Dataset contains seven features which consists of both ambient atmospheric conditons like Relative Humidity and ambient temperature of outside air and Air handling unit machine parameters like pressure, operating speed, supply Air temperature, Chilled water pipeline actuator percentage of opening and Relative Humidity to predict variable set point.

```
#Importing data from google drive
from google.colab import drive
drive.mount('drive')
```

```
Mounted at drive
```

```
#Giving path location
train_path="/content/drive/My Drive/Project_data.xlsx"
```

```
import pandas as pd
project_data = pd.read_excel(train_path) #reading data in excel format using pandas read
```

```
print("Number of data points in train data", project_data.shape)
print('-'*50)
print("The attributes of data :", project_data.columns.values)
```

```
Number of data points in train data (460, 8)
--------------------------------------------------
The attributes of data : ['AHU_Pressure' 'AHU_Speed' 'AHU_RH' 'AHU_SAT' 'AHU_CHW_STS
 'AMB_RH' 'AHU_SP']
```

```
##check missing values
project_data.isnull().sum()
```

```
AHU_Pressure    1
AHU_Speed       1
AHU_RH          1
AHU_SAT         1
AHU_CHW_STS     1
AMB_TEMP        0
AMB_RH          0
AHU_SP          1
dtype: int64
```

```
#using describe for analysis of project data
project_data.describe()
```

	AHU_Pressure	AHU_Speed	AHU_RH	AHU_SAT	AHU_CHW_STS	AMB_TEMP	A
count	459.000000	459.000000	459.000000	459.000000	459.000000	460.000000	460.(
mean	68.677211	43.945512	61.705076	21.752026	30.349150	26.713348	68.8
std	42.713603	22.607884	5.188076	2.452894	24.722212	3.175642	22.9
min	0.000000	0.000000	44.070000	15.740000	0.000000	19.990000	0.3
25%	15.460000	32.310000	58.220000	20.085000	12.675000	24.357500	50.9

```
#Filling Missing values with Mean values
project_data['AHU_Pressure']=project_data['AHU_Pressure'].fillna(68.6)
project_data['AHU_Speed']=project_data['AHU_Speed'].fillna(43.94)
project_data['AHU_RH']=project_data['AHU_RH'].fillna(61.70)
project_data['AHU_SAT']=project_data['AHU_SAT'].fillna(21.75)
project_data['AHU_CHW_STS']=project_data['AHU_CHW_STS'].fillna(30.34)
project_data['AHU_SP']=project_data['AHU_SP'].fillna(16.07)
```

```
##check missing values
project_data.isnull().sum()
```

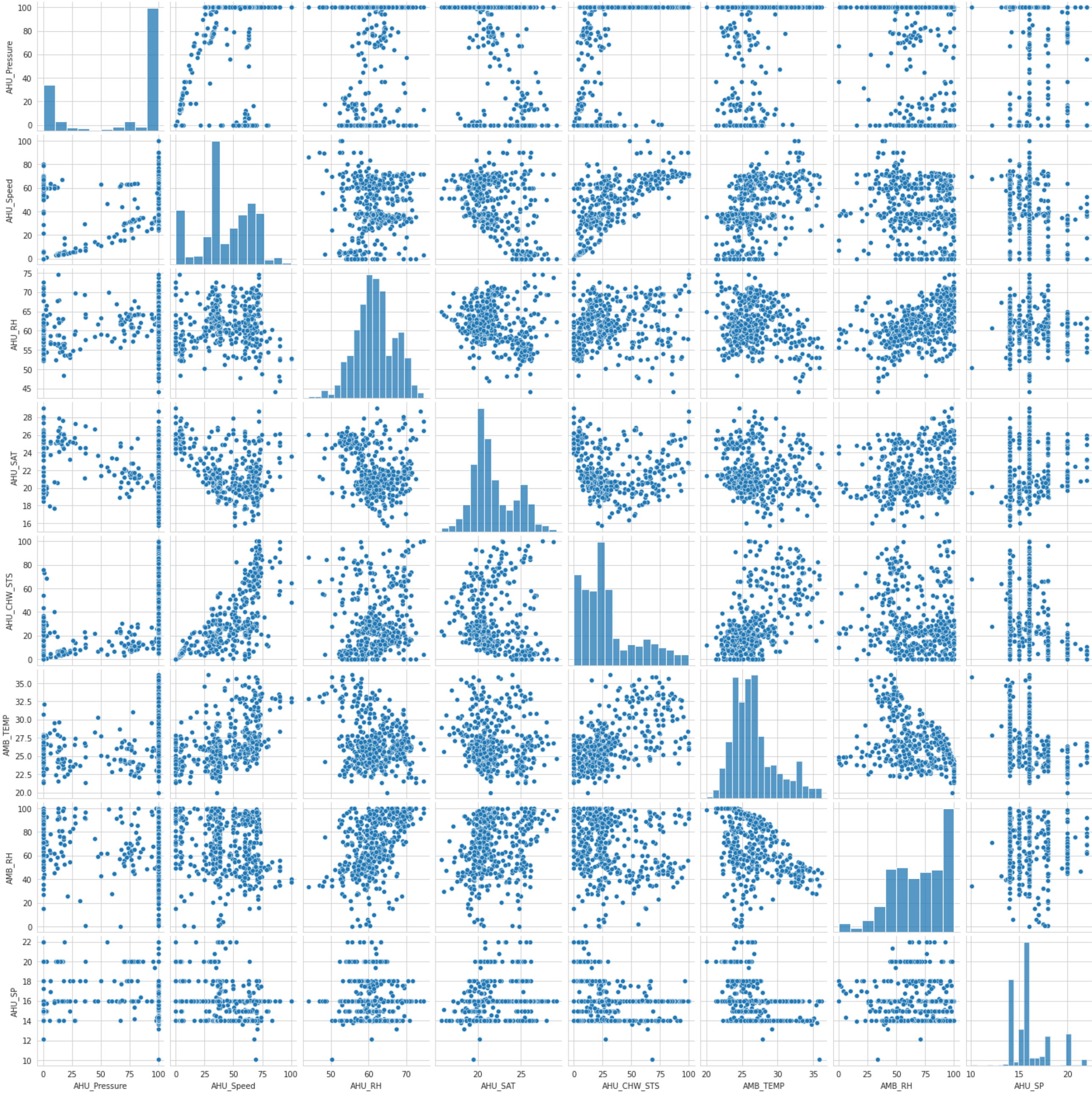
```
AHU_Pressure    0
AHU_Speed       0
AHU_RH          0
AHU_SAT         0
AHU_CHW_STS     0
AMB_TEMP        0
AMB_RH          0
AHU_SP          0
dtype: int64
```

```
project_data.head()
```

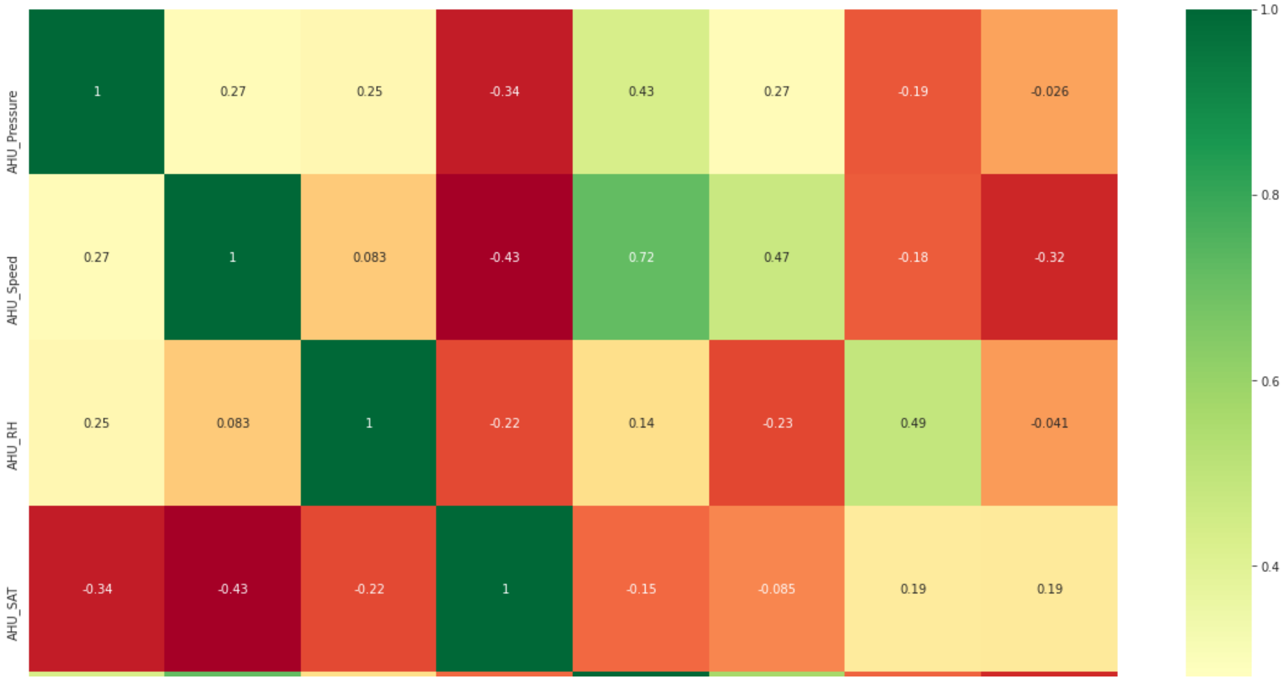
	AHU_Pressure	AHU_Speed	AHU_RH	AHU_SAT	AHU_CHW_STS	AMB_TEMP	AMB_RH	AHU_SP
0	0.00	0.00	57.65	24.89	0.00	22.73	71.45	16.0
1	0.00	0.00	58.19	23.96	0.00	22.58	76.18	16.0
2	80.37	32.50	64.15	21.22	8.07	22.61	79.67	16.0
3	82.08	33.53	64.09	21.13	8.84	22.97	73.53	16.0
4	76.38	31.49	63.63	21.48	11.97	22.91	69.04	16.0

```
#using seaborn pair plot to see relation between feature analysis
sns.pairplot(project_data)
```

```
<seaborn.axisgrid.PairGrid at 0x7f3cf33fb630>
```



```
import seaborn as sns
#get correlations of each features in dataset
corrmat = project_data.corr()
top_corr_features = corrmat.index
plt.figure(figsize=(20,20))
#plot heat map
g=sns.heatmap(project_data[top_corr_features].corr(),annot=True,cmap="RdYlGn")
```




```
#Dropping prediction variable from dataset
y = project_data['AHU_SP'].values
X = project_data.drop(['AHU_SP'], axis=1)
X.head(1)
```

	AHU_Pressure	AHU_Speed	AHU_RH	AHU_SAT	AHU_CHW_STS	AMB_TEMP	AMB_RH
0	0.0	0.0	57.65	24.89	0.0	22.73	71.45

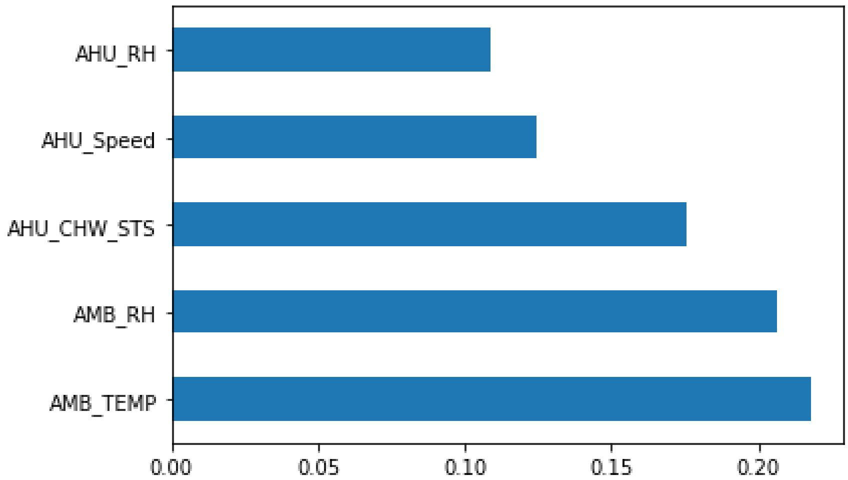
```
### Feature Importance

from sklearn.ensemble import ExtraTreesRegressor
import matplotlib.pyplot as plt
model = ExtraTreesRegressor()
model.fit(X,y)
```

```
ExtraTreesRegressor(bootstrap=False, ccp_alpha=0.0, criterion='mse',
                    max_depth=None, max_features='auto', max_leaf_nodes=None,
                    max_samples=None, min_impurity_decrease=0.0,
                    min_impurity_split=None, min_samples_leaf=1,
                    min_samples_split=2, min_weight_fraction_leaf=0.0,
                    n_estimators=100, n_jobs=None, oob_score=False,
                    random_state=None, verbose=0, warm_start=False)
```

```
print(model.feature_importances_)
```

```
[0.08708302 0.12429334 0.10846965 0.08036415 0.17563671 0.21760065
 0.20655247]
```

```
#plot graph of feature importances for better visualization
feat_importances = pd.Series(model.feature_importances_, index=X.columns)
feat_importances.nlargest(5).plot(kind='barh')
plt.show()
```




```
# train test split
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=0)
```

RandomForestRegressor

```
from sklearn.ensemble import RandomForestRegressor
```

```
import numpy as np
n_estimators = [int(x) for x in np.linspace(start = 100, stop = 1200, num = 12)]
print(n_estimators)
```

```
[100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200]
```

```
from sklearn.model_selection import RandomizedSearchCV
```

```
#Randomized Search CV

# Number of trees in random forest
n_estimators = [int(x) for x in np.linspace(start = 100, stop = 1200, num = 12)]
# Number of features to consider at every split
max_features = ['auto', 'sqrt']
# Maximum number of levels in tree
max_depth = [int(x) for x in np.linspace(5, 30, num = 6)]
# max_depth.append(None)
# Minimum number of samples required to split a node
min_samples_split = [2, 5, 10, 15, 100]
# Minimum number of samples required at each leaf node
min_samples_leaf = [1, 2, 5, 10]
```

```
# Create the random grid
random_grid = {'n_estimators': n_estimators,
               'max_features': max_features,
               'max_depth': max_depth,
               'min_samples_split': min_samples_split,
               'min_samples_leaf': min_samples_leaf}
```

```
print(random_grid)
```

```
{'n_estimators': [100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200], 'ma
```

```
# Use the random grid to search for best hyperparameters
# First create the base model to tune
rf = RandomForestRegressor()


# Random search of parameters, using 3 fold cross validation,
# search across 100 different combinations
rf_random = RandomizedSearchCV(estimator = rf, param_distributions = random_grid,scoring='
```

```
rf_random.fit(X_train,y_train)
```

```
Fitting 5 folds for each of 10 candidates, totalling 50 fits
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    1.2s remaining:    0.0s
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
```

```
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqrt
[CV]  n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqr
[CV] n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqrt
[CV]  n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqr
```

```
#best parameters
rf_random.best_params_
```

```
{'max_depth': 25,
 'max_features': 'sqrt',
 'min_samples_leaf': 1,
 'min_samples_split': 2,
 'n_estimators': 1000}
```

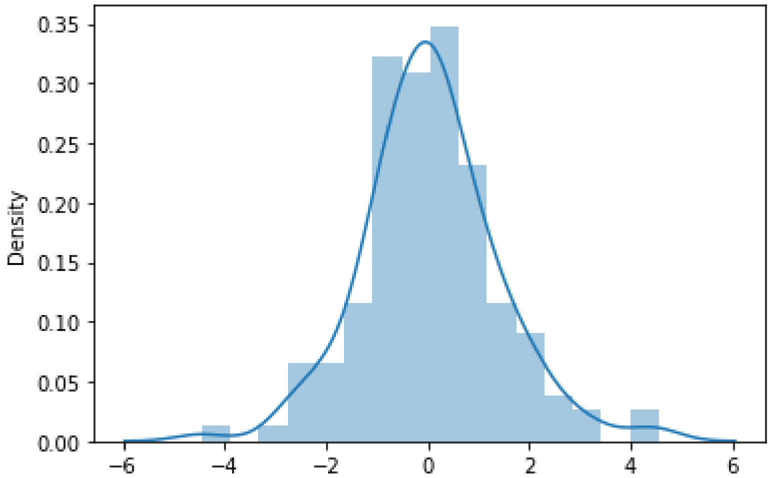
```
#best score
rf_random.best_score_
```

```
-2.089919541406836
```

```
predictions=rf_random.predict(X_test)
```

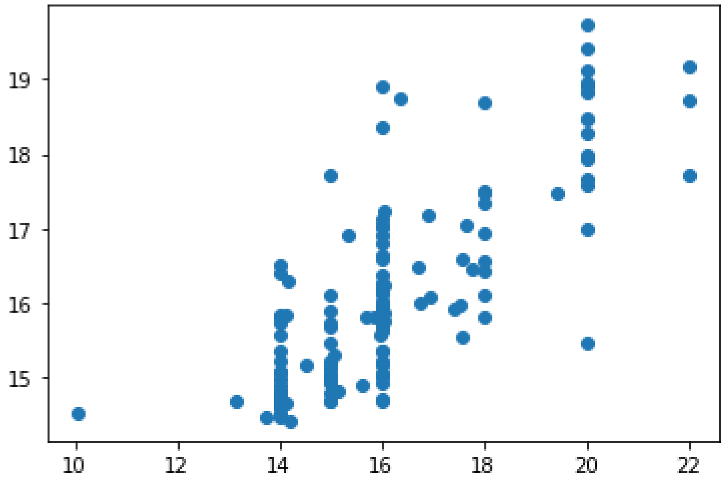
```
import seaborn as sns
sns.distplot(y_test-predictions)
```

```
/usr/local/lib/python3.6/dist-packages/seaborn/distributions.py:2551: FutureWarning:
  warnings.warn(msg, FutureWarning)
<matplotlib.axes._subplots.AxesSubplot at 0x7f3cf8cb9278>
```



```
plt.scatter(y_test,predictions)
```

```
<matplotlib.collections.PathCollection at 0x7f3cf79fb1d0>
```




```
from sklearn import metrics
```

```
print('MAE:', metrics.mean_absolute_error(y_test, predictions))
print('MSE:', metrics.mean_squared_error(y_test, predictions))
print('RMSE:', np.sqrt(metrics.mean_squared_error(y_test, predictions)))
```

```
MAE: 0.9868490579710102
MSE: 1.8005124787746296
RMSE: 1.341831762470478
```

GradientBoostingRegressor

```
from sklearn.ensemble import GradientBoostingClassifier
from sklearn import datasets, ensemble
```

```
rf1=ensemble.GradientBoostingRegressor()
```

```
# Random search of parameters, using 3 fold cross validation,
# search across 100 different combinations
rf1_random = RandomizedSearchCV(estimator = rf1, param_distributions = random_grid,scoring
```

```
rf1_random.fit(X_train,y_train)
```

```
Fitting 5 folds for each of 10 candidates, totalling 50 fits
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.4s remaining:    0.0s
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
```

```
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt,
[CV]  n_estimators=900, min_samples_split=5, min_samples_leaf=5, max_features=sqrt
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sqr
[CV]  n_estimators=1100, min_samples_split=10, min_samples_leaf=2, max_features=sq
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=aut
[CV]  n_estimators=300, min_samples_split=100, min_samples_leaf=5, max_features=au
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto,
[CV]  n_estimators=400, min_samples_split=5, min_samples_leaf=5, max_features=auto
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=auto
[CV]  n_estimators=700, min_samples_split=5, min_samples_leaf=10, max_features=aut
[CV] n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqrt
[CV]  n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqr
[CV] n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqrt
[CV]  n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqr
[CV] n_estimators=1000, min_samples_split=2, min_samples_leaf=1, max_features=sqrt
```

```
#best parameters
rf1_random.best_params_
```

```
{'max_depth': 25,
 'max_features': 'sqrt',
 'min_samples_leaf': 1,
 'min_samples_split': 2,
 'n_estimators': 1000}
```

```
#best score
```

```
rf1_random.best_score_
```

```
-2.078266080137614
```

```
predictions1=rf1_random.predict(X_test)
```

```
print('MAE:', metrics.mean_absolute_error(y_test, predictions1))
print('MSE:', metrics.mean_squared_error(y_test, predictions1))
print('RMSE:', np.sqrt(metrics.mean_squared_error(y_test, predictions1)))
```

```
MAE: 1.023274184408106
MSE: 1.8924409377206084
RMSE: 1.3756601825016992
```

SUMMARY

```
# http://zetcode.com/python/prettytable/

from prettytable import PrettyTable
x = PrettyTable()
x.field_names = ["Algorithm","MAX_DEPTH", "MIN_SAMPLE_SPLIT", "Error Value"]

x.add_row(["RandomForestRegressor","25","2", 0.98])
x.add_row(["GradientBoostingRegressor", "25", "2",1.02])
print(x)
```

```
+---------------------------+-----------+------------------+-------------+
|         Algorithm         | MAX_DEPTH | MIN_SAMPLE_SPLIT | Error Value |
+---------------------------+-----------+------------------+-------------+
|   RandomForestRegressor   |     25    |        2         |     0.98    |
| GradientBoostingRegressor |     25    |        2         |     1.02    |
+---------------------------+-----------+------------------+-------------+
```

Reference:

1)https://www.primexvents.com/why-machine-learning-is-the-future-of-hvac-and-building-management/

2)https://www.linkedin.com/pulse/machine-learning-hvac-controls-mike-donlon/

3)https://www.frontiersin.org/articles/10.3389/fbuil.2020.00049/full

4)https://www.ibm.com/blogs/research/2018/07/reduce-energy-cooling/

5)https://www.youtube.com/watch?v=VpHv8SZE0eI