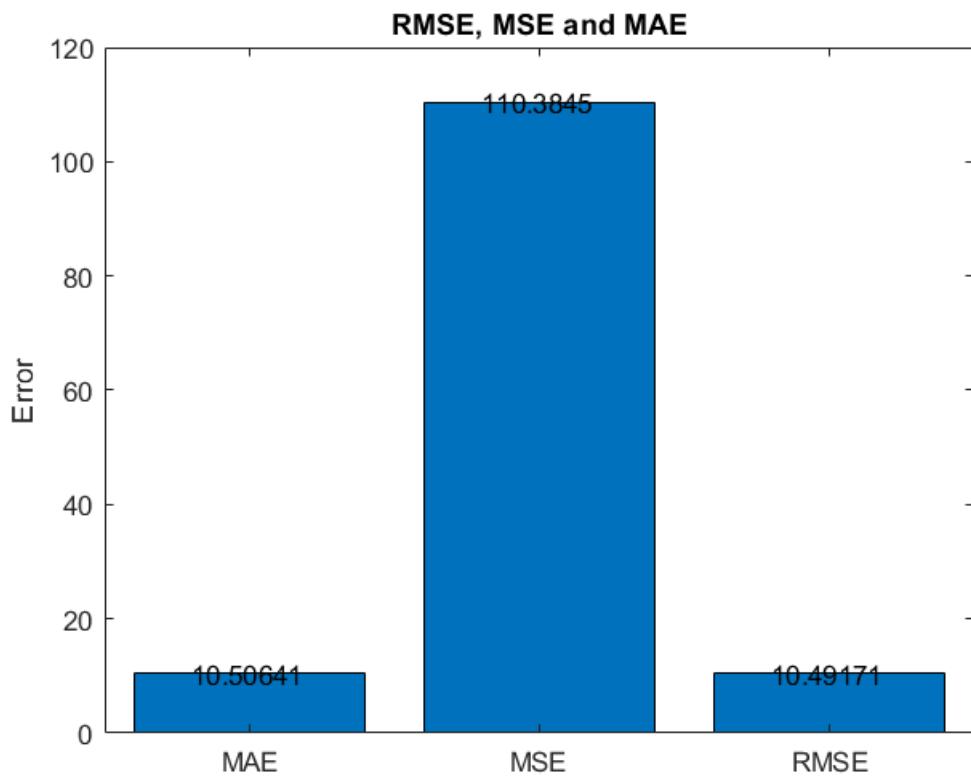
RMSE_week = 0.2358

estimate_week=model_week.predictFcn(input_val);
estimate_week=fDenormalize(estimate_week,AEds.max,AEds.min);
output_week=fDenormalize(output_val,AEds.max,AEds.min);
figure; bar([estimate_week,output_week]); xlabel('samples'); ylabel('value');
legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
title('Active Energy (KWh) with 1 week of prediction');

```



```
[rmse_week,mse_week,mae_week]=fBar_RmseMseMae(estimate_week,output_week)
```



rmse\_week = 10.5064

```

mse_week = 110.3845
mae_week = 10.4917

save(fullfile(datapath,'rmse_week.mat'),'rmse_week');
save(fullfile(datapath,'mse_week.mat'),'mse_week');
save(fullfile(datapath,'mae_week.mat'),'mae_week');

%figure; plot([estimate_week,output_week]); xlabel('samples'); ylabel('value');
%legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
%title('Active Energy (KWh) with 1 week of prediction');
clear model_week output_week estimate_week rmse_week mse_week mae_week RMSE_week

```

## RMSE (Testing): 1 day [threshold = 0.750;training\_size=0.85;]

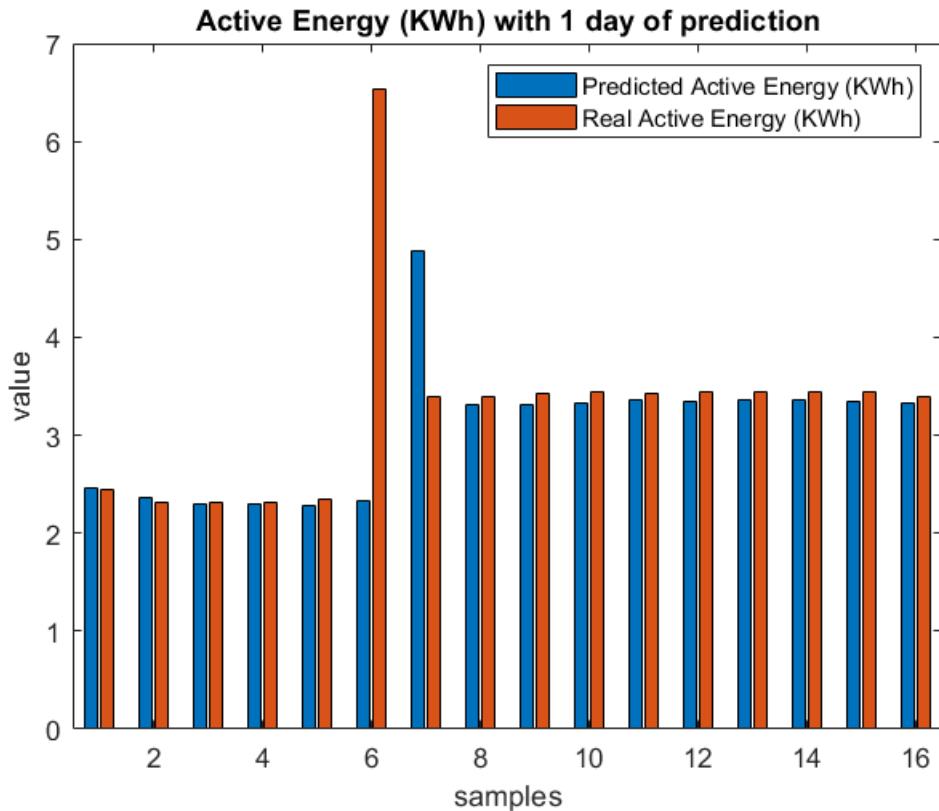
```

% input: Energy
input_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size):size(NewDataFeatures,1));
% output: Energy in the next time step
output_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size)+1:size(NewDataFeatures,
    ,ind_Active_Energy));%Active Energy index 5
% Generate model
%[model_day, RMSE_day] = trainRegressionModel_day(input_train, output_train);
[model_day, RMSE_day] = trainRegressionModel_day_filtered(input_train, output_train);
RMSE_day

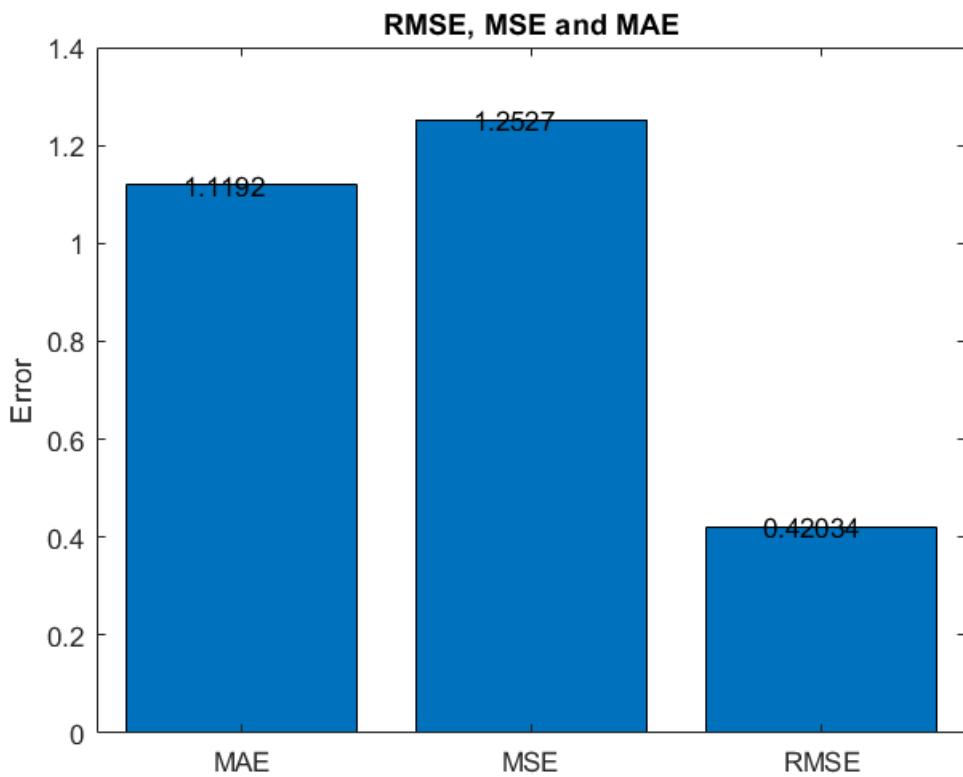
RMSE_day = 0.0535

estimate_day=model_day.predictFcn(input_val);
estimate_day=fDenormalize(estimate_day,AEds.max,AEds.min);
output_day=fDenormalize(output_val,AEds.max,AEds.min);
figure; bar([estimate_day,output_day]); xlabel('samples'); ylabel('value');
legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
title('Active Energy (KWh) with 1 day of prediction');

```



```
[rmse_day,mse_day,mae_day]=fBar_RmseMseMae(estimate_day,output_day);
```



```
save(fullfile(datapath,'rmse_day.mat'), 'rmse_day');
```

```

save(fullfile(datapath,'mse_day.mat'),'mse_day');
save(fullfile(datapath,'mae_day.mat'),'mae_day');

%figure; plot([estimate_day,output_day]); xlabel('samples'); ylabel('value');
%legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
%title('Active Energy (KWh) with 1 day of prediction');
clear model_day output_day estimate_day rmse_day mse_day mae_day RMSE_day

```

## RMSE (Testing): 1 hour [threshold = 0.750;training\_size=0.85;]

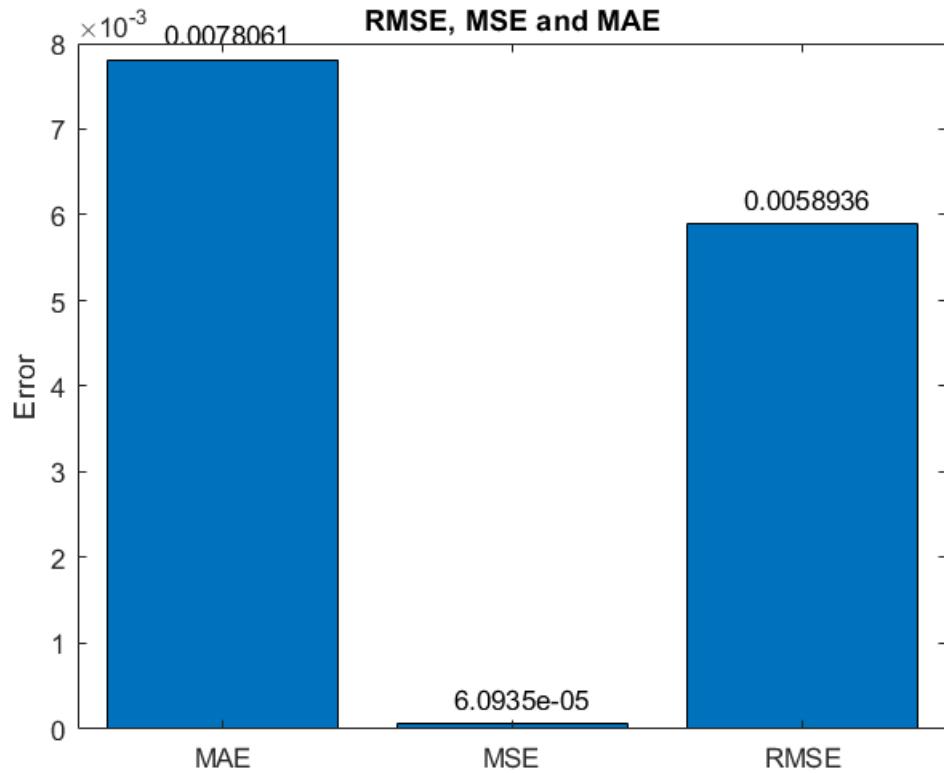
```

% input: Energy
input_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size):size(NewDataFeatures,1));
% output: Energy in the next time step
output_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size)+1:size(NewDataFeatures,
    ,ind_Active_Energy));%Active Energy index 5
% Generate model
%[model_hour, RMSE_hour] = trainRegressionModel_hour(input_train, output_train);
[model_hour, RMSE_hour] = trainRegressionModel_hour_filtered(input_train, output_train);
RMSE_hour

RMSE_hour = 0.0232

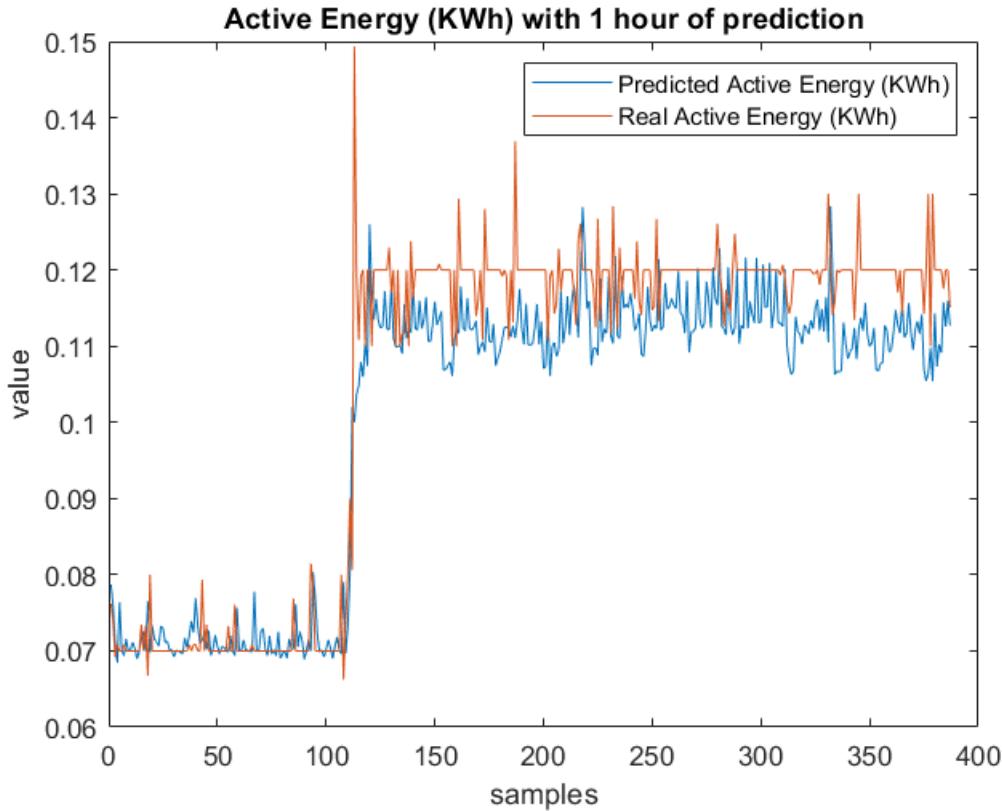
estimate_hour=model_hour.predictFcn(input_val);
estimate_hour=fDenormalize(estimate_hour,AEds.max,AEds.min);
output_hour=fDenormalize(output_val,AEds.max,AEds.min);
%figure; bar([estimate_hour,output_hour]); xlabel('samples'); ylabel('value');
%legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
%title('Active Energy (KWh) with 1 hour of prediction');
[rmse_hour,mse_hour,mae_hour]=fBar_RmseMseMae(estimate_hour,output_hour);

```



```
save(fullfile(datapath,'rmse_hour.mat'),'rmse_hour');
save(fullfile(datapath,'mse_hour.mat'),'mse_hour');
save(fullfile(datapath,'mae_hour.mat'),'mae_hour');

figure; plot([estimate_hour,output_hour]); xlabel('samples'); ylabel('value');
legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
title('Active Energy (KWh) with 1 hour of prediction');
```



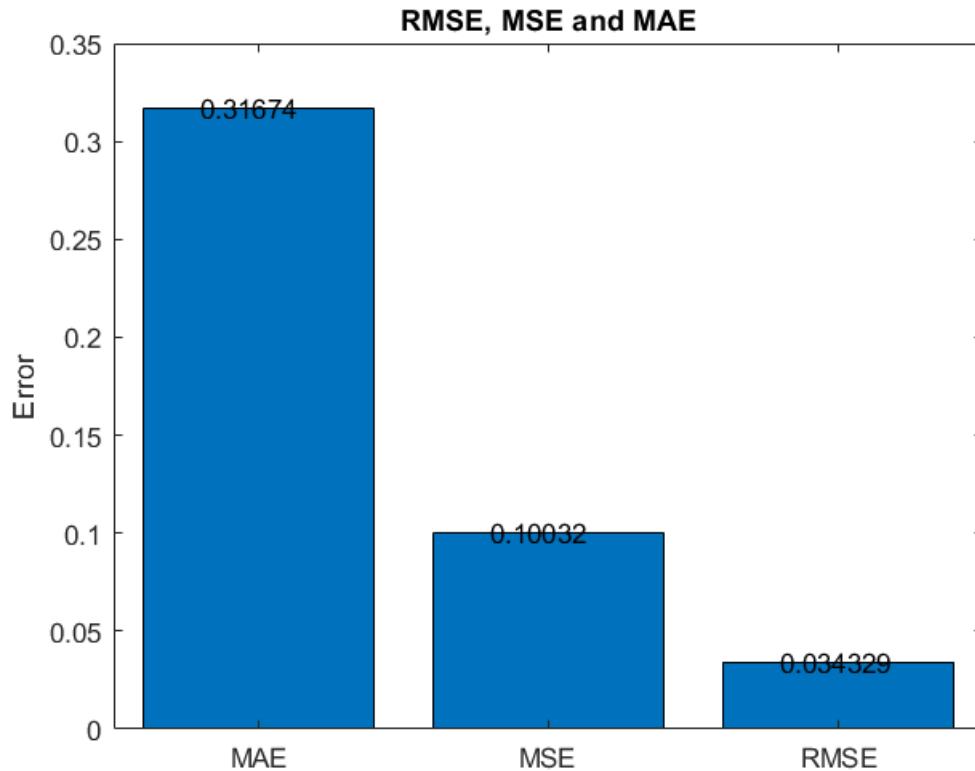
```
clear model_hour output_hour estimate_hour rmse_hour mse_hour mae_hour RMSE_hour
```

**RMSE (Testing): minute [threshold = 0.750;training\_size=0.85;]**

```
% input: Energy
input_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size):size(NewDataFeatures,1));
% output: Energy in the next time step
output_val=NewDataFeatures(round(size(NewDataFeatures,1)*training_size)+1:size(NewDataFeatures,1),ind_Active_Energy);%Active Energy index 5
% Generate model
[model_minute, RMSE_minute] = trainRegressionModel_minute(input_train, output_train);
RMSE_minute

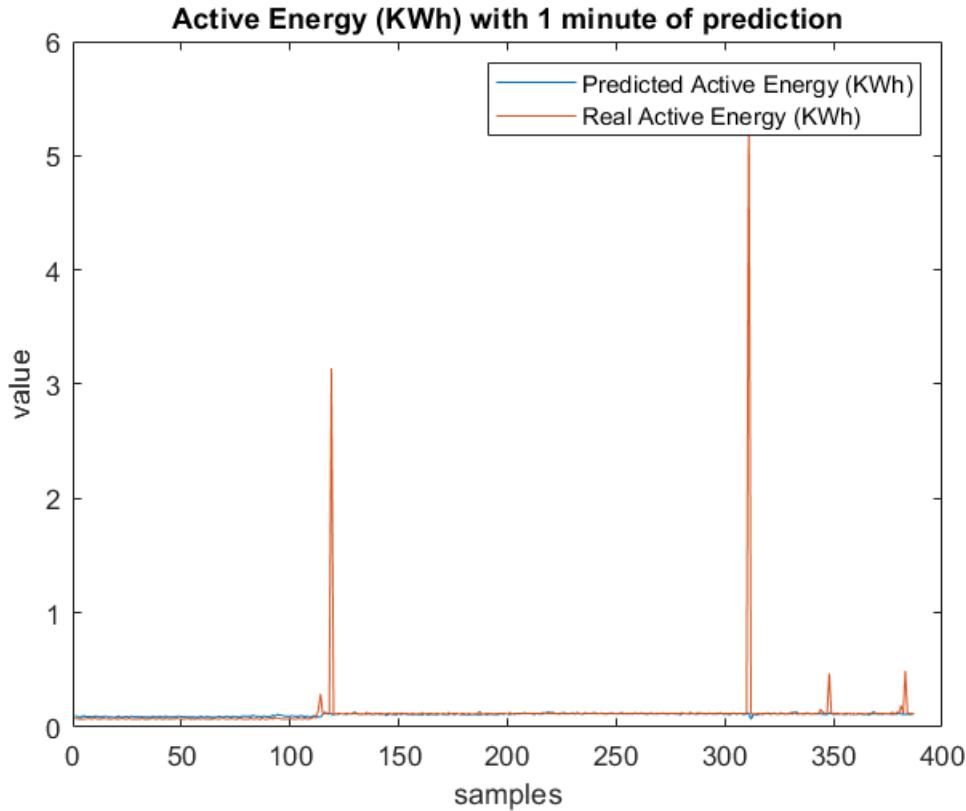
RMSE_minute = 0.0305

estimate_minute=model_minute.predictFcn(input_val);
estimate_minute=fDenormalize(estimate_minute,AEds.max,AEds.min);
output_minute=fDenormalize(output_val,AEds.max,AEds.min);
%figure; bar([estimate_minute,output_minute]);xlabel('samples');ylabel('value');
%legend('Predicted Active Energy (KWh)','Real Active Energy (KWh)');
%title('Active Energy (KWh) with 1 minute of prediction');
[rmse_minute,mse_minute,mae_minute]=fBar_RmseMseMae(estimate_minute,output_minute);
```



```
save(fullfile(datapath,'rmse_minute.mat'),'rmse_minute');
save(fullfile(datapath,'mse_minute.mat'),'mse_minute');
save(fullfile(datapath,'mae_minute.mat'),'mae_minute');

figure; plot([estimate_minute,output_minute]); xlabel('samples'); ylabel('value');
legend('Predicted Active Energy (KWh)', 'Real Active Energy (KWh)');
title('Active Energy (KWh) with 1 minute of prediction');
```

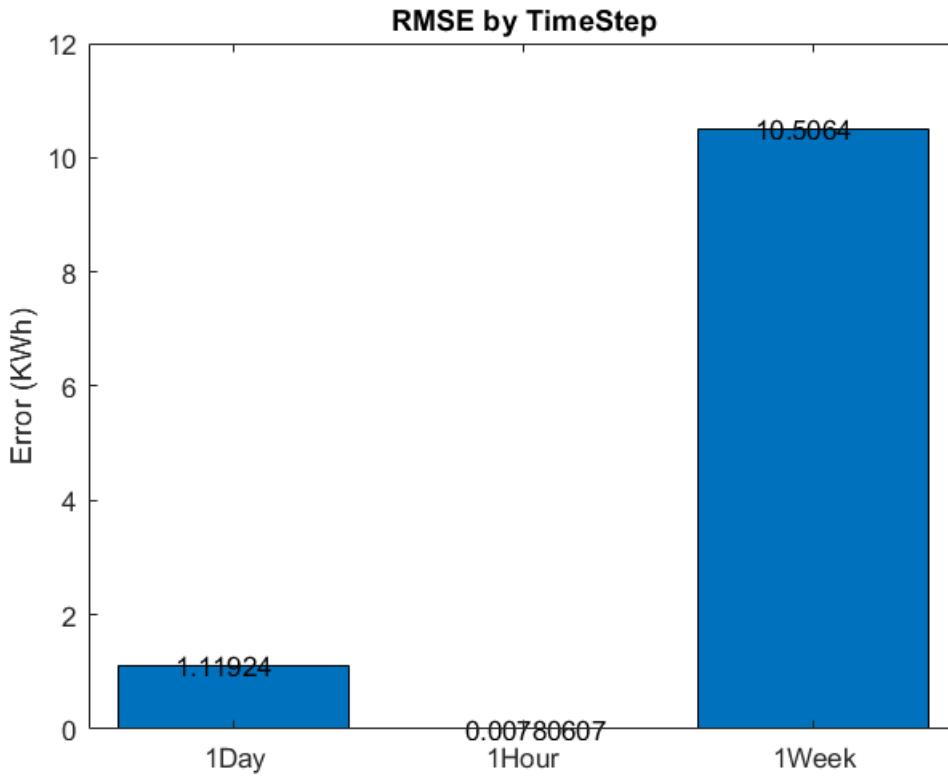


```
clear model_minute output_minute estimate_minute rmse_minute mse_minute mae_minute RMSE_minute
```

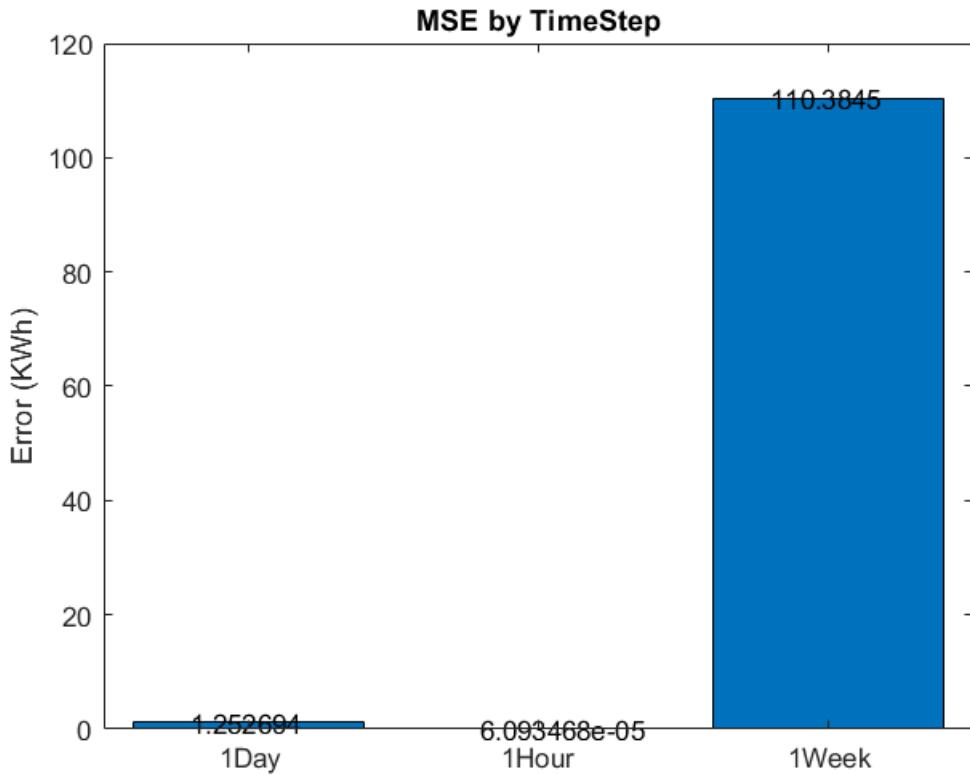
**Summary RMSE (Testing): Week, Day, Hour and Min [threshold = 0.750; training\_size=0.85;]**

```
%Month
rmse_month = load(fullfile(datapath, 'rmse_month.mat')); rmse_month=rmse_month.rmse_month;
mse_month = load(fullfile(datapath, 'mse_month.mat')); mse_month=mse_month.mse_month;
mae_month = load(fullfile(datapath, 'mae_month.mat')); mae_month=mae_month.mae_month;
%Week
rmse_week = load(fullfile(datapath, 'rmse_week.mat')); rmse_week=rmse_week.rmse_week;
mse_week = load(fullfile(datapath, 'mse_week.mat')); mse_week=mse_week.mse_week;
mae_week = load(fullfile(datapath, 'mae_week.mat')); mae_week=mae_week.mae_week;
%Day
rmse_day = load(fullfile(datapath, 'rmse_day.mat')); rmse_day=rmse_day.rmse_day;
mse_day = load(fullfile(datapath, 'mse_day.mat')); mse_day=mse_day.mse_day;
mae_day = load(fullfile(datapath, 'mae_day.mat')); mae_day=mae_day.mae_day;
%Hour
rmse_hour = load(fullfile(datapath, 'rmse_hour.mat')); rmse_hour=rmse_hour.rmse_hour;
mse_hour = load(fullfile(datapath, 'mse_hour.mat')); mse_hour=mse_hour.mse_hour;
mae_hour = load(fullfile(datapath, 'mae_hour.mat')); mae_hour=mae_hour.mae_hour;
%Minute
rmse_minute = load(fullfile(datapath, 'rmse_minute.mat')); rmse_minute=rmse_minute.rmse_minute;
mse_minute = load(fullfile(datapath, 'mse_minute.mat')); mse_minute=mse_minute.mse_minute;
mae_minute = load(fullfile(datapath, 'mae_minute.mat')); mae_minute=mae_minute.mae_minute;
```

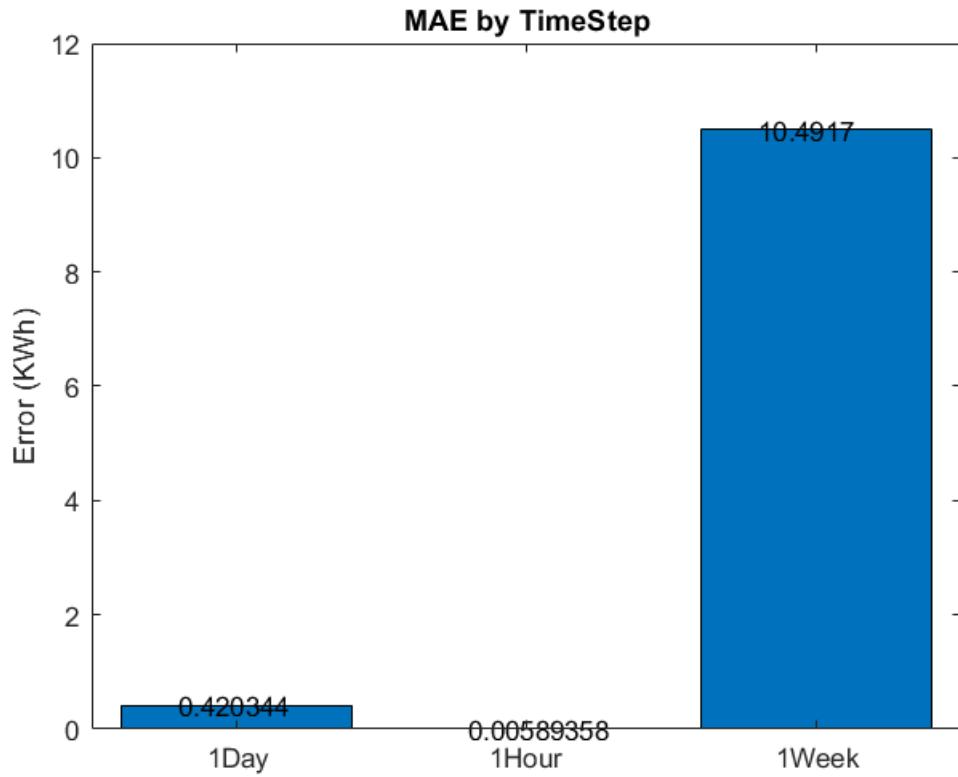
```
%c = categorical({'1Month','1Week','1Day','1Hour','1Min'});
%values = [rmse_month rmse_week rmse_day rmse_hour rmse_minute];%rmse
c = categorical({'1Week','1Day','1Hour'});
values = [rmse_week rmse_day rmse_hour];%rmse
figure;
b=bar(c,values);
ylabel('Error (KWh)')
title('RMSE by TimeStep')
xtips1 = b(1).XEndPoints - 0.2;
ytips1 = b(1).YEndPoints + 0.0003;
labels1 = string(b(1).YData);
text(xtips1,ytips1,labels1,'VerticalAlignment','middle')
```



```
%values = [mse_month mse_week mse_day mse_hour mse_minute];%mse
values = [mse_week mse_day mse_hour];%mse
figure;
b=bar(c,values);
ylabel('Error (KWh)')
title('MSE by TimeStep')
xtips1 = b(1).XEndPoints - 0.2;
ytips1 = b(1).YEndPoints + 0.0003;
labels1 = string(b(1).YData);
text(xtips1,ytips1,labels1,'VerticalAlignment','middle')
```



```
%values = [mae_month mae_week mae_day mae_hour mae_minute];%1-R2
values = [mae_week mae_day mae_hour];%1-R2
figure;
b=bar(c,values);
ylabel('Error (KWh)')
title('MAE by TimeStep')
xtips1 = b(1).XEndPoints - 0.2;
ytips1 = b(1).YEndPoints + 0.0003;
labels1 = string(b(1).YData);
text(xtips1,ytips1,labels1,'VerticalAlignment','middle')
```



## FutureWork

```
%Continue to record more data on more workstations.
```

```
%Create a model for estimating memory and CPU consumption since there are spaces without these  
%Make a real time consumption prediction system.
```