The Following Code Explores Various Models and **Effective Vizualisations** That are Easy to Understand

Detailed Explanation on **Statistical Concepts**

The Best Mean Squared Error **(MSE)** Numeric Obtained By a Few Models was: **0.0317** and an Accuray of **97.11%**

Concepts Like **VIF and PCA** have been used to transform the dataset, Vizualizations Include Scatter Plots and Hist Plots

Models are Subject to Betterment with Stringent Hyper parameter tuning, Like using **GridSearchCV** to Run through multiple combinations of potential hyperparameters

```
import pandas as pd
import matplotlib.pyplot as plt
from matplotlib import style
import seaborn as sns
import numpy as np
from sklearn.impute import KNNImputer
from sklearn.experimental import enable_iterative_imputer
from sklearn.impute import IterativeImputer
from statsmodels.stats.outliers_influence import
variance_inflation_factor
import matplotlib.pyplot as plt
from sklearn.metrics import mean_squared_error

from sklearn.metrics import accuracy_score
from sklearn.tree import DecisionTreeRegressor
from sklearn.ensemble import RandomForestRegressor
from sklearn.neighbors import KNeighborsRegressor
from sklearn.svm import SVR
from sklearn.linear_model import LinearRegression
from sklearn.ensemble import AdaBoostRegressor
from sklearn.ensemble import GradientBoostingRegressor
from xgboost import XGBRegressor
from sklearn.linear_model import
Lasso,Ridge,BayesianRidge,ElasticNet,HuberRegressor,LinearRegression,L
ogisticRegression,SGDRegressor
```

```
df=pd.read_csv('../input/synchronous-machine-dataset/
SynchronousMachine.csv')
df.rename(columns = {'I_y':'Load Current', 'PF':'Power Factor',
                              'e_PF':'Power Factor
Error','d_if':'Excitation Current Change','I_f':'Excitation Current'},
inplace = True)
df.head()
```

```
   Load Current  Power Factor  Power Factor Error  Excitation Current
Change  \
```

```
0           3.0         0.66                0.34
0.383
1           3.0         0.68                0.32
0.372
2           3.0         0.70                0.30
0.360
3           3.0         0.72                0.28
0.338
4           3.0         0.74                0.26
0.317

   Excitation Current
0               1.563
1               1.552
2               1.540
3               1.518
4               1.497
```

```
def describe(df):                               # Function to explore major
elements in a Dataset
                                                # Will help to find null
values present and deal with them
  columns=df.columns.to_list()           # Function will help to
directly find numerical and categorical columns
  ncol=df.describe().columns.to_list()
  ccol=[]
  for i in columns:
    if(ncol.count(i)==0):
      ccol.append(i)
    else:
      continue
  print('Name of all columns in the dataframe:')
  print(columns)
  print('')
  print('Number of columns in the dataframe:')
  print(len(columns))
  print('')
  print('Name of all numerical columns in the dataframe:')
  print(ncol)
  print('')
  print('Number of numerical columns in the dataframe:')
  print(len(ncol))
  print('')
  print('Name of all categorical columns in the dataframe:')
  print(ccol)
  print('')
  print('Number of categorical columns in the dataframe:')
  print(len(ccol))
  print('')
```

```
print('-----------------------------------------------------------------------
---------------------------------')
  print('')
  print('Number of Null Values in Each Column:')
  print('')
  print(df.isnull().sum())
  print('')
  print('')
  print('Number of Unique Values in Each Column:')
  print('')
  print(df.nunique())
  print('')
  print('')
  print('Basic Statistics and Measures for Numerical Columns:')
  print('')
  print(df.describe().T)
  print('')
  print('')
  print('Other Relevant Metadata Regarding the Dataframe:')
  print('')
  print(df.info())
  print('')
  print('')

describe(df)
```

```
Name of all columns in the dataframe:
['Load Current', 'Power Factor', 'Power Factor Error', 'Excitation
Current Change', 'Excitation Current']

Number of columns in the dataframe:
5

Name of all numerical columns in the dataframe:
['Load Current', 'Power Factor', 'Power Factor Error', 'Excitation
Current Change', 'Excitation Current']

Number of numerical columns in the dataframe:
5

Name of all categorical columns in the dataframe:
[]

Number of categorical columns in the dataframe:
0

-----------------------------------------------------------------------
--------------------------

Number of Null Values in Each Column:
```

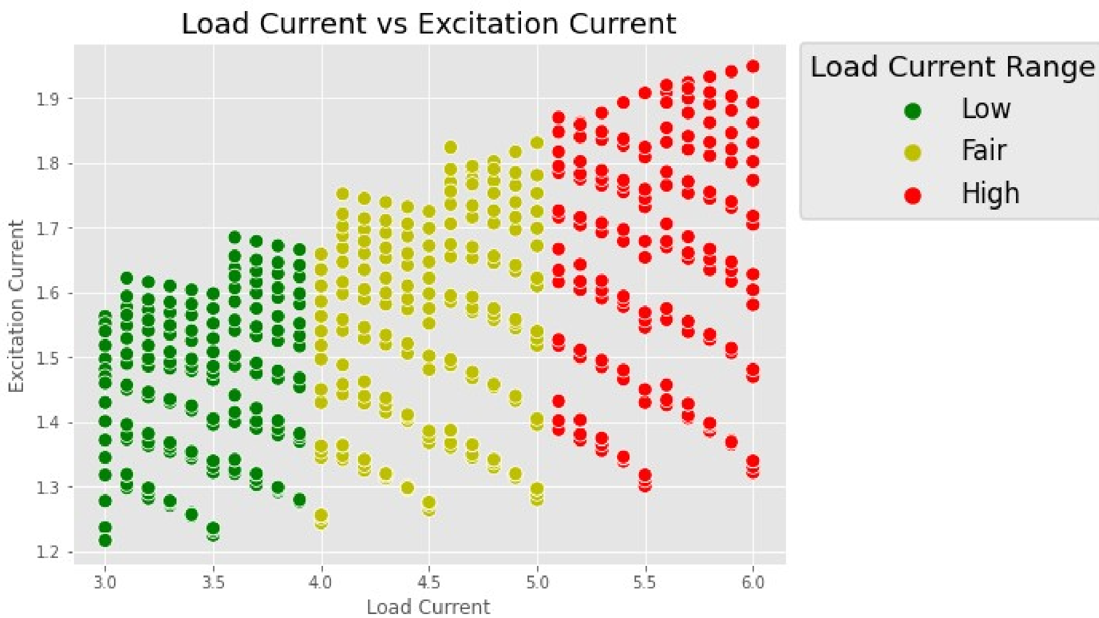
```
Load Current                 0
Power Factor                 0
Power Factor Error           0
Excitation Current Change    0
Excitation Current           0
dtype: int64


Number of Unique Values in Each Column:

Load Current                  31
Power Factor                  36
Power Factor Error            36
Excitation Current Change    306
Excitation Current           306
dtype: int64


Basic Statistics and Measures for Numerical Columns:

                           count      mean       std    min    25%
50%  \
Load Current               557.0  4.499820  0.896024  3.000  3.700
4.500
Power Factor               557.0  0.825296  0.103925  0.650  0.740
0.820
Power Factor Error         557.0  0.174704  0.103925  0.000  0.080
0.180
Excitation Current Change  557.0  0.350659  0.180566  0.037  0.189
0.345
Excitation Current         557.0  1.530659  0.180566  1.217  1.369
1.525

                             75%    max
Load Current               5.300  6.000
Power Factor               0.920  1.000
Power Factor Error         0.260  0.350
Excitation Current Change  0.486  0.769
Excitation Current         1.666  1.949


Other Relevant Metadata Regarding the Dataframe:

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 557 entries, 0 to 556
Data columns (total 5 columns):
 #   Column                     Non-Null Count  Dtype
---  ------                     --------------  -----
```

```
 0   Load Current               557 non-null    float64
 1   Power Factor               557 non-null    float64
 2   Power Factor Error         557 non-null    float64
 3   Excitation Current Change  557 non-null    float64
 4   Excitation Current         557 non-null    float64
dtypes: float64(5)
memory usage: 21.9 KB
None
```

```python
import warnings
warnings.filterwarnings("ignore")
# We are creating 3 categories for better vizualisation
# Split was chosen after Personal research and is subject to change

df['Load Current Range']=0
for i in range(0,len(df)):
  if(df['Load Current'][i]>5):
    df['Load Current Range'][i]='High'
  elif(df['Load Current'][i]<4):
    df['Load Current Range'][i]='Low'
  else:
    df['Load Current Range'][i]='Fair'
```

```python
oe=['g','y','r']
plt.tight_layout()
plt.style.use('ggplot')
fig, ax = plt.subplots(figsize=(8, 6))
sns.set_context('talk')
plt.title('Load Current vs Excitation Current')
sns.scatterplot( x="Load Current",y='Excitation Current', hue="Load
Current Range",data=df,palette=oe)
plt.legend(bbox_to_anchor=(1.02, 1), loc='upper left',
borderaxespad=0, title='Load Current Range')
```

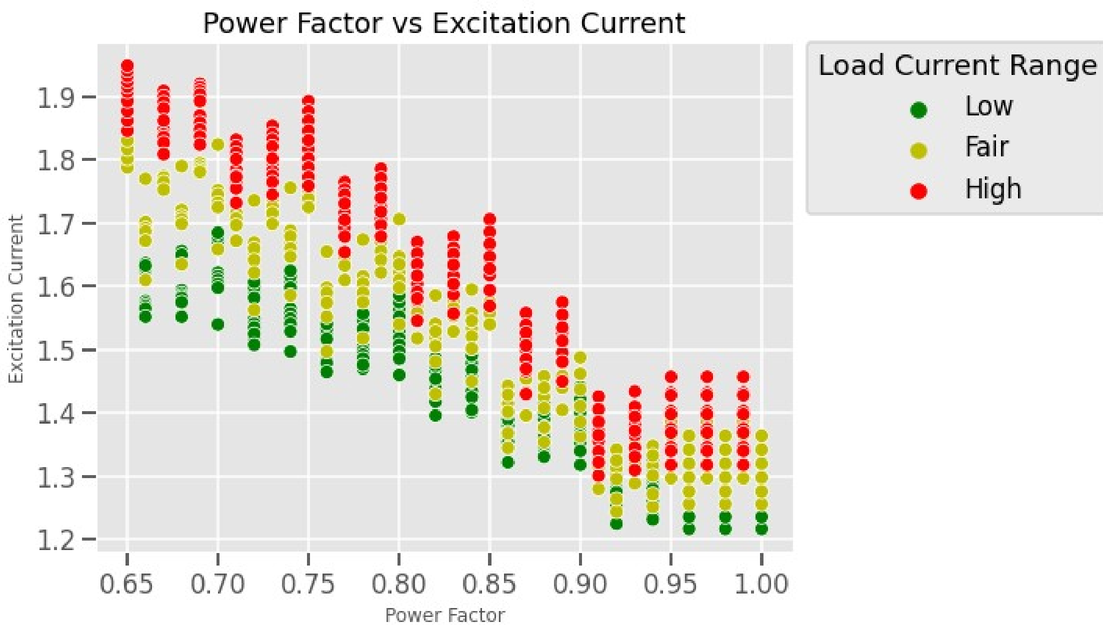
```
<matplotlib.legend.Legend at 0x7feb77a37510>

<Figure size 432x288 with 0 Axes>
```




```
oe=['g','y','r']
plt.tight_layout()
plt.style.use('ggplot')
fig, ax = plt.subplots(figsize=(8, 6))
sns.set_context('talk')
plt.title('Power Factor vs Excitation Current')
sns.scatterplot( x="Power Factor",y='Excitation Current', hue="Load
Current Range",data=df,palette=oe)
plt.legend(bbox_to_anchor=(1.02, 1), loc='upper left',
borderaxespad=0, title='Load Current Range')
```

```
<matplotlib.legend.Legend at 0x7feb77942a90>
```

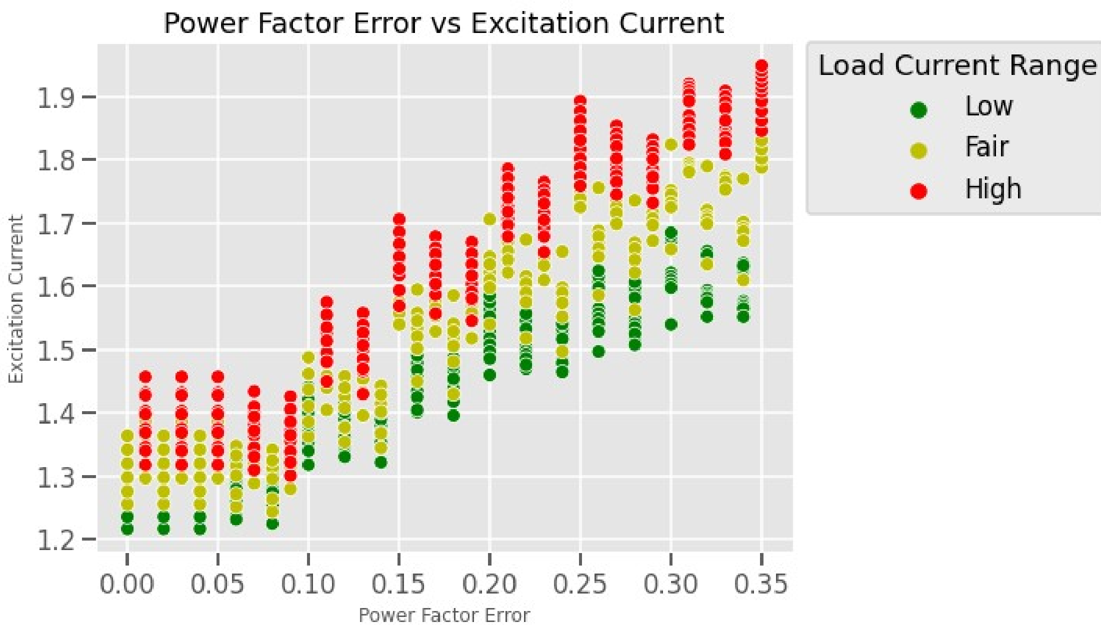
```
<Figure size 432x288 with 0 Axes>
```




```
oe=['g','y','r']
plt.tight_layout()
plt.style.use('ggplot')
fig, ax = plt.subplots(figsize=(8, 6))
sns.set_context('talk')
plt.title('Power Factor Error vs Excitation Current')
sns.scatterplot( x="Power Factor Error",y='Excitation Current',
hue="Load Current Range",data=df,palette=oe)
plt.legend(bbox_to_anchor=(1.02, 1), loc='upper left',
borderaxespad=0, title='Load Current Range')
```

```
<matplotlib.legend.Legend at 0x7feb7608c910>
```

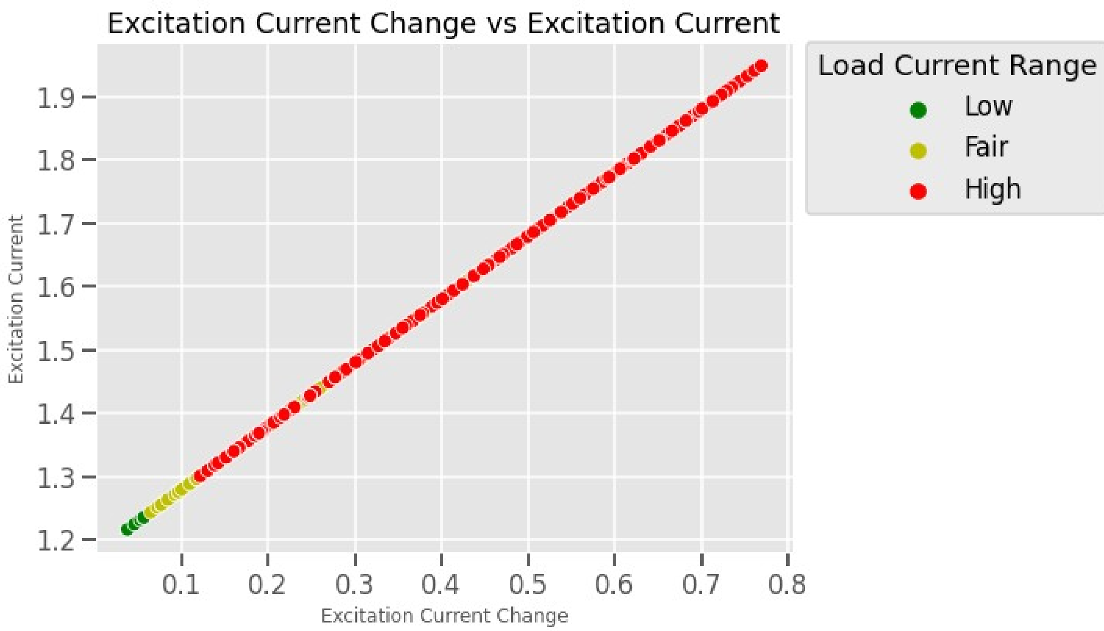
```
<Figure size 432x288 with 0 Axes>
```




```
oe=['g','y','r']
plt.tight_layout()
plt.style.use('ggplot')
fig, ax = plt.subplots(figsize=(8, 6))
sns.set_context('talk')
plt.title('Excitation Current Change vs Excitation Current')
sns.scatterplot( x="Excitation Current Change",y='Excitation Current',
hue="Load Current Range",data=df,palette=oe)
plt.legend(bbox_to_anchor=(1.02, 1), loc='upper left',
borderaxespad=0, title='Load Current Range')
```

```
<matplotlib.legend.Legend at 0x7feb75fbde10>
```

```
<Figure size 432x288 with 0 Axes>
```



Relationship between all independent variables to the target variable see pretty linear, Next we can look up the Statistics for ols regression to check for p value, F-Statistics and regression coefficients for each variable to see how much change each independent variable bring to the target variable (i.e. excitation current)

```
import statsmodels.formula.api as sm

from statsmodels.api import OLS
reg=OLS(df['Excitation Current'],df['Load Current'] ).fit()
print(reg.summary())
print('')
print('')
reg=OLS(df['Excitation Current'],df['Power Factor'] ).fit()
print(reg.summary())
print('')
print('')
reg=OLS(df['Excitation Current'],df['Power Factor Error'] ).fit()
print(reg.summary())
print('')
print('')
reg=OLS(df['Excitation Current'],df['Excitation Current
Change'] ).fit()
print(reg.summary())
print('')
print('')
```

```
                                 OLS Regression Results

======================================================================
=================
Dep. Variable:     Excitation Current   R-squared (uncentered):
```

```
0.968
Model:                            OLS   Adj. R-squared (uncentered):
0.968
Method:                 Least Squares   F-statistic:
1.668e+04
Date:                Fri, 10 Dec 2021   Prob (F-statistic):
0.00
Time:                        13:56:05   Log-Likelihood:
-74.876
No. Observations:                 557   AIC:
151.8
Df Residuals:                     556   BIC:
156.1
Df Model:                           1

Covariance Type:            nonrobust

======================================================================
==========
                 coef    std err          t      P>|t|      [0.025
0.975]
----------------------------------------------------------------------
----------
Load Current     0.3305      0.003    129.166      0.000       0.325
0.335
======================================================================
========
Omnibus:                       20.333   Durbin-Watson:
0.145
Prob(Omnibus):                  0.000   Jarque-Bera (JB):
15.965
Skew:                          -0.324   Prob(JB):
0.000341
Kurtosis:                       2.482   Cond. No.
1.00
======================================================================
========

Notes:
[1] R² is computed without centering (uncentered) since the model does
not contain a constant.
[2] Standard Errors assume that the covariance matrix of the errors is
correctly specified.


                            OLS Regression Results

======================================================================
=================
Dep. Variable:     Excitation Current   R-squared (uncentered):
```

```
0.946
Model:                            OLS   Adj. R-squared (uncentered):
0.946
Method:                 Least Squares   F-statistic:
9797.
Date:                Fri, 10 Dec 2021   Prob (F-statistic):
0.00
Time:                        13:56:05   Log-Likelihood:
-216.89
No. Observations:                 557   AIC:
435.8
Df Residuals:                     556   BIC:
440.1
Df Model:                           1

Covariance Type:            nonrobust

======================================================================
==========
                   coef    std err          t      P>|t|      [0.025
0.975]
----------------------------------------------------------------------
----------
Power Factor     1.8025      0.018     98.981      0.000       1.767
1.838
======================================================================
========
Omnibus:                      320.212   Durbin-Watson:
0.426
Prob(Omnibus):                  0.000   Jarque-Bera (JB):
33.136
Skew:                           0.087   Prob(JB):
6.38e-08
Kurtosis:                       1.818   Cond. No.
1.00
======================================================================
========

Notes:
[1] R² is computed without centering (uncentered) since the model does
not contain a constant.
[2] Standard Errors assume that the covariance matrix of the errors is
correctly specified.


                                 OLS Regression Results

======================================================================
=================
Dep. Variable:     Excitation Current   R-squared (uncentered):
```

```
0.819
Model:                            OLS   Adj. R-squared (uncentered):
0.819
Method:                 Least Squares   F-statistic:
2523.
Date:                Fri, 10 Dec 2021   Prob (F-statistic):
8.49e-209
Time:                        13:56:05   Log-Likelihood:
-554.64
No. Observations:                 557   AIC:
1111.
Df Residuals:                     556   BIC:
1116.
Df Model:                           1

Covariance Type:            nonrobust

======================================================================
================
                         coef    std err          t      P>|t|
[0.025      0.975]
----------------------------------------------------------------------
----------------
Power Factor Error     6.8650      0.137     50.228      0.000
6.596       7.133
======================================================================
========
Omnibus:                      137.625   Durbin-Watson:
0.427
Prob(Omnibus):                  0.000   Jarque-Bera (JB):
25.100
Skew:                          -0.024   Prob(JB):
3.54e-06
Kurtosis:                       1.961   Cond. No.
1.00
======================================================================
========

Notes:
[1] R² is computed without centering (uncentered) since the model does
not contain a constant.
[2] Standard Errors assume that the covariance matrix of the errors is
correctly specified.


                                 OLS Regression Results

======================================================================
=================
Dep. Variable:     Excitation Current   R-squared (uncentered):
```

```
0.877
Model:                            OLS   Adj. R-squared (uncentered):
0.877
Method:                 Least Squares   F-statistic:
3976.
Date:                Fri, 10 Dec 2021   Prob (F-statistic):
1.71e-255
Time:                        13:56:05   Log-Likelihood:
-446.95
No. Observations:                 557   AIC:
895.9
Df Residuals:                     556   BIC:
900.2
Df Model:                           1

Covariance Type:            nonrobust

======================================================================
=======================
                               coef    std err          t      P>|t|
[0.025      0.975]
----------------------------------------------------------------------
-----------------------
Excitation Current Change     3.6608      0.058     63.058      0.000
3.547       3.775
======================================================================
========
Omnibus:                       78.953   Durbin-Watson:
0.284
Prob(Omnibus):                  0.000   Jarque-Bera (JB):
26.884
Skew:                          -0.291   Prob(JB):
1.45e-06
Kurtosis:                       2.095   Cond. No.
1.00
======================================================================
========

Notes:
[1] R² is computed without centering (uncentered) since the model does
not contain a constant.
[2] Standard Errors assume that the covariance matrix of the errors is
correctly specified.
```

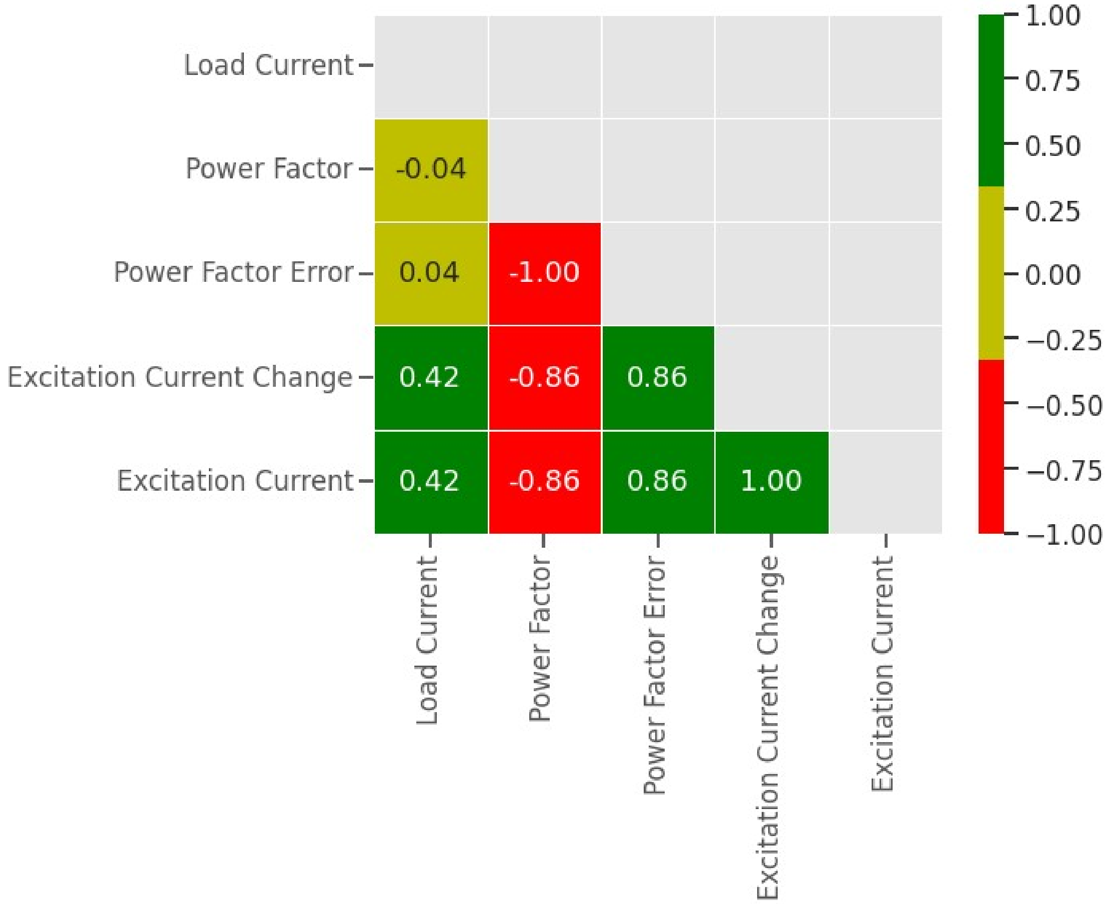
Findings from the above tables:

1. R^2 and Adjusted R^2 range from **0.81 to 0.96**. This means that **all Independent variables can explain upto (81,96)% of variance in the dependent variables (excitation current)**. In layman terms, all seem to be a **good fit** for our regression.

2. **A high F-Statistic in sync with a very low (0 or close to 0) Prob(F-Statistic)** Basically proves that our independent variable is a better predictor than just the intercept term (coeff) with a **very high degree of certainty**.

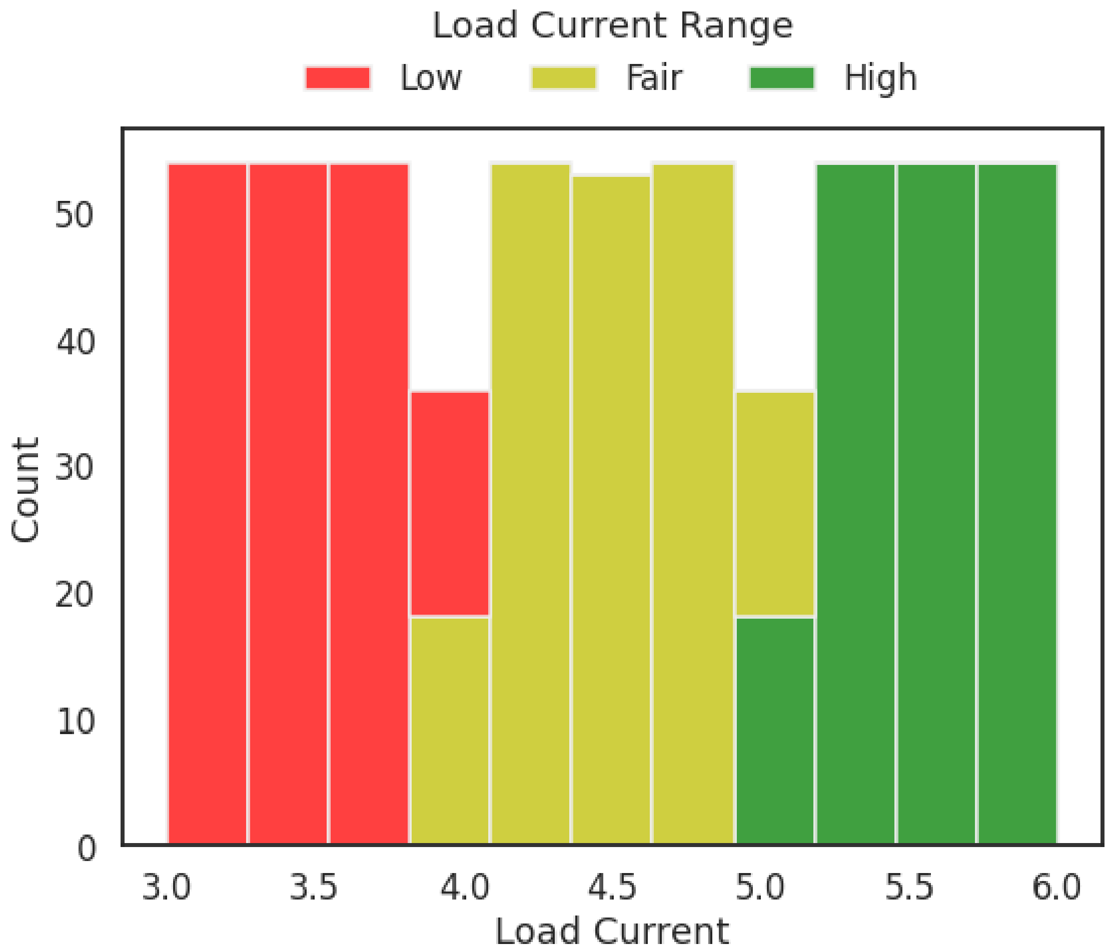
3. High t-test value in-sync with P>|t| being (0,0.05) also corroborates for **strong significance**.

```
corr = df.corr()
oe=['r','y','g']
fig, ax = plt.subplots(figsize=(8, 6))
dropSelf = np.zeros_like(corr)
dropSelf[np.triu_indices_from(dropSelf)] = True
sns.set_style("white")
sns.heatmap(corr, cmap=oe, linewidths=.5, annot=True, fmt=".2f",
mask=dropSelf)
plt.show()
```



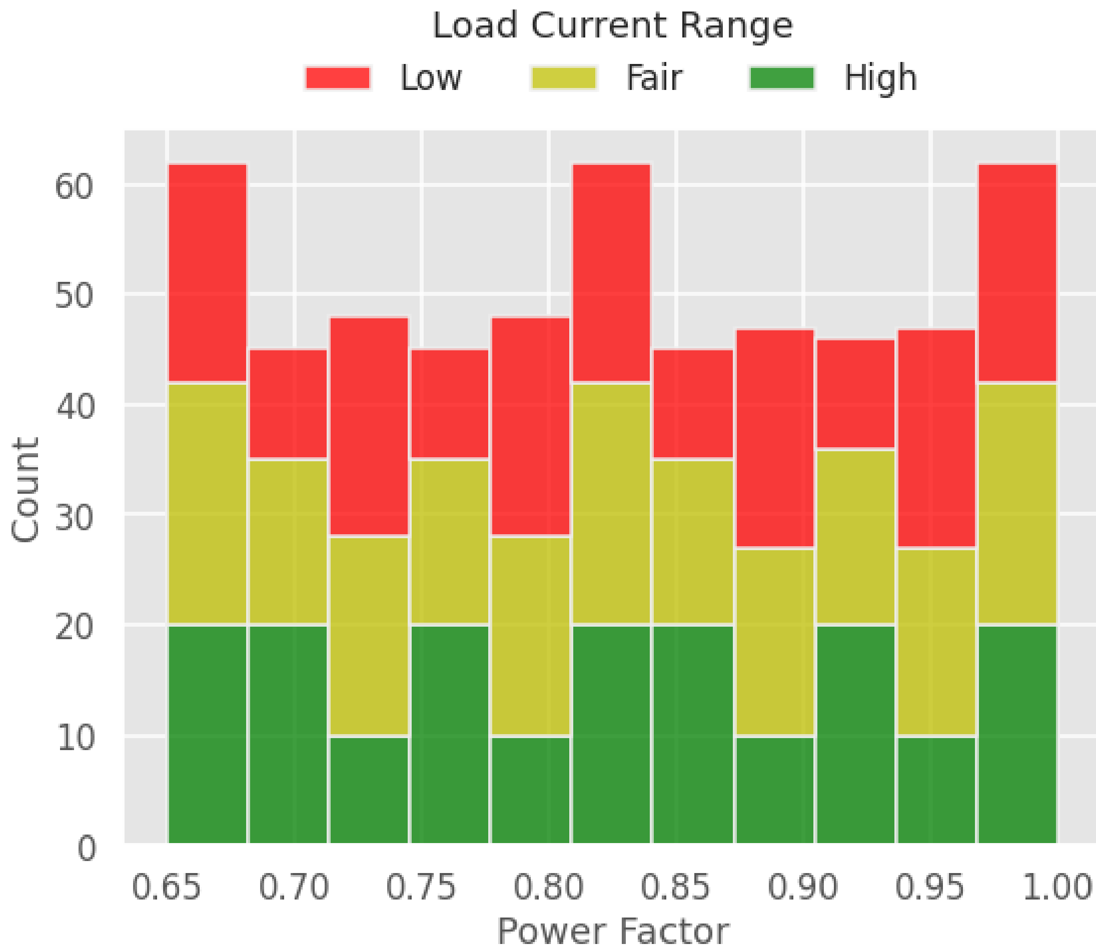
```
def outliers(df_column):
  oe=['r','y','g']
  q75, q25 = np.percentile(df_column, [75 ,25])
  iqr = q75 - q25
  print('q75: ',q75)
  print('q25: ',q25)
  print('Inter Quartile Range: ',round(iqr,2))
  print('Outliers lie before', q25-1.8*iqr, 'and beyond', q75+1.8*iqr)


  # Usually 1.5 times IQR is considered, but we have used 1.8 for
broader range since datapoints are very less

  print('Number of Rows with Left Extreme Outliers:', len(df[df_column
<q25-1.8*iqr]))
  print('Number of Rows with Right Extreme Outliers:',
len(df[df_column>q75+1.8*iqr]))
  fig, ax = plt.subplots(figsize=(8, 6))
  plt.tight_layout()
  plt.style.use('ggplot')
  sns.set_context('talk')
  sns.histplot(data=df, x=df_column, hue="Load Current
Range",multiple="stack",palette=oe)
  sns.move_legend(ax, "lower center", bbox_to_anchor=(.5, 1), ncol=3,
title='Load Current Range', frameon=False)
  print('')


outliers(df['Load Current'])
```

```
q75:  5.3
q25:  3.7
Inter Quartile Range:  1.6
Outliers lie before 0.8200000000000007 and beyond 8.18
Number of Rows with Left Extreme Outliers: 0
Number of Rows with Right Extreme Outliers: 0
```



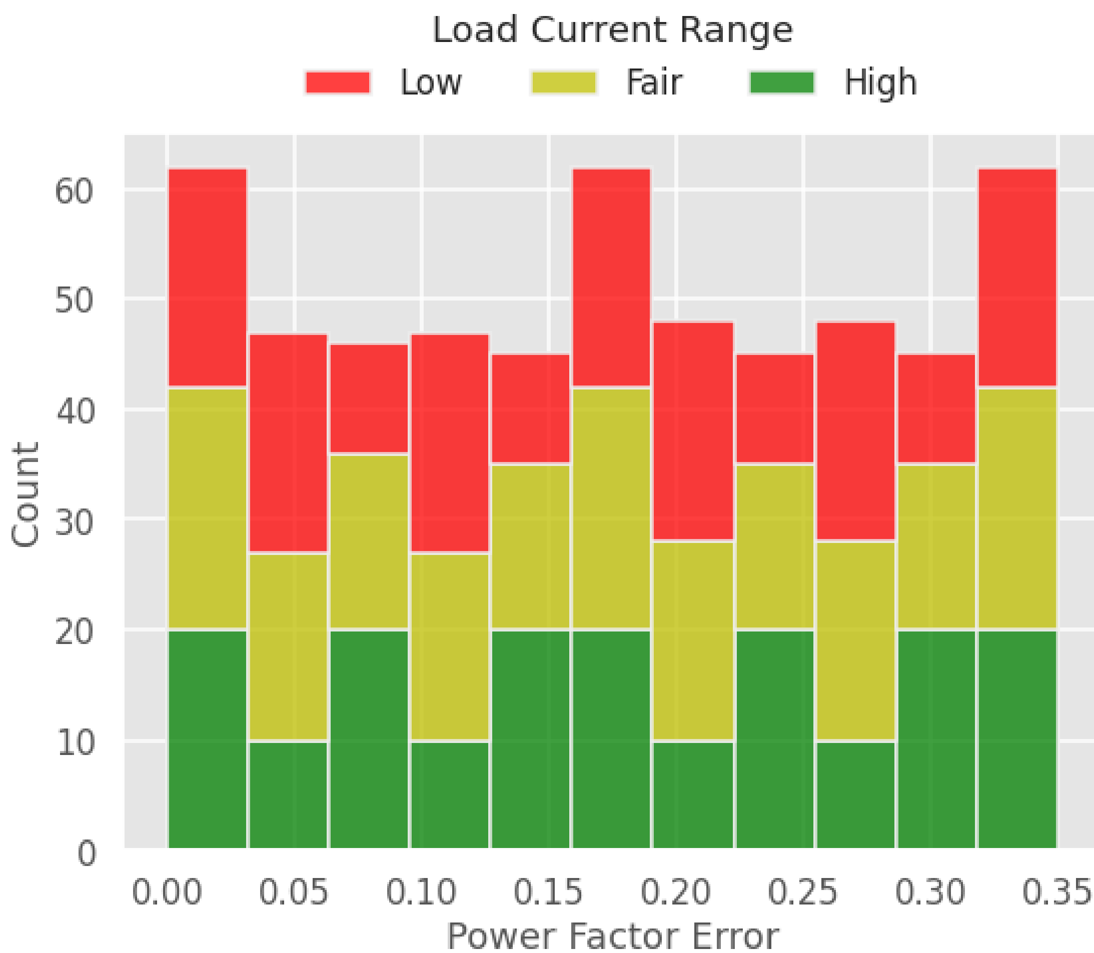

```
outliers(df['Power Factor'])
```

```
q75:  0.92
q25:  0.74
Inter Quartile Range:  0.18
Outliers lie before 0.41599999999999987 and beyond 1.2440000000000002
Number of Rows with Left Extreme Outliers: 0
Number of Rows with Right Extreme Outliers: 0
```



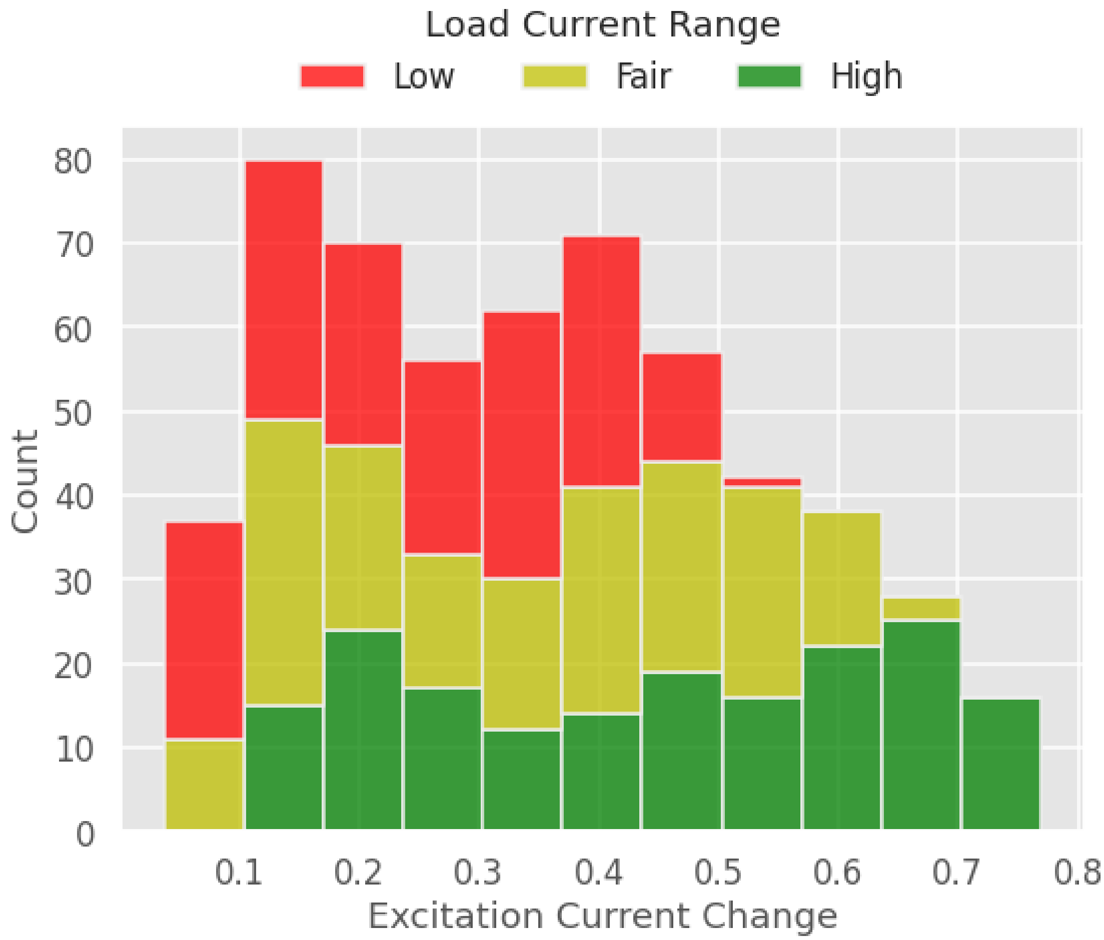

```
outliers(df['Power Factor Error'])
```

```
q75:  0.26
q25:  0.08
Inter Quartile Range:  0.18
Outliers lie before -0.244 and beyond 0.5840000000000001
Number of Rows with Left Extreme Outliers: 0
Number of Rows with Right Extreme Outliers: 0
```




```
outliers(df['Excitation Current Change'])
```

```
q75:  0.486
q25:  0.189
Inter Quartile Range:  0.3
Outliers lie before -0.34559999999999996 and beyond 1.0206
Number of Rows with Left Extreme Outliers: 0
Number of Rows with Right Extreme Outliers: 0
```



NO OUTLIERS found hence, we can directly move on to the next segment

```
vif = df.copy()
vif.drop(columns=['Excitation Current','Load Current
Range'],axis=1,inplace=True)
vif_data = pd.DataFrame()
vif_data["feature"] = vif.columns
vif_data["VIF"] = [variance_inflation_factor(vif.values, i)
                          for i in range(len(vif.columns))]

vif_data
```

	feature	VIF
0	Load Current	2.422514
1	Power Factor	33.038855
2	Power Factor Error	21.168319
3	Excitation Current Change	9.349596

```
# Scale Data For Higher Efficiency
from sklearn.preprocessing import StandardScaler # Converts Columnar
Data into Standard Normal Distribution
scaler=StandardScaler()
```

```
scaler.fit(vif)
scaled_data=scaler.transform(vif)
scaled_data
```

```
array([[-1.67536583, -1.59195683,  1.59195683,  0.17927073],
       [-1.67536583, -1.39933818,  1.39933818,  0.11829639],
       [-1.67536583, -1.20671953,  1.20671953,  0.05177893],
       ...,
       [ 1.67576692,  1.20101359, -1.20101359, -1.05684546],
       [ 1.67576692,  1.39363224, -1.39363224, -1.05684546],
       [ 1.67576692,  1.58625089, -1.58625089, -1.05684546]])
```

```
from sklearn.decomposition import PCA # Reduce Dimensions by Principal
Component Analysis To Compensate for Variables with High VIF
pca=PCA(n_components=2)
pca.fit(scaled_data)
x_pca=pca.transform(scaled_data)
x_pca
```

```
array([[ 1.66616981,  2.22773971],
       [ 1.41100071,  2.15425755],
       [ 1.15269745,  2.0818543 ],
       ...,
       [-1.71437613, -1.88407492],
       [-1.93506951, -1.96942498],
       [-2.15576289, -2.05477504]])
```

```
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(x_pca,
df['Excitation Current'], test_size=0.2, random_state=42)
reg = LinearRegression()
reg.fit(x_train, y_train)
print('Test Accuracy of Linear Regression:
',round(100*reg.score(x_test, y_test),2),'%')
print('')
print('Train Accuracy of Linear
Regression:',round(100*reg.score(x_train, y_train),2),'%')
print('')
y_pred=reg.predict(x_test)
print('Mean Squared Error (MSE):
',round(np.sqrt(mean_squared_error(y_test,y_pred)),4))
```

```
Test Accuracy of Linear Regression:  95.49 %

Train Accuracy of Linear Regression: 95.51 %

Mean Squared Error (MSE):  0.0389
```

```
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(x_pca,
df['Excitation Current'], test_size=0.2, random_state=27)
```

```
reg=Lasso(alpha=0.001)
reg.fit(x_train, y_train)
print('Test Accuracy of Lasso Regression:
',round(100*reg.score(x_test, y_test),2),'%')
print('')
print('Train Accuracy of Lasso
Regression:',round(100*reg.score(x_train, y_train),2),'%')
print('')
y_pred=reg.predict(x_test)
print('Mean Squared Error (MSE):
',round(np.sqrt(mean_squared_error(y_test,y_pred)),4))
```

```
Test Accuracy of Lasso Regression:  96.12 %

Train Accuracy of Lasso Regression: 95.36 %

Mean Squared Error (MSE):  0.0341
```

```
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(x_pca,
df['Excitation Current'], test_size=0.2, random_state=27)
reg=Ridge(alpha=0.002)
reg.fit(x_train, y_train)
print('Test Accuracy of Ridge Regression:
',round(100*reg.score(x_test, y_test),2),'%')
print('')
print('Train Accuracy of Ridge
Regression:',round(100*reg.score(x_train, y_train),2),'%')
print('')
y_pred=reg.predict(x_test)
print('Mean Squared Error (MSE):
',round(np.sqrt(mean_squared_error(y_test,y_pred)),4))
```

```
Test Accuracy of Ridge Regression:  96.12 %

Train Accuracy of Ridge Regression: 95.36 %

Mean Squared Error (MSE):  0.0341
```

```
from sklearn.model_selection import train_test_split
from sklearn.linear_model import ElasticNet
x_train, x_test, y_train, y_test = train_test_split(x_pca,
df['Excitation Current'], test_size=0.2, random_state=27)
reg=ElasticNet(alpha=0.005)
reg.fit(x_train, y_train)
print('Test Accuracy of ElacticNet Regression:
',round(100*reg.score(x_test, y_test),2),'%')
print('')
print('Train Accuracy of ElacticNet
Regression:',round(100*reg.score(x_train, y_train),2),'%')
print('')
```

```
y_pred=reg.predict(x_test)
print('Mean Squared Error (MSE):
',round(np.sqrt(mean_squared_error(y_test,y_pred)),4))
```

```
Test Accuracy of ElacticNet Regression:  96.11 %

Train Accuracy of ElacticNet Regression: 95.33 %

Mean Squared Error (MSE):  0.0341
```

```
from sklearn.tree import DecisionTreeRegressor
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(x_pca,
df['Excitation Current'], test_size=0.2, random_state=4)
reg=DecisionTreeRegressor()
reg.fit(x_train, y_train)
print('Test Accuracy of DecisionTree Regression:
',round(100*reg.score(x_test, y_test),2),'%')
print('')
print('Train Accuracy of DecisionTree
Regression:',round(100*reg.score(x_train, y_train),2),'%')
print('')
y_pred=reg.predict(x_test)
print('Mean Squared Error (MSE):
',round(np.sqrt(mean_squared_error(y_test,y_pred)),4))
```

```
Test Accuracy of DecisionTree Regression:  96.14 %

Train Accuracy of DecisionTree Regression: 100.0 %

Mean Squared Error (MSE):  0.0367
```

```
from sklearn.model_selection import RandomizedSearchCV
# Number of trees in random forest
n_estimators = [int(x) for x in np.linspace(start = 103, stop = 300,
num = 5)]
# 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(10, 110, num = 5)]
max_depth.append(None)
# Minimum number of samples required to split a node
min_samples_split = [2, 5, 10]
# Minimum number of samples required at each leaf node
min_samples_leaf = [1, 2, 4]
# Method of selecting samples for training each tree
bootstrap = [True, False]
# 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,
               'bootstrap': bootstrap}

rf = RandomForestRegressor()
rf_random = RandomizedSearchCV(estimator = rf, param_distributions =
random_grid, n_iter = 100, cv = 3, verbose=2, random_state=42, n_jobs
= -1)
# Fit the random search model
rf_random.fit(x_train, y_train)
```

```
Fitting 3 folds for each of 100 candidates, totalling 300 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent
workers.
[Parallel(n_jobs=-1)]: Done  33 tasks      | elapsed:    6.0s

[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=110, bootstrap=True
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=2,
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[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=1,
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[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=2,
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max_features=auto, max_depth=10, bootstrap=False
```

```
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4,
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max_features=auto, max_depth=110, bootstrap=True, total=   0.4s
```

```
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```

```
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[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=1,
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[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=2,
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[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=1,
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[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.5s
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```

```
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[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=True, total=   0.8s
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```

```
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[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=1,
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[CV] n_estimators=201, min_samples_split=5, min_samples_leaf=1,
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[CV]  n_estimators=201, min_samples_split=5, min_samples_leaf=1,
max_features=auto, max_depth=85, bootstrap=True, total=   0.5s
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[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=4,
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[CV] n_estimators=201, min_samples_split=2, min_samples_leaf=4,
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[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=False, total=   0.4s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True, total=   0.4s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=4,
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[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=4,
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max_features=auto, max_depth=None, bootstrap=False
[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False, total=   0.5s[CV]
n_estimators=250, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=110, bootstrap=True
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=110, bootstrap=True, total=   0.6s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=False, total=   0.3s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=False
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=False, total=   0.5s
```

```
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=False
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=False, total=   0.3s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False, total=   0.6s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.3s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.5s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=10, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=10, bootstrap=False, total=   0.3s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=35, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=35, bootstrap=False, total=   0.7s
[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=35, bootstrap=True
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=35, bootstrap=True, total=   0.6s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=True
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=True, total=   0.6s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=True
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=True, total=   0.6s
[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=85, bootstrap=False
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=85, bootstrap=False, total=   0.5s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=True
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=True, total=   0.4s
[CV] n_estimators=103, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=10, bootstrap=True
```

```
[CV]  n_estimators=103, min_samples_split=10, min_samples_leaf=2, max_features=sqrt, max_depth=10, bootstrap=True, total=   0.2s
[CV] n_estimators=103, min_samples_split=5, min_samples_leaf=4, max_features=auto, max_depth=None, bootstrap=True
[CV]  n_estimators=103, min_samples_split=5, min_samples_leaf=4, max_features=auto, max_depth=None, bootstrap=True, total=   0.3s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=4, max_features=sqrt, max_depth=None, bootstrap=True
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=4, max_features=sqrt, max_depth=None, bootstrap=True, total=   0.7s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=4, max_features=sqrt, max_depth=None, bootstrap=True
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=4, max_features=sqrt, max_depth=None, bootstrap=True, total=   0.8s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=1, max_features=auto, max_depth=110, bootstrap=True
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=1, max_features=auto, max_depth=110, bootstrap=True, total=   0.4s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=4, max_features=auto, max_depth=None, bootstrap=False
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=4, max_features=auto, max_depth=None, bootstrap=False, total=   0.6s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=2, max_features=auto, max_depth=35, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=2, max_features=auto, max_depth=35, bootstrap=False, total=   0.3s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=1, max_features=sqrt, max_depth=35, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=1, max_features=sqrt, max_depth=35, bootstrap=False, total=   0.6s
[CV] n_estimators=201, min_samples_split=5, min_samples_leaf=1, max_features=auto, max_depth=85, bootstrap=True
[CV]  n_estimators=201, min_samples_split=5, min_samples_leaf=1, max_features=auto, max_depth=85, bootstrap=True, total=   0.5s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=4, max_features=sqrt, max_depth=35, bootstrap=True
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=4, max_features=sqrt, max_depth=35, bootstrap=True, total=   0.7s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4, max_features=auto, max_depth=60, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4, max_features=auto, max_depth=60, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4, max_features=sqrt, max_depth=10, bootstrap=True
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4, max_features=sqrt, max_depth=10, bootstrap=True, total=   0.4s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4, max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4, max_features=sqrt, max_depth=None, bootstrap=False, total=   0.3s
```

```
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.3s
[CV] n_estimators=300, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=True
[CV]  n_estimators=300, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=True, total=   0.7s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=False
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=False, total=   0.3s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False, total=   0.6s
[CV] n_estimators=201, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False
[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False, total=   0.5s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True, total=   0.8s[CV]
n_estimators=250, min_samples_split=5, min_samples_leaf=1,
max_features=auto, max_depth=10, bootstrap=False
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=1,
max_features=auto, max_depth=10, bootstrap=False, total=   0.5s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False, total=   0.4s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=None, bootstrap=False
```

```
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=1,
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[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=False
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=False, total=   0.5s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.5s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=35, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=35, bootstrap=False, total=   0.7s
[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=35, bootstrap=True
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=35, bootstrap=True, total=   0.6s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=True
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=True, total=   0.6s
[CV] n_estimators=103, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=None, bootstrap=True
[CV]  n_estimators=103, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=None, bootstrap=True, total=   0.3s
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=110, bootstrap=False
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=110, bootstrap=False, total=   0.5s
[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=85, bootstrap=False
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=85, bootstrap=False, total=   0.5s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=True
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=True, total=   0.4s
[CV] n_estimators=103, min_samples_split=5, min_samples_leaf=4,
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max_features=auto, max_depth=None, bootstrap=True, total=   0.3s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=True
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=True, total=   0.8s
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=False
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=False, total=   0.4s
```

```
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=False
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=False, total=   0.4s
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=85, bootstrap=False
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=85, bootstrap=False, total=   0.4s
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max_features=auto, max_depth=None, bootstrap=False, total=   0.6s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=2,
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[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=False, total=   0.3s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=35, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=35, bootstrap=False, total=   0.6s
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[CV]  n_estimators=201, min_samples_split=5, min_samples_leaf=1,
max_features=auto, max_depth=85, bootstrap=True, total=   0.5s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=True
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=True, total=   0.7s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=60, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=60, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True, total=   0.4s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=4,
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max_features=auto, max_depth=85, bootstrap=True, total=   0.7s
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max_features=auto, max_depth=110, bootstrap=True, total=   0.7s
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[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=35, bootstrap=False, total=   0.4s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False
```

```
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False, total=   0.6s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True, total=   0.8s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True, total=   0.6s

[Parallel(n_jobs=-1)]: Done 154 tasks      | elapsed:   20.7s


[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False, total=   0.6s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True, total=   0.8s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=True, total=   0.6s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=10, bootstrap=True
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=10, bootstrap=True, total=   0.4s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=10, bootstrap=False
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=10, bootstrap=False, total=   0.6s
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=True
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=1,
max_features=auto, max_depth=60, bootstrap=True, total=   0.5s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=None, bootstrap=True
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=None, bootstrap=True, total=   0.6s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=False
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=False
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=10, bootstrap=False, total=   0.3s
```

```
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=85, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=85, bootstrap=False, total=   0.6s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=False
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=False, total=   0.5s
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max_features=auto, max_depth=None, bootstrap=True, total=   0.7s
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[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False, total=   0.6s
[CV] n_estimators=103, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False
[CV]  n_estimators=103, min_samples_split=2, min_samples_leaf=1,
max_features=sqrt, max_depth=110, bootstrap=False, total=   0.2s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=60, bootstrap=True
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=60, bootstrap=True, total=   0.4s
[CV] n_estimators=201, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True
[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True, total=   0.5s
[CV] n_estimators=300, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=True
```

```
[CV]  n_estimators=300, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=True, total=   0.7s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=85, bootstrap=True
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=85, bootstrap=True, total=   0.3s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=False
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=False, total=   0.4s
[CV] n_estimators=300, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=True
[CV]  n_estimators=300, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=True, total=   0.7s
[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=10, bootstrap=True
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=10, bootstrap=True, total=   0.6s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=110, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=110, bootstrap=False, total=   0.7s
[CV] n_estimators=201, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=60, bootstrap=False
[CV]  n_estimators=201, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=60, bootstrap=False, total=   0.4s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=10, bootstrap=False
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=10, bootstrap=False, total=   0.6s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=None, bootstrap=True
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=None, bootstrap=True, total=   0.6s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=True
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=110, bootstrap=True, total=   0.4s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=60, bootstrap=True
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=60, bootstrap=True, total=   0.7s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=85, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=85, bootstrap=False, total=   0.6s
[CV] n_estimators=250, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=False
[CV]  n_estimators=250, min_samples_split=2, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=False, total=   0.5s
```

```
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False, total=   0.4s
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False, total=   0.4s
[CV] n_estimators=103, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=True
[CV]  n_estimators=103, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=110, bootstrap=True, total=   0.2s
[CV] n_estimators=201, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=35, bootstrap=False
[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=2,
max_features=sqrt, max_depth=35, bootstrap=False, total=   0.4s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=85, bootstrap=True
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=85, bootstrap=True, total=   0.7s
[CV] n_estimators=300, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=85, bootstrap=False
[CV]  n_estimators=300, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=85, bootstrap=False, total=   0.6s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False, total=   0.3s
[CV] n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=None, bootstrap=True
[CV]  n_estimators=201, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=None, bootstrap=True, total=   0.5s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=True
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=True, total=   0.4s
[CV] n_estimators=103, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=10, bootstrap=False
[CV]  n_estimators=103, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=10, bootstrap=False, total=   0.2s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=None, bootstrap=False
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=None, bootstrap=False, total=   0.6s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=1,
max_features=sqrt, max_depth=10, bootstrap=False, total=   0.3s
[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True
```

```
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True, total=   0.6s
[CV] n_estimators=250, min_samples_split=5, min_samples_leaf=4,
max_features=auto, max_depth=10, bootstrap=False
[CV]  n_estimators=250, min_samples_split=5, min_samples_leaf=4,
max_features=auto, max_depth=10, bootstrap=False, total=   0.5s
[CV] n_estimators=300, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=300, min_samples_split=5, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.5s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=85, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=60, bootstrap=True
[CV]  n_estimators=152, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=60, bootstrap=True, total=   0.4s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=10, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=sqrt, max_depth=10, bootstrap=False, total=   0.3s
[CV] n_estimators=201, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True
[CV]  n_estimators=201, min_samples_split=2, min_samples_leaf=2,
max_features=auto, max_depth=35, bootstrap=True, total=   0.5s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=60, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=60, bootstrap=False, total=   0.3s
[CV] n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=60, bootstrap=False
[CV]  n_estimators=152, min_samples_split=10, min_samples_leaf=2,
max_features=auto, max_depth=60, bootstrap=False, total=   0.3s
[CV] n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=False
[CV]  n_estimators=250, min_samples_split=10, min_samples_leaf=4,
max_features=sqrt, max_depth=35, bootstrap=False, total=   0.5s
[CV] n_estimators=300, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=True
[CV]  n_estimators=300, min_samples_split=10, min_samples_leaf=4,
max_features=auto, max_depth=110, bootstrap=True, total=   0.7s
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=4,
max_features=sqrt, max_depth=None, bootstrap=False, total=   0.6s
```

```
[CV] n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=110, bootstrap=False
[CV]  n_estimators=300, min_samples_split=2, min_samples_leaf=1,
max_features=auto, max_depth=110, bootstrap=False, total=   0.7s
[CV] n_estimators=152, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=35, bootstrap=True
[CV]  n_estimators=152, min_samples_split=5, min_samples_leaf=1,
max_features=sqrt, max_depth=35, bootstrap=True, total=   0.4s

[Parallel(n_jobs=-1)]: Done 300 out of 300 | elapsed:   37.9s finished

RandomizedSearchCV(cv=3, estimator=RandomForestRegressor(),
n_iter=100,
                   n_jobs=-1,
                   param_distributions={'bootstrap': [True, False],
                                        'max_depth': [10, 35, 60, 85,
110,
                                                      None],
                                        'max_features': ['auto',
'sqrt'],
                                        'min_samples_leaf': [1, 2, 4],
                                        'min_samples_split': [2, 5,
10],
                                        'n_estimators': [103, 152,
201, 250,
                                                         300]},
                   random_state=42, verbose=2)

rf_random.best_params_

{'n_estimators': 103,
 'min_samples_split': 2,
 'min_samples_leaf': 1,
 'max_features': 'sqrt',
 'max_depth': None,
 'bootstrap': True}

x_train, x_test, y_train, y_test = train_test_split(x_pca,
df['Excitation Current'], test_size=0.2, random_state=4)
reg=RandomForestRegressor(n_estimators=103, min_samples_split= 2,
min_samples_leaf= 1, max_features= 'sqrt',max_depth= None, bootstrap=
True)
reg.fit(x_train, y_train)
print('Test Accuracy of RandomForestRegressor:
',round(100*reg.score(x_test, y_test),2),'%')
print('')
print('Train Accuracy of
RandomForestRegressor :',round(100*reg.score(x_train, y_train),2),'%')
print('')
y_pred=reg.predict(x_test)
```

```
print('Mean Squared Error (MSE):
',round(np.sqrt(mean_squared_error(y_test,y_pred)),4))
```

```
Test Accuracy of RandomForestRegressor:  97.06 %

Train Accuracy of RandomForestRegressor : 99.54 %

Mean Squared Error (MSE):  0.032
```