Table of Contents

1 Abstract
2 Business Problem For a Telecommunication Company
3 Import Libaries
4 Load Data
5 Data Exploration & Visualization
6 Data Engineering
6.1 Group state column into south and north
6.1.1 Comments
6.2 Drop unnecessary columns
6.3 Drop higly correlated features
6.4 One Hot Encoder Categorial Columns
6.5 Train test split
6.6 Standarize Features
6.7 Building analysis functions
7 Logistic Regression
7.1 Optimization and Tuning
7.2 Best performing parameters for Logistic Regression Model
7.3 Results Comments
8 Descion Tree Classifier
8.1 Hyperparameter Tuning for decision tree using Gridsearch
8.1.1 Select Best Parameters for Descion tree classifier
8.2 Results Comments
9 Random Forest Classifier
9.1 Hyperparameter Tuning for Random Forest using Gridsearch
9.2 Best Paramerts for Random Forest
9.3 Results & Comments
10 KNN Classifier
10.1 Tuning & Optimization (Iterate over n values)
10.1.1 Select Best K for KNN Machine Learning Model
10.1.1.1 K=3
10.1.2 Iterate over 1 < n < 26
10.1.2.1 K=1
10.2 Results & Comments
11 XGBoost
11.1 Results & comments
12 Gaussian NB
12.1 Results & Comments
13 AdaBoostClassifier
13.1 Results & Comments
14 Gradient Boosting Classifier
14.1 Results & comments
15 SVM Classifier
15.1 Tuning & Optimization
15.1.1 Hypertuning of SVM Classifier throgh GridSearhCV
15.1.1.1 Best paramets for SVM Classifier

- 15.2 Results & Comments
  - 15.2.1 SVM with RFE
  - 15.2.2 SVM with SelectKBest
- 15.3 Results & Comments
- 16 Stacking
  - 16.1 Results & Comments
- 17 SGDClassifier (Lasso & Ridge regularizations)
- 7.1 Results & Comments
- Logistic Regession - RandomizedSearchCV
- 8.1 Results & Comments
- SGDClassifier - RandomizedSearchCV
- 9.1 Tuning & Optimization
- 9.2 Results & Comments
- Data Interpretation
- 0.1 Most Important features Accoring to DecisionTree Model
  - 20.1.1 Top 5 Important Features Affecting Churn Rate
- 0.2 Top Positive and Negative Features According to Logistic Regression
  - 20.2.1 Top Negative Factors affectig Churn Rate
  - 20.2.2 Top Positive Fators Affectig Churn Rate
- Conclusion
- 1.1 Increasing churn factors
  - 21.1.1 Total day charge
  - 21.1.2 Customer service calls
  - 21.1.3 Total evening charge
  - 21.1.4 Total internatioanl charge
- 1.2 Decreasing churn factors
  - 21.2.1 Voice mail plan
  - 21.2.2 International plan
- Recomendations
- Future Work

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
- 6.1 Group state
  - 6.1.1 Commen
- 6.2 Drop unnece
- 6.3 Drop higly co
- 6.4 One Hot Ene
- 6.5 Train test spl
- 6.6 Standarize F
- 6.7 Building anal

7 Logistic Regress
- 7.1 Optimization
- 7.2 Best perform
- 7.3 Results Com

8 Descion Tree Cla
- 8.1 Hyperparame
  - 8.1.1 Select Be
- 8.2 Results Com

9 Random Forest
- 9.1 Hyperparame
- 9.2 Best Parame
- 9.3 Results & Co

10 KNN Classifier
- 10.1 Tuning & Op
  - 10.1.1 Select B
    - 10.1.1.1 K=3
  - 10.1.2 Iterate
    - 10.1.2.1 K=1
- 10.2 Results & C

11 XGBoost
- 11.1 Results & co

12 Gaussian NB
- 12.1 Results & C

13 AdaBoostClassi
- 13.1 Results &

14 Gradient Boosti
- 14.1 Results &

15 SVM Classifier
- 15.1 Tuning & O
  - 15.1.1 Hypertu
    - 15.1.1.1 Be

1 Abstract

mer churn in the telecomunication industry In this project, machine learning models are to predict possible customer churn in a telecomunication industry. Our models are powerful can determine churn factors Therefore, we can give a company the advantage of taking before losing customers.

2 Business Problem For a Telecommunication Company

1) ermine important factors affection churn.

2) ermine factors increasing churn rate.

3) ermine factors decresing churn rate.

3 Import Libaries

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [229]:

```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

from sklearn.preprocessing import LabelEncoder
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split


from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.ensemble import RandomForestClassifier


from sklearn import tree
from sklearn import svm
from sklearn import ensemble
from sklearn import neighbors
from sklearn import linear_model
from sklearn import metrics
from sklearn import preprocessing

from sklearn import metrics
from sklearn.linear_model import LinearRegression
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import KFold
from sklearn.preprocessing import OneHotEncoder
from sklearn.metrics import accuracy_score, confusion_matrix, classific
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import BaggingClassifier, RandomForestClassifier
from sklearn.model_selection import cross_val_score


from sklearn.model_selection import cross_validate
%matplotlib inline

from IPython.display import Image
import matplotlib as mlp
import matplotlib.pyplot as plt
import numpy as np
import os
import pandas as pd
import sklearn


from sklearn.model_selection import ShuffleSplit

from sklearn.model_selection import StratifiedKFold

from sklearn.metrics import classification_report

import warnings
warnings.filterwarnings('ignore')


```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select B
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

```
import seaborn as sns
sns.set_style('darkgrid', {'axes.facecolor': '0.9'})

from sklearn.preprocessing import LabelEncoder, OneHotEncoder, Standard
from sklearn.model_selection import train_test_split, cross_val_score,
from sklearn.metrics import make_scorer
from sklearn.metrics import classification_report, confusion_matrix, ac
from sklearn.metrics import  f1_score, fbeta_score, r2_score, roc_auc_s

from sklearn.linear_model import LogisticRegression, SGDClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.svm import SVC
from sklearn.svm import SVC
from sklearn.naive_bayes import GaussianNB

from sklearn.metrics import precision_recall_curve
from sklearn.metrics import plot_precision_recall_curve, average_precis

from sklearn.metrics import plot_confusion_matrix

```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building final
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

4 Load Data

In [230]:

```
df = pd.read_csv('bigml_59c28831336c6604c800002a.csv')

print (df.shape)

```

3333, 21)

In [231]:
```
# Load data

df.head(10)
```

Out[231]:

	state	account length	area code	phone number	international plan	voice mail plan	number vmail messages	total day minutes
0	KS	128	415	382-4657	no	yes	25	265.1
1	OH	107	415	371-7191	no	yes	26	161.6
2	NJ	137	415	358-1921	no	no	0	243.4
3	OH	84	408	375-9999	yes	no	0	299.4
4	OK	75	415	330-6626	yes	no	0	166.7
5	AL	118	510	391-8027	yes	no	0	223.4
6	MA	121	510	355-9993	no	yes	24	218.2
7	MO	147	415	329-9001	yes	no	0	157.0
8	LA	117	408	335-4719	no	no	0	184.5
9	WV	141	415	330-8173	yes	yes	37	258.6

0 rows × 21 columns

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [232]:
```
df.dtypes
```

Out[232]:

```
tate                      object
ccount length              int64
rea code                   int64
hone number               object
nternational plan         object
oice mail plan            object
umber vmail messages       int64
otal day minutes         float64
otal day calls             int64
otal day charge          float64
otal eve minutes         float64
otal eve calls             int64
otal eve charge          float64
otal night minutes       float64
otal night calls           int64
otal night charge        float64
otal intl minutes        float64
otal intl calls            int64
otal intl charge         float64
ustomer service calls      int64
hurn                        bool
type: object
```

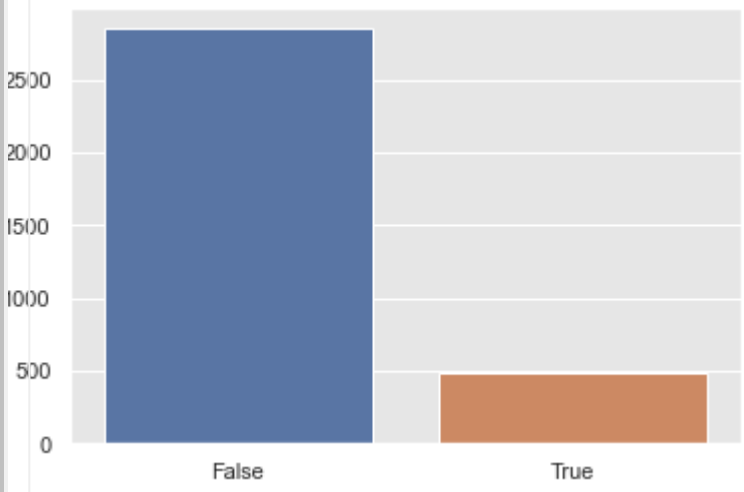
Data Exploration & Visualization

In [233]:
```
#Data Visualization

y = df["churn"].value_counts()
#print (y)
sns.barplot(y.index, y.values)

#sns.countplot(x ='churn', data = churn_data)
#plt.show()
```

Out[233]:
```
AxesSubplot:>
```

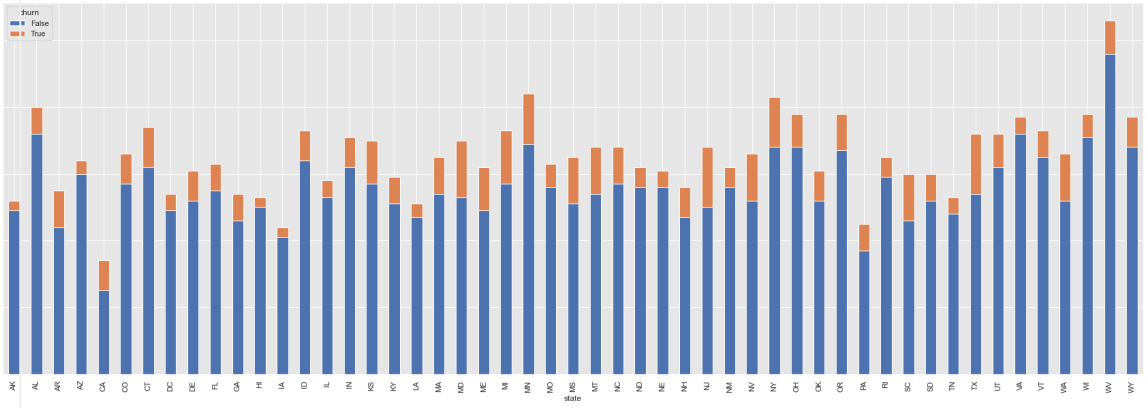


In [234]:
```
y_True = df["churn"][df["churn"] == True]
print ("Churn Percentage = "+str( (y_True.shape[0] / df["churn"].shape[
```

```
urn Percentage = 14.491449144914492
```

In [235]:
```
#Churn by state
df.groupby(["state", "churn"]).size().unstack().plot(kind='bar', stacke
```

Out[235]:
```
AxesSubplot:xlabel='state'>
```

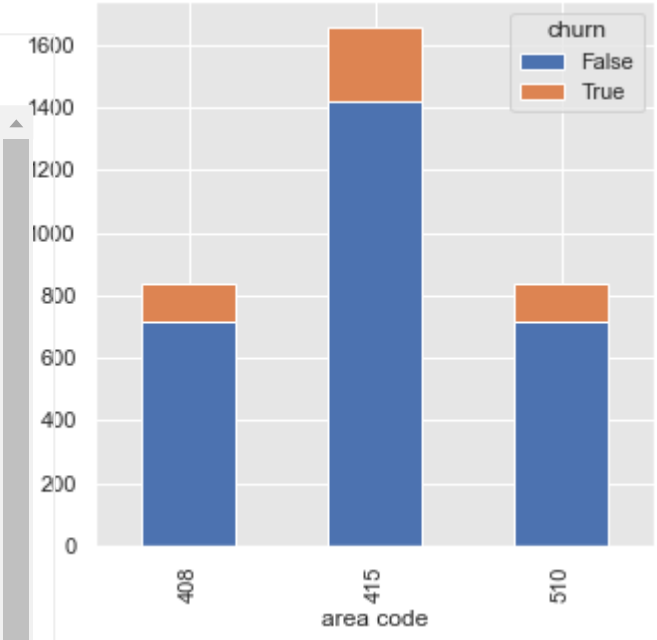


Contents

1 Abstract
2 Busines Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Decsion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [236]:
```
#Churn by area code
df.groupby(["area code", "churn"]).size().unstack().plot(kind='bar', st
```

Out[236]: <AxesSubplot:xlabel='area code'>



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [237]:
```
1 df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3333 entries, 0 to 3332
Data columns (total 21 columns):
 #   Column                  Non-Null Count  Dtype
---  ------                  --------------  -----
 0   state                   3333 non-null   object
 1   account length          3333 non-null   int64
 2   area code               3333 non-null   int64
 3   phone number            3333 non-null   object
 4   international plan      3333 non-null   object
 5   voice mail plan         3333 non-null   object
 6   number vmail messages   3333 non-null   int64
 7   total day minutes       3333 non-null   float64
 8   total day calls         3333 non-null   int64
 9   total day charge        3333 non-null   float64
 10  total eve minutes       3333 non-null   float64
 11  total eve calls         3333 non-null   int64
 12  total eve charge        3333 non-null   float64
 13  total night minutes     3333 non-null   float64
 14  total night calls       3333 non-null   int64
 15  total night charge      3333 non-null   float64
 16  total intl minutes      3333 non-null   float64
 17  total intl calls        3333 non-null   int64
 18  total intl charge       3333 non-null   float64
 19  customer service calls  3333 non-null   int64
 20  churn                   3333 non-null   bool
types: bool(1), float64(8), int64(8), object(4)
emory usage: 524.2+ KB
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [238]:
```
1 df.dtypes
```

Out[238]:
```
tate                    object
ccount length            int64
rea code                 int64
hone number             object
nternational plan       object
oice mail plan          object
umber vmail messages     int64
otal day minutes       float64
otal day calls           int64
otal day charge        float64
otal eve minutes       float64
otal eve calls           int64
otal eve charge        float64
otal night minutes     float64
otal night calls         int64
otal night charge      float64
otal intl minutes      float64
otal intl calls          int64
otal intl charge       float64
ustomer service calls    int64
hurn                      bool
type: object
```

In [239]:
```
#check for missing values
df.isnull().sum()
```

Out[239]:
```
state                     0
account length            0
area code                 0
phone number              0
international plan        0
voice mail plan           0
number vmail messages     0
total day minutes         0
total day calls           0
total day charge          0
total eve minutes         0
total eve calls           0
total eve charge          0
total night minutes       0
total night calls         0
total night charge        0
total intl minutes        0
total intl calls          0
total intl charge         0
customer service calls    0
churn                     0
type: int64
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [240]:
```
# check for duplicated rows
df.duplicated().sum()

```

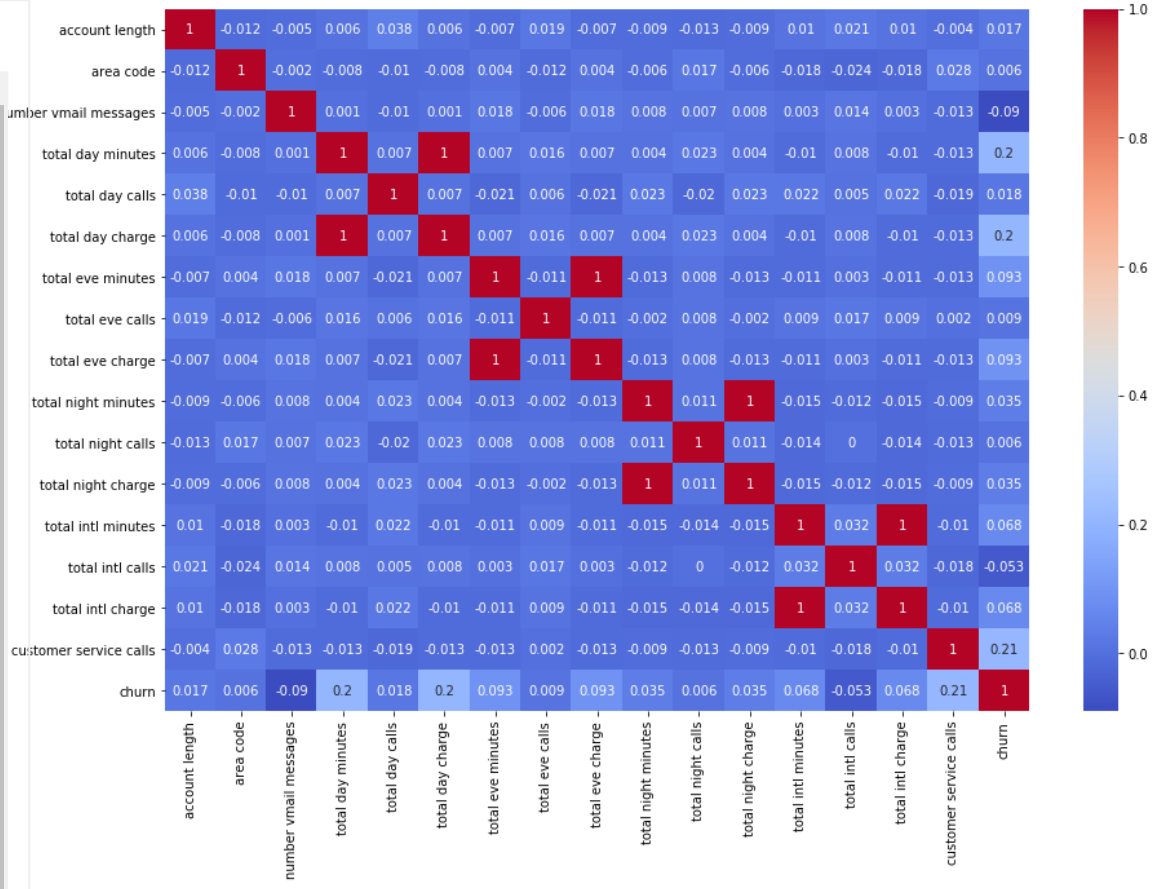
Out[240]:

In [15]:

```
#Correlation Analysis
cor = df.corr()
plt.figure(figsize=(15,10))
sns.heatmap(cor.round(3),annot=True,cmap='coolwarm')
plt.show()
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best



In [267]:
```
1 df.dtypes
```

Out[267]:
```
state                    object
account length            int64
area code                 int64
phone number             object
international plan       object
voice mail plan          object
number vmail messages     int64
total day minutes       float64
total day calls           int64
total day charge        float64
total eve minutes       float64
total eve calls           int64
total eve charge        float64
total night minutes     float64
total night calls         int64
total night charge      float64
total intl minutes      float64
total intl calls          int64
total intl charge       float64
customer service calls    int64
churn                      bool
type: object
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Comment
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
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10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [260]:
```
1 df.corr()
```

Out[260]:

	account length	area code	number vmail messages	total day minutes	total day calls	total day charge	total eve minutes	to
account length	1.000000	-0.012463	-0.004628	0.006216	0.038470	0.006214	-0.006757	0.0
area code	-0.012463	1.000000	-0.001994	-0.008264	-0.009646	-0.008264	0.003580	-0.0
number vmail messages	-0.004628	-0.001994	1.000000	0.000778	-0.009548	0.000776	0.017562	-0.0
total day minutes	0.006216	-0.008264	0.000778	1.000000	0.006750	1.000000	0.007043	0.0
total day calls	0.038470	-0.009646	-0.009548	0.006750	1.000000	0.006753	-0.021451	0.0
total day charge	0.006214	-0.008264	0.000776	1.000000	0.006753	1.000000	0.007050	0.0
total eve minutes	-0.006757	0.003580	0.017562	0.007043	-0.021451	0.007050	1.000000	-0.0
total eve calls	0.019260	-0.011886	-0.005864	0.015769	0.006462	0.015769	-0.011430	1.0
total eve charge	-0.006745	0.003607	0.017578	0.007029	-0.021449	0.007036	1.000000	-0.0
otal night minutes	-0.008955	-0.005825	0.007681	0.004323	0.022938	0.004324	-0.012584	-0.0
otal night calls	-0.013176	0.016522	0.007123	0.022972	-0.019557	0.022972	0.007586	0.0
otal night charge	-0.008960	-0.005845	0.007663	0.004300	0.022927	0.004301	-0.012593	-0.0
total intl minutes	0.009514	-0.018288	0.002856	-0.010155	0.021565	-0.010157	-0.011035	0.0
total intl calls	0.020661	-0.024179	0.013957	0.008033	0.004574	0.008032	0.002541	0.0
total intl charge	0.009546	-0.018395	0.002884	-0.010092	0.021666	-0.010094	-0.011067	0.0
customer service calls	-0.003796	0.027572	-0.013263	-0.013423	-0.018942	-0.013427	-0.012985	0.0
churn	0.016541	0.006174	-0.089728	0.205151	0.018459	0.205151	0.092796	0.0

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

6 Data Engineering

In [268]:
```
df.groupby(['state', 'churn']).sum().head()
```

Out[268]:

		account length	area code	number vmail messages	total day minutes	total day calls	total day charge	total eve minutes
state	churn							
AK	False	4640	21567	471	8796.3	4684	1495.39	9088.6
	True	414	1245	0	479.7	270	81.55	494.1
AL	False	7065	31063	545	13235.4	7156	2250.02	13770.8
	True	777	3387	29	1645.4	772	279.70	1866.2
AR	False	4173	19506	367	7721.0	4484	1312.59	8541.4

6. Group state column into south and north

In [269]:
```
df['churn'] = df['churn'].astype('str')
```

In [179]:
```
south=["MD", "DE", "VA", "WV", "KY", "TN", "NC", "SC", "FL", "GA", "AL"
df['state_south']=df['state'].isin(south)
```

In [180]:
```
df['state_south'].value_counts()
```

Out[180]:
```
alse    2226
rue     1107
ame: state_south, dtype: int64
```

In [181]:
```
north=[ "AZ", "CA", "CO", "CT", "DC", "HI", "ID", "IL", "IN", "IA", "KS
df['state_north']=df['state'].isin(north)
```

In [182]:
```
df['state_north'] = df['state_north'].astype('str')
df['state_south'] = df['state_south'].astype('str')
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [183]:
```
1 df.head()
```

Out[183]:

	state	account length	area code	phone number	international plan	voice mail plan	number vmail messages	total day minutes
0	KS	128	415	382-4657	no	yes	25	265.1
1	OH	107	415	371-7191	no	yes	26	161.6
2	NJ	137	415	358-1921	no	no	0	243.4
3	OH	84	408	375-9999	yes	no	0	299.4
4	OK	75	415	330-6626	yes	no	0	166.7

rows × 23 columns

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparame
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select B
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

6.1 Comments

I tri to include state_north and state_southin the models but both features are insignificant. I dec d to remove state feature.

In [332]:
```
1 df.dtypes
```

Out[332]:

```
tate                          object
ccount length                  int64
rea code                       int64
hone number                   object
nternational plan             object
oice mail plan                object
umber vmail messages           int64
otal day minutes             float64
otal day calls                 int64
otal day charge              float64
otal eve minutes             float64
otal eve calls                 int64
otal eve charge              float64
otal night minutes           float64
otal night calls               int64
otal night charge            float64
otal intl minutes            float64
otal intl calls                int64
otal intl charge             float64
ustomer service calls          int64
hurn                            bool
tate_south                      bool
tate_north                      bool
type: object
```

6.2 Drop unnecessary columns

In [241]:
```
#Remove phonenumber (is not important) ; redundant column

df=df.drop(['phone number'], axis=1)
```

```
df=df.drop(['state'], axis=1)
```

In [243]:
```
df=df.drop(['account length'], axis=1 )
```

6.3 Drop higly correlated features

In [244]:
```
# We kept total day charge
df=df.drop(['total intl minutes'], axis=1)
```

In [245]:
```
# We kept total night charge
df=df.drop(['total night minutes'], axis=1)
```

In [246]:
```
#We kept total evening minutes
df=df.drop(['total eve minutes'], axis=1)

```

In [247]:
```
# We kept total day charge
df=df.drop(['total day minutes'], axis=1)
```

In [32]:
```
df.dtypes
```

Out[32]:
```
tate                          object
rea code                       int64
nternational plan             object
oice mail plan                object
umber vmail messages           int64
otal day calls                 int64
otal day charge              float64
otal eve calls                 int64
otal eve charge              float64
otal night calls               int64
otal night charge            float64
otal intl calls                int64
otal intl charge             float64
ustomer service calls          int64
hurn                            bool
type: object
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [41]:
```
1 df.head()
```

Out[41]:

	state	account length	area code	international plan	voice mail plan	number vmail messages	total day minutes	total day calls	cha
0	KS	128	415	no	yes	25	265.1	110	
1	OH	107	415	no	yes	26	161.6	123	
2	NJ	137	415	no	no	0	243.4	114	
3	OH	84	408	yes	no	0	299.4	71	
4	OK	75	415	yes	no	0	166.7	113	

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [145]:
```
for c in cat_col_names:
    print(df[c].value_counts())
```

```
0    3010
1     323
Name: international plan, dtype: int64
49    106
23     84
4      83
       80
5      78
3      78
7      78
0      77
5      77
       74
2      73
3      73
5      73
3      72
4      72
5      71
5      70
0      70
7      68
5      68
1      68
7      66
3      66
       66
9      65
9      65
5      65
       64
       63
4      63
2      62
3      62
1      62
5      61
       61
9      61
0      60
1      60
7      59
4      58
0      56
       55
       54
0      54
2      53
1      53
       52
3      51
3      45
2      44
       34
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

```
Name: state, dtype: int64
0    2411
1     922
Name: voice mail plan, dtype: int64
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

6.4 One Hot Encoder Categorial Columns

In [138]:

```
total_col_names=df.columns

#find numeric columns

num_cols=df._get_numeric_data().columns

# Remove "object"-type features from X
cont_features = [col for col in df.columns if df[col].dtype in [np.floa

# Remove "object"-type features from X_train and X_test
df_cont =df.loc[:, cont_features]

#Category column

cat_col_names=list(set(total_col_names)-set(num_cols))

# Create X_cat which contains only the categorical variables
features_cat = [col for col in df.columns if df[col].dtype in [np.objec
df_cat = df.loc[:, features_cat]

# OneHotEncode categorical variables
ohe = OneHotEncoder(handle_unknown='ignore')

df_cat_ohe = ohe.fit_transform(df_cat)

# Convert these columns into a DataFrame
columns = ohe.get_feature_names(input_features=df_cat.columns)
df_cat = pd.DataFrame(df_cat_ohe.todense(), columns=columns)

```

In [140]:

```
df_cont.head()
```

Out[140]:

	area code	number vmail messages	total day calls	total day charge	total eve calls	total eve charge	total night calls	total night charge	total intl calls	cha
0	415	25	110	45.07	99	16.78	91	11.01	3	
1	415	26	123	27.47	103	16.62	103	11.45	3	
2	415	0	114	41.38	110	10.30	104	7.32	5	
3	408	0	71	50.90	88	5.26	89	8.86	7	
4	415	0	113	28.34	122	12.61	121	8.41	3	

In [49]:
```
1 df_cont.columns
```

Out[49]:
```
Index(['area code', 'number vmail messages', 'total day calls',
       'total day charge', 'total eve calls', 'total eve charge',
       'total night calls', 'total night charge', 'total intl calls',
       'total intl charge', 'customer service calls', 'churn'],
      dtype='object')
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [141]:
```
1 df = pd.concat([pd.DataFrame(df_cont), df_cat], axis=1)
```

In [196]:
```
1 df.head()
```

Out[196]:

	account length	area code	number vmail messages	total day minutes	total day calls	total day charge	total eve minutes	total eve calls	tota eve charge
0	128	415	25	265.1	110	45.07	197.4	99	16
1	107	415	26	161.6	123	27.47	195.5	103	16
2	137	415	0	243.4	114	41.38	121.2	110	10
3	84	408	0	299.4	71	50.90	61.9	88	5
4	75	415	0	166.7	113	28.34	148.3	122	12

rows × 72 columns

In [349]:
```
1 df.columns
```

Out[349]:
```
ndex(['area code', 'number vmail messages', 'total day calls',
       'total day charge', 'total eve calls', 'total eve charge',
       'total night calls', 'total night charge', 'total intl calls',
       'total intl charge', 'customer service calls', 'churn',
       'international plan_no', 'international plan_yes', 'voice mail plan_
o',
       'voice mail plan_yes', 'state_south_False', 'state_south_True',
       'state_north_False', 'state_north_True'],
      dtype='object')
```

In [198]:
```
1 df.dtypes
```

Out[198]:
```
ccount length              int64
rea code                   int64
umber vmail messages       int64
otal day minutes         float64
otal day calls             int64
                           ...
tate_WY                  float64
nternational plan_no     float64
nternational plan_yes    float64
oice mail plan_no        float64
oice mail plan_yes       float64
ength: 72, dtype: object
```

In [50]:
```
df.shape
```

Out[50]: (3333, 16)

In [51]:
```
df.shape
```

Out[51]: (3333, 16)

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop highly
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparame
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

6.5 Train test split

In [142]:
```
## separate dependent and independent variables
X = df.drop(['churn'], axis=1)
y = df['churn']
```

In [143]:
```
## splitting whole dataset into train and test dataset
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2
print(f"Size Of The Train Dataset :- {len(X_train)}")
print(f"Size Of The Test Dataset :- {len(X_test)}")
```

```
ize Of The Train Dataset :- 2666
ize Of The Test Dataset :- 667
```

6.6 Standarize Features

In [144]:
```
scaler = StandardScaler()
scaled_x_train = scaler.fit_transform(X_train)
scaled_X_test = scaler.transform(X_test)
scaled_X_train = pd.DataFrame(scaled_x_train, columns=X_train.columns)
```

6.7 Building analysis functions

In [145]:

```
#Function to draw the ROC curve and to calculate the area under the cur
from sklearn.metrics import roc_curve, auc
from sklearn.svm import SVC

def roc_curve_and_auc(clf, X_train, X_test, y_train, y_test):

    # Calculate the probability scores of each point in the training se
    y_train_score = clf.fit(X_train, y_train).decision_function(X_trair

    # Calculate the fpr, tpr, and thresholds for the training set
    train_fpr, train_tpr, thresholds = roc_curve(y_train, y_train_score

    # Calculate the probability scores of each point in the test set
    y_test_score = clf.decision_function(X_test)

    # Calculate the fpr, tpr, and thresholds for the test set
    test_fpr, test_tpr, test_thresholds = roc_curve(y_test, y_test_scor

    # ROC curve for training set
    plt.figure(figsize=(10, 8))
    lw = 2
    plt.plot(train_fpr, train_tpr, color='darkorange',
             lw=lw, label='Train ROC curve')
    plt.plot(test_fpr, test_tpr, color='blue',
             lw=lw, label='Test ROC curve')
    plt.plot([0, 1], [0, 1], color='navy', lw=lw, linestyle='--')
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])
    plt.yticks([i/20.0 for i in range(21)])
    plt.xticks([i/20.0 for i in range(21)])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title(
        'Receiver operating characteristic (ROC) Curve for Training and
    plt.legend(loc='lower right')
    plt.show()
    # Print the area under the roc curve
    print('Training AUC: {}'.format(round(auc(train_fpr, train_tpr), 5)
    print('Testing AUC: {}'.format(round(auc(test_fpr, test_tpr), 5)))
```

In [146]:

```
#Plot coefficients
def plot_coefficients(clf):
    weights_clf = pd.Series(clf.coef_[0], index=X.columns.values)
    weights_clf.sort_values(inplace=True)
    plt.figure(figsize=(15, 6))
    plt.xticks(rotation=90)
    features = plt.bar(weights_clf.index, weights_clf.values)
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [147]:

```
#Function to draw precision recall curve
def plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train):
    fig = plt.figure(figsize = (8, 8))
    lw =3
    no_skill = len(y[y==1]) / len(y)
    # plot the no skill precision-recall curve
    plt.plot([0, 1], [no_skill, no_skill], linestyle='--', lw = lw, lab
    # calculate model precision-recall curve
    precision, recall, _ = precision_recall_curve(y_test, y_pred_test)
    train_precision, train_recall, _ = precision_recall_curve(y_train,
    # plot the model precision-recall curve
    plt.plot(recall, precision, marker='.', lw = lw, label='Test Set')
    plt.plot(train_recall,train_precision, marker='.',lw=lw, label='Tra
    # axis labels
    plt.xlabel('Recall')
    plt.ylabel('Precision')
    # show the legend
    plt.legend()

    # show the plot
    plt.show()
```

In [148]:

```
#To plot coefficients
def plot_feature_importances(model):
    n_features = X_train.shape[1]
    plt.figure(figsize=(8, 8))
    plt.barh(range(n_features), model.feature_importances_, align='cent
    plt.yticks(np.arange(n_features), X_train.columns.values)
    plt.xlabel('Feature importance')
    plt.ylabel('Feature')
```

In [149]:

```

#Plot confusion matrix
def confusion_matrix_df(y_test, y_pred_test):
    confusion_mat = confusion_matrix(y_test, y_pred_test, labels=[0, 1]
    _row = confusion_mat.sum(axis=0)
    _col = [np.nan] + list(confusion_mat.sum(axis=1)) + [sum(_row)]
    con_df = pd.DataFrame({})
    con_df["Predicted"] = ["Actual"] + ["No Churn", "Churn"] + ["All"]
    for label, idx in {"No Churn": 0, "Churn": 1}.items():
        temp = [np.nan] + list(confusion_mat[:, idx]) + [_row[idx]]
        con_df[label] = temp

    con_df["All"] = _col
    return con_df
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [150]:

```
#Function to print the metrics: Confusion Matrix, Classification Report
def model_evaluation(X_train, X_test, y_train, y_test, y_pred_train, y_

    print('MODEL EVALUATION METRICS:\n',
          '-----------------------------------------------------')

    print('Confusion Matrix for train & test set: \n')
    print(confusion_matrix_df(y_train, y_pred_train), '\n')
    print(confusion_matrix_df(y_test, y_pred_test), '\n')

    print('-----------------------------------------------------')
    print('\nClassification Report for train & test set\n',
          '\nTrain set\n',
          classification_report(y_train, y_pred_train),
          '\n\nTest set\n',
          classification_report(y_test, y_pred_test))

    print('-----------------------------------------------------\n')
    print("Cohen's Kappa for train and test set:\n ",
          round(cohen_kappa_score(y_train, y_pred_train), 4),
          round(cohen_kappa_score(y_test, y_pred_test), 4))

    print("f2 score for train and test set: \n ",
          round(fbeta_score(y_train, y_pred_train, 2.0), 4),
          round(fbeta_score(y_test, y_pred_test, 2.0), 4))

    print('roc auc score for train and test set:\n ',
          round(roc_auc_score(y_train, y_pred_train), 4),
          round(roc_auc_score(y_test, y_pred_test), 4))

    print('Mean Cross Validation Score:\n', round(cross_val_score(clf,
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

7. Logistic Regression

7.1 Optimization and Tuning

In [61]:

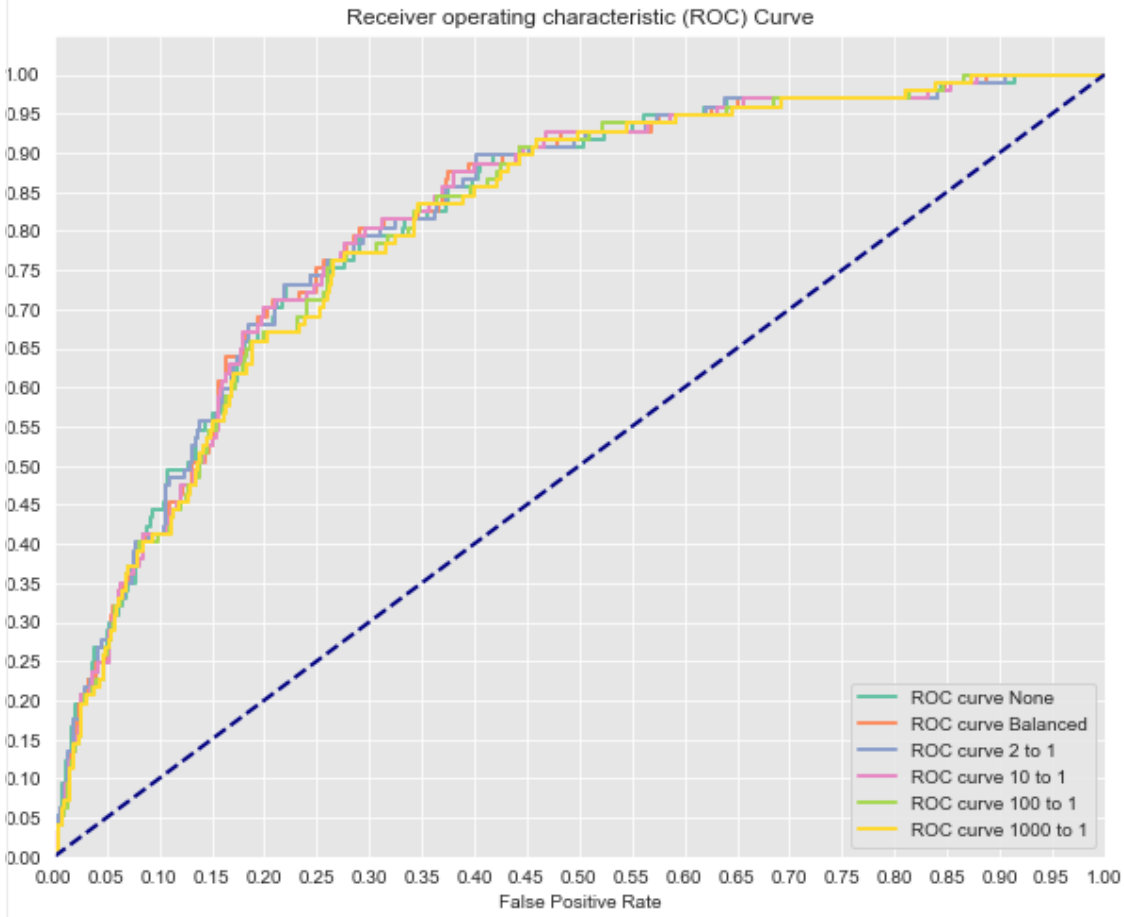
```
# Now let's compare a few different regularization performances on the
weights = [None, 'balanced', {1:2, 0:1}, {1:10, 0:1}, {1:100, 0:1}, {1:
names = ['None', 'Balanced', '2 to 1', '10 to 1', '100 to 1', '1000 to
colors = sns.color_palette('Set2')

plt.figure(figsize=(10,8))

for n, weight in enumerate(weights):
    # Fit a model
    logreg = LogisticRegression(fit_intercept=False, C=1e20, class_weig
    model_log = logreg.fit(scaled_X_train, y_train)
    print(model_log)

    # Predict
    y_hat_test = logreg.predict(scaled_X_test)

    y_score = logreg.fit(scaled_X_train, y_train).decision_function(sca

    fpr, tpr, thresholds = roc_curve(y_test, y_score)

    print('AUC for {}: {}'.format(names[n], auc(fpr, tpr)))
    print('----------------------------------------------------------------
    lw = 2
    plt.plot(fpr, tpr, color=colors[n],
             lw=lw, label='ROC curve {}'.format(names[n]))

plt.plot([0, 1], [0, 1], color='navy', lw=lw, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])

plt.yticks([i/20.0 for i in range(21)])
plt.xticks([i/20.0 for i in range(21)])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver operating characteristic (ROC) Curve')
plt.legend(loc='lower right')
plt.show()
```

```
ogisticRegression(C=1e+20, fit_intercept=False)
UC for None: 0.81423403870501
----------------------------------------------------------------------
----------
ogisticRegression(C=1e+20, class_weight='balanced', fit_intercept=False)
UC for Balanced: 0.814794718755652
----------------------------------------------------------------------
----------
ogisticRegression(C=1e+20, class_weight={0: 1, 1: 2}, fit_intercept=Fals
)
UC for 2 to 1: 0.8150479291011034
----------------------------------------------------------------------
----------
ogisticRegression(C=1e+20, class_weight={0: 1, 1: 10}, fit_intercept=Fal
e)
UC for 10 to 1: 0.8137457044673538
----------------------------------------------------------------------
----------
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

```
LogisticRegression(C=1e+20, class_weight={0: 1, 1: 100}, fit_intercept=Fa
lse)
AUC for 100 to 1: 0.8077590884427563
------------------------------------------------------------------------
------------
LogisticRegression(C=1e+20, class_weight={0: 1, 1: 1000}, fit_intercept=F
alse)
AUC for 1000 to 1: 0.8059504431181045
------------------------------------------------------------------------
------------
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [362]:
```
1 ! pip install imbalanced-learn
```

```
Requirement already satisfied: imbalanced-learn in c:\users\mirnamamaranda
\anaconda3\anaconda\lib\site-packages (0.8.0)
Requirement already satisfied: numpy>=1.13.3 in c:\users\mirnamamaranda\ana
conda3\anaconda\lib\site-packages (from imbalanced-learn) (1.19.2)
Requirement already satisfied: scipy>=0.19.1 in c:\users\mirnamamaranda\ana
conda3\anaconda\lib\site-packages (from imbalanced-learn) (1.5.2)
Requirement already satisfied: joblib>=0.11 in c:\users\mirnamamaranda\anac
onda3\anaconda\lib\site-packages (from imbalanced-learn) (0.17.0)
Requirement already satisfied: scikit-learn>=0.24 in c:\users\mirnamamarand
a\anaconda3\anaconda\lib\site-packages (from imbalanced-learn) (0.24.1)
Requirement already satisfied: threadpoolctl>=2.0.0 in c:\users\mirnamamara
nda\anaconda3\anaconda\lib\site-packages (from scikit-learn>=0.24->imbalanc
ed-learn) (2.1.0)
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

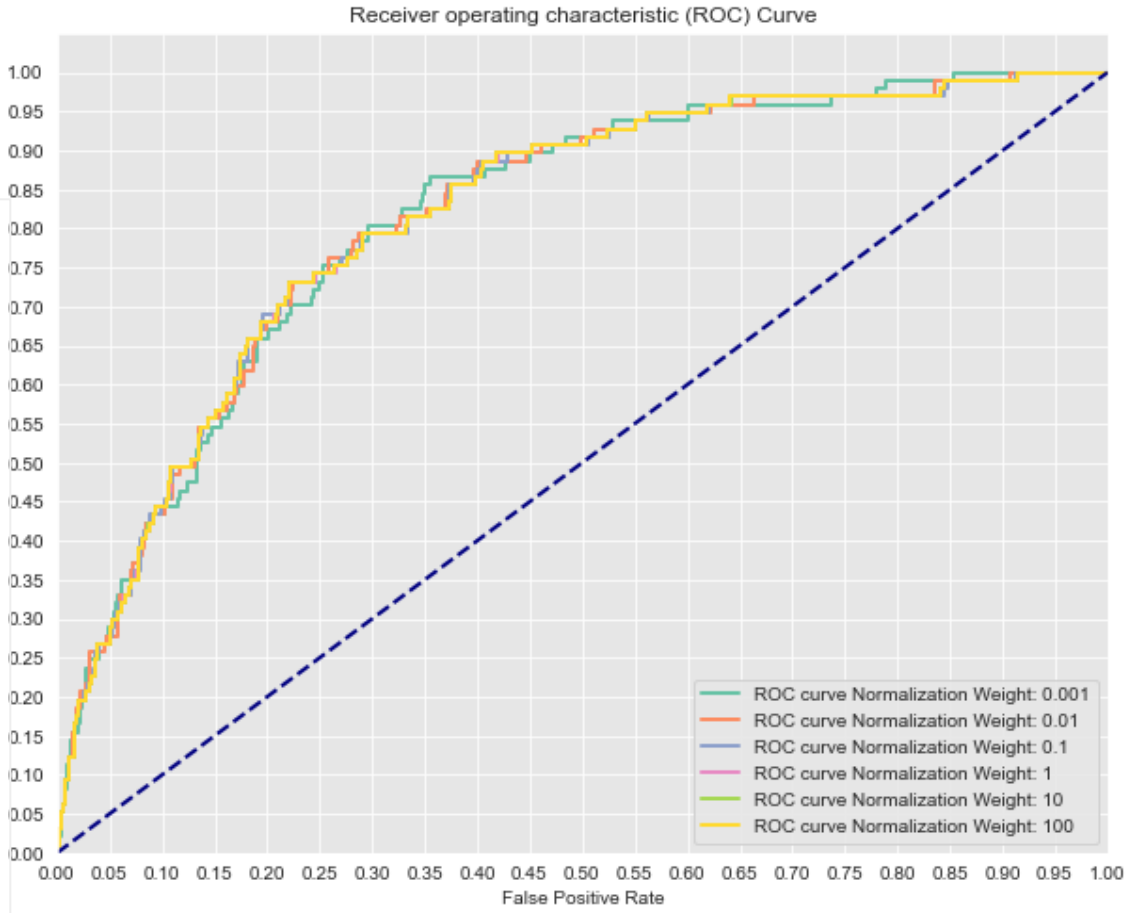
In [63]:

```
# Now let's compare a few different regularization performances on the
C_param_range = [0.001, 0.01, 0.1, 1, 10, 100]
names = [0.001, 0.01, 0.1, 1, 10, 100]
colors = sns.color_palette('Set2')

plt.figure(figsize=(10, 8))

for n, c in enumerate(C_param_range):
    # Fit a model
    logreg = LogisticRegression(fit_intercept=False, C=c, solver='libli
    model_log = logreg.fit(scaled_X_train, y_train)
    print(model_log)
# Preview model params

# Predict
    y_hat_test = logreg.predict(scaled_X_test)

    y_score = logreg.fit(scaled_X_train, y_train).decision_function(sca

    fpr, tpr, thresholds = roc_curve(y_test, y_score)

    print('AUC for {}: {}'.format(names[n], auc(fpr, tpr)))
    print('----------------------------------------------------------')
    lw = 2
    plt.plot(fpr, tpr, color=colors[n],
             lw=lw, label='ROC curve Normalization Weight: {}'.format(r

plt.plot([0, 1], [0, 1], color='navy', lw=lw, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])

plt.yticks([i/20.0 for i in range(21)])
plt.xticks([i/20.0 for i in range(21)])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver operating characteristic (ROC) Curve')
plt.legend(loc='lower right')
plt.show()
```

```
ogisticRegression(C=0.001, fit_intercept=False, solver='liblinear')
UC for 0.001: 0.8137999638270935
----------------------------------------------------------
ogisticRegression(C=0.01, fit_intercept=False, solver='liblinear')
UC for 0.01: 0.8139989148128052
----------------------------------------------------------
ogisticRegression(C=0.1, fit_intercept=False, solver='liblinear')
UC for 0.1: 0.8140893470790378
----------------------------------------------------------
ogisticRegression(C=1, fit_intercept=False, solver='liblinear')
UC for 1: 0.8142159522517635
----------------------------------------------------------
ogisticRegression(C=10, fit_intercept=False, solver='liblinear')
UC for 10: 0.8142340387050099
----------------------------------------------------------
ogisticRegression(C=100, fit_intercept=False, solver='liblinear')
UC for 100: 0.81423403870501
----------------------------------------------------------
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 SelectBe
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

7.2 Best performing parameters for Logistic Regression Model

In [64]:

```
clf = LogisticRegression(fit_intercept=False, C=100,
                         solver='liblinear', class_weight='balanced')
clf.fit(scaled_X_train, y_train)
y_pred_train = clf.predict(scaled_X_train)
y_pred_test = clf.predict(scaled_X_test)


model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred

roc_curve_and_auc(clf, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn   Churn     All
   Actual       NaN     NaN     NaN
 No Churn    1407.0   873.0  2280.0
    Churn      50.0   336.0   386.0
      All    1457.0  1209.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
 No Churn     348.0  222.0  570.0
    Churn      12.0   85.0   97.0
      All     360.0  307.0  667.0

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

lassification Report for train & test set
```

In [65]:

```
clf.coef_.round(2)
```

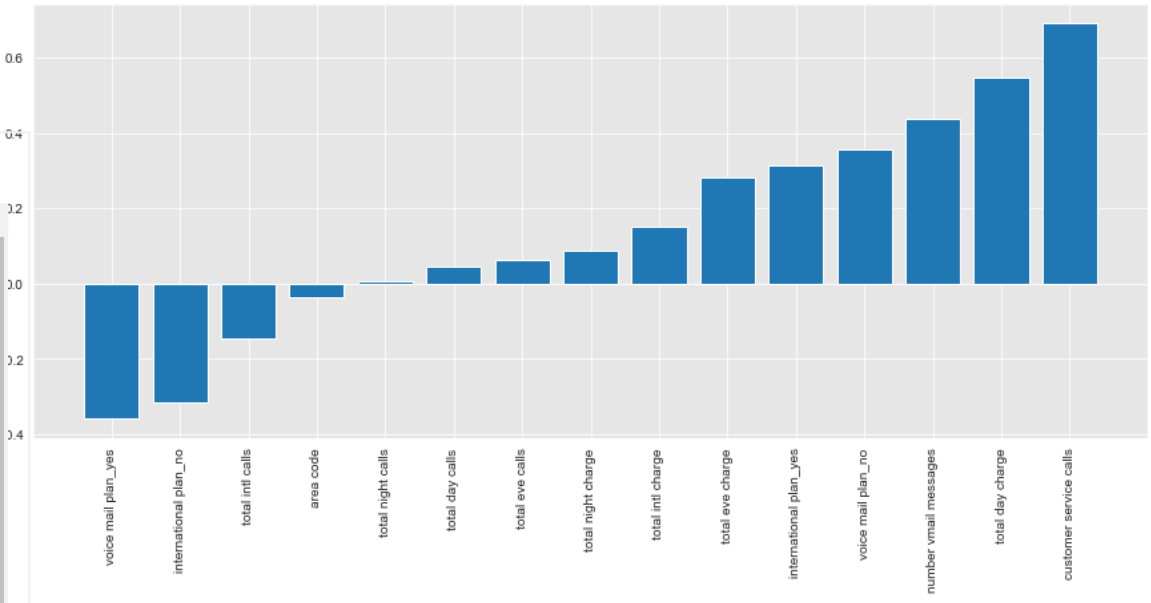
Out[65]:

```
rray([[-0.04,  0.44,  0.05,  0.55,  0.06,  0.28,  0.01,  0.09, -0.15,
        0.15,  0.69, -0.32,  0.32,  0.36, -0.36]])
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [66]:
```
1 plot_coefficients(clf)
```



Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparam
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparam
9.2 Best Parame
9.3 Results &
10 KNN Classifier
10.1 Tuning &
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results &
11 XGBoost
11.1 Results &
12 Gaussian NB
12.1 Results &
13 AdaBoostClassi
13.1 Results &
14 Gradient Boosti
14.1 Results &
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

7. Results Comments

The ean cross validation is 76.87%. We have a precision of 0.28 and recall of 0.88 for the test set. e don't have overfitting. It means we are able to detect the churn customers 88% but 28% of the stomers we say 'churn' was true.

Mos mportant positive churn factors:

1)C tomer service calls

2)T l day charge

3)N ber voicemail messages

4)V e mail plan _no

5)In national plan_yes

6)T l evening charge

Mos mportant negative churn features:

1)V e mail plan _yes

2)In national plan_no

3)T l International call

4)A code

8. Descion Tree Classifier

In [67]:

```
from sklearn.tree import DecisionTreeClassifier


tree_clf = DecisionTreeClassifier(criterion='gini', max_depth=5)
tree_clf.fit(scaled_X_train, y_train)

# Model Performance
# Test set predictions
pred = tree_clf.predict(scaled_X_test)



tree_clf_score = cross_val_score(tree_clf, scaled_X_train, y_train, cv=
mean_tree_clf_score = np.mean(tree_clf_score)

print(f"Mean Cross Validation Score: {mean_tree_clf_score :.2%}")
```

```
ean Cross Validation Score: 93.96%
```

In [68]:

```
print('Training r^2:', tree_clf.score(scaled_X_train, y_train))
print('Test r^2:', tree_clf.score(scaled_X_test, y_test))

print(classification_report(y_test,pred))
```

```
aining r^2: 0.9538634658664666
est r^2: 0.9175412293853074
              precision    recall  f1-score   support

       False       0.94      0.96      0.95       570
        True       0.76      0.64      0.69        97

    accuracy                           0.92       667
   macro avg       0.85      0.80      0.82       667
eighted avg       0.91      0.92      0.91       667
```

8.4 Hyperparameter Tuning for decision tree using GridSearch

In [69]:

```
dt_param_grid = {
    'criterion': ['gini', 'entropy'],
    'max_depth': [None, 2, 3, 4, 5, 6],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 3, 4, 5, 6]
}

num_decision_trees = 3 * 2 * 6 * 3 * 3 * 6
print(f"Grid Search will have to search through {num_decision_trees} di
```

```
rid Search will have to search through 648 different permutations.
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select B
10.1.1.1 K=3
10.1.2 Iterati
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

In [70]:

```
from sklearn.model_selection import train_test_split, GridSearchCV, cro
# Instantiate GridSearchCV
dt_grid_search = GridSearchCV(tree_clf, dt_param_grid, cv=10, return_tr

# Fit to the data
dt_grid_search.fit(scaled_X_train, y_train)

#Examine best parameters

# Mean training score
dt_gs_training_score = np.mean(dt_grid_search.cv_results_['mean_train_s

# Mean test score
dt_gs_testing_score = dt_grid_search.score(scaled_X_test, y_test)

print(f"Mean Training Score: {dt_gs_training_score :.2%}")
print(f"Mean Test Score: {dt_gs_testing_score :.2%}")
print("Best Parameter Combination Found During Grid Search:")
dt_grid_search.best_params_
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

Out[70]:

```
ean Training Score: 93.67%
ean Test Score: 92.80%
est Parameter Combination Found During Grid Search:

'criterion': 'gini',
'max_depth': 6,
'min_samples_leaf': 4,
'min_samples_split': 10}
```

8.1 Select Best Parameters for Descion tree classifier

In [71]:

```
dt_param_grid2 = {
    'criterion': ['gini'],
    'max_depth': [ 6],
    'min_samples_split': [4],
    'min_samples_leaf': [10]
}

dt_grid_search2 = GridSearchCV(tree_clf, dt_param_grid2, cv=10, return_

# Fit to the data

clf=dt_grid_search2 .fit(scaled_X_train, y_train)



#Examine best parameters

# Mean training score
dt_gs_training_score2 = np.mean(clf.cv_results_['mean_train_score'])

# Mean test score
dt_gs_testing_score2 = clf.score(scaled_X_test, y_test)


print(f"Mean Training Score: {dt_gs_training_score2 :.2%}")
print(f"Mean Test Score: {dt_gs_testing_score2 :.2%}")

# Model Performance
# Test set predictions
y_pred_test =clf.predict(scaled_X_test)
y_pred_train =clf.predict(scaled_X_train)

print(classification_report(y_test,y_pred_test))

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred



plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)

plot_feature_importances(tree_clf)
```

Contents

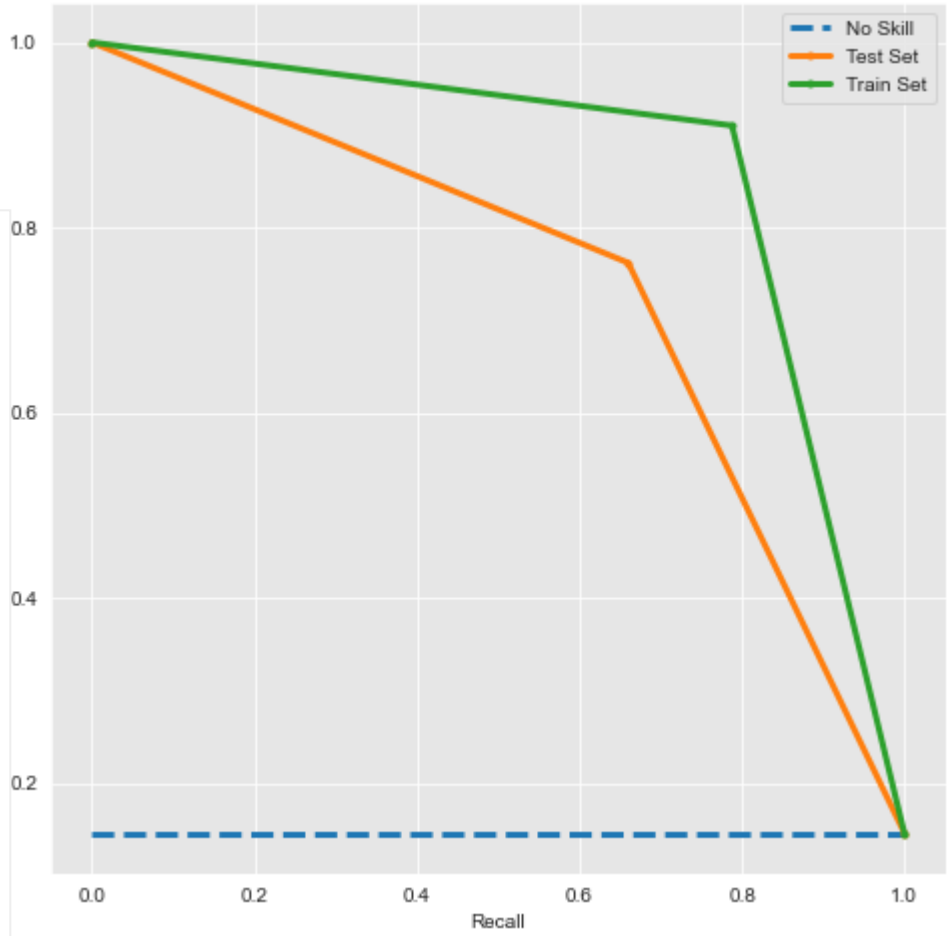
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
ean Training Score: 95.79%
ean Test Score: 92.05%
              precision    recall  f1-score   support

       False       0.94      0.96      0.95       570
        True       0.76      0.66      0.71        97

    accuracy                           0.92       667
   macro avg       0.85      0.81      0.83       667
eighted avg       0.92      0.92      0.92       667

ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:
```

```
  Predicted  No Churn  Churn     All
0    Actual       NaN    NaN     NaN
1  No Churn    2250.0   30.0  2280.0
2     Churn      82.0  304.0   386.0
3       All    2332.0  334.0  2666.0

  Predicted  No Churn  Churn    All
0    Actual       NaN    NaN    NaN
1  No Churn     550.0   20.0  570.0
2     Churn      33.0   64.0   97.0
3       All     583.0   84.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       0.96      0.99      0.98      2280
        True       0.91      0.79      0.84       386

    accuracy                           0.96      2666
   macro avg       0.94      0.89      0.91      2666
eighted avg       0.96      0.96      0.96      2666


est set
              precision    recall  f1-score   support

       False       0.94      0.96      0.95       570
        True       0.76      0.66      0.71        97

    accuracy                           0.92       667
   macro avg       0.85      0.81      0.83       667
eighted avg       0.92      0.92      0.92       667

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

ohen's Kappa for train and test set:
 0.8203 0.6615
2 score for train and test set:
 0.8094 0.678
oc auc score for train and test set:
 0.8872 0.8124
ean Cross Validation Score:
0.9373
```

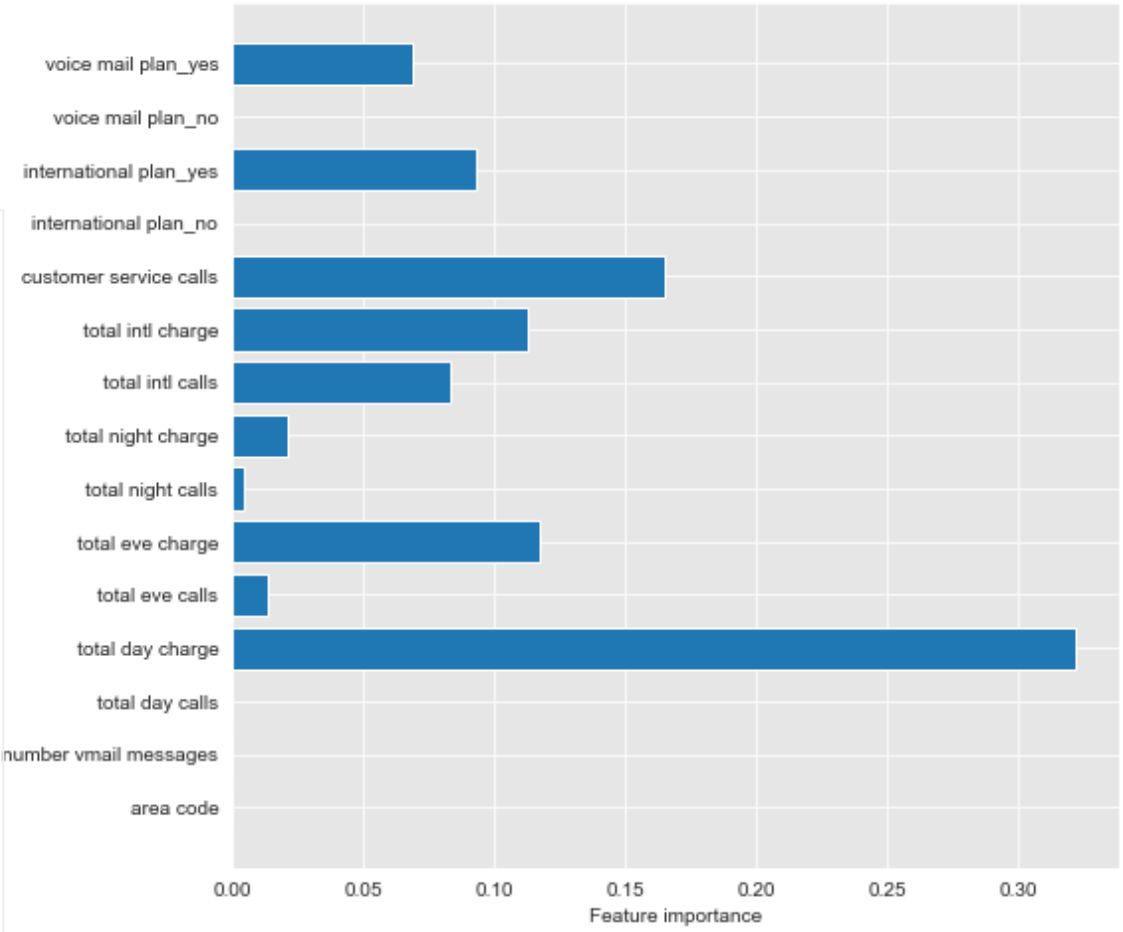
Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best



Contents

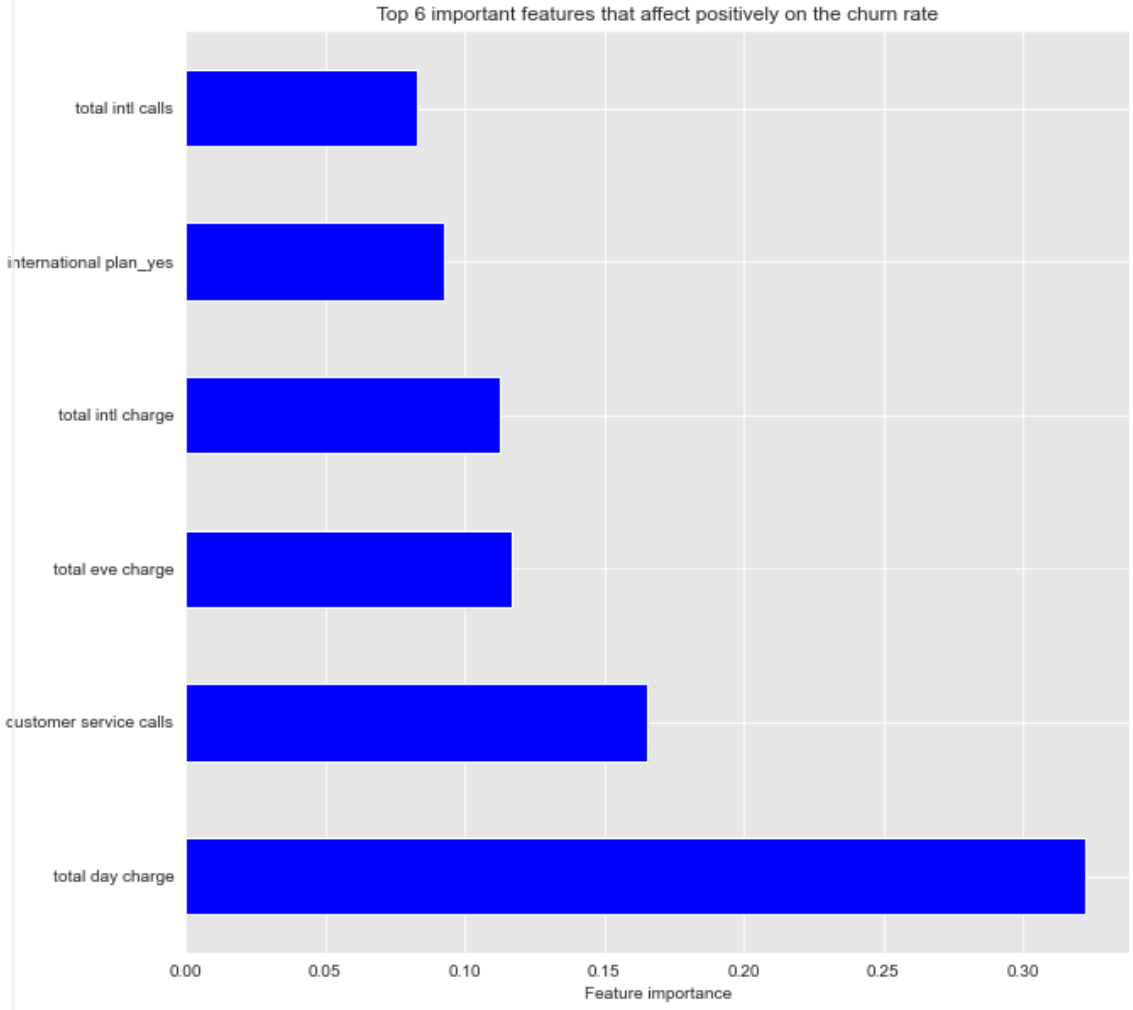
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [72]:

```
# Get Feature Importance from the classifier

feature_importance = tree_clf.feature_importances_
print (tree_clf.feature_importances_)
feat_importances = pd.Series(tree_clf.feature_importances_, index=X.col
feat_importances = feat_importances.nlargest(6)
feat_importances.plot(kind='barh' , figsize=(10,10), color="b")

plt.xlabel('Feature importance')
plt.ylabel('Positive Churn Factors')
plt.title('Top 6 important features that affect positively on the churr
```

```
0.         0.         0.         0.32193796 0.0134261  0.11687289
0.00422496 0.02131784 0.08281552 0.11242512 0.1652558  0.
0.0928464  0.         0.0688774 ]
```

Out[72]: ext(0.5, 1.0, 'Top 6 important features that affect positively on the chur rate')



Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparam
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparam
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

8.2 Results Comments

We ve a precision of 0.87 and recall of 0.65 for the test set. We don't have overfitting. It means we e able to detect the churn customers 65% but 87% of the customers we say 'churn' was true.

The p 5 factors affecting te churn rate:

1) T l day charge 2) Customer service calls 3) Total evening charge 4) Total international charge
3) T l International plan_yes 4) Total international calls

9 Random Forest Classifier

In [76]:

```
rf_clf = RandomForestClassifier()
rf_clf .fit(scaled_X_train, y_train)

# Model Performance
# Test set predictions
pred = rf_clf .predict(scaled_X_test)



rf_clf_score = cross_val_score(rf_clf, scaled_X_train, y_train, cv=10)
mean_rf_clf_score = np.mean(tree_clf_score)

print(f"Mean Cross Validation Score: {mean_rf_clf_score :.2%}")
```

```
ean Cross Validation Score: 93.96%
```

In [77]:
```
print('Training r^2:', tree_clf.score(scaled_X_train, y_train))
print('Test r^2:', tree_clf.score(scaled_X_test, y_test))

print(classification_report(y_test,pred))
```

```
Training r^2: 0.9538634658664666
Test r^2: 0.9175412293853074
              precision    recall  f1-score   support

       False       0.94      0.98      0.96       570
        True       0.87      0.60      0.71        97

    accuracy                           0.93       667
   macro avg       0.90      0.79      0.83       667
eighted avg       0.92      0.93      0.92       667
```


Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test sp
6.6 Standarize F
6.7 Building appl
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

9. Hyperparameter Tuning for Random Forest using GridSearch

In [78]:
```
rf_param_grid = {
    'n_estimators': [10, 30, 100],
    'criterion': ['gini', 'entropy'],
    'max_depth': [None, 2, 6, 10],
    'min_samples_split': [5, 10],
    'min_samples_leaf': [3, 6]
}

rf_grid_search = GridSearchCV(rf_clf, dt_param_grid, cv=10, return_trai

# Fit to the data
rf_grid_search.fit(scaled_X_train, y_train)

#Examine best parameters

# Mean training score
rf_gs_training_score = np.mean(rf_grid_search.cv_results_['mean_train_s

# Mean test score
rf_gs_testing_score = rf_grid_search.score(scaled_X_test, y_test)

print(f"Mean Training Score: {rf_gs_training_score :.2%}")
print(f"Mean Test Score: {rf_gs_testing_score :.2%}")
print("Best Parameter Combination Found During Grid Search:")
rf_grid_search.best_params_
```

```
ean Training Score: 91.03%
ean Test Score: 93.85%
est Parameter Combination Found During Grid Search:

'criterion': 'entropy',
'max_depth': None,
'min_samples_leaf': 1,
'min_samples_split': 5}
```

In [78]:

9.2 Best Paramerts for Random Forest

In [79]:

```
dt_param_grid2 = {
    'criterion': ['entropy'],
    'max_depth': [ None],
    'min_samples_split': [5],
    'min_samples_leaf': [1]
}

dt_grid_search2 = GridSearchCV(rf_clf, dt_param_grid2, cv=10, return_tr

# Fit to the data

clf=dt_grid_search2.fit(scaled_X_train, y_train)



#Examine best parameters

# Mean training score
dt_gs_training_score2 = np.mean(clf.cv_results_['mean_train_score'])

# Mean test score
dt_gs_testing_score2 = clf.score(scaled_X_test, y_test)


print(f"Mean Training Score: {dt_gs_training_score2 :.2%}")
print(f"Mean Test Score: {dt_gs_testing_score2 :.2%}")

# Model Performance
# Test set predictions
y_pred_test =clf.predict(scaled_X_test)
y_pred_train =clf.predict(scaled_X_train)
```

```
ean Training Score: 98.82%
ean Test Score: 93.25%
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

In [80]:

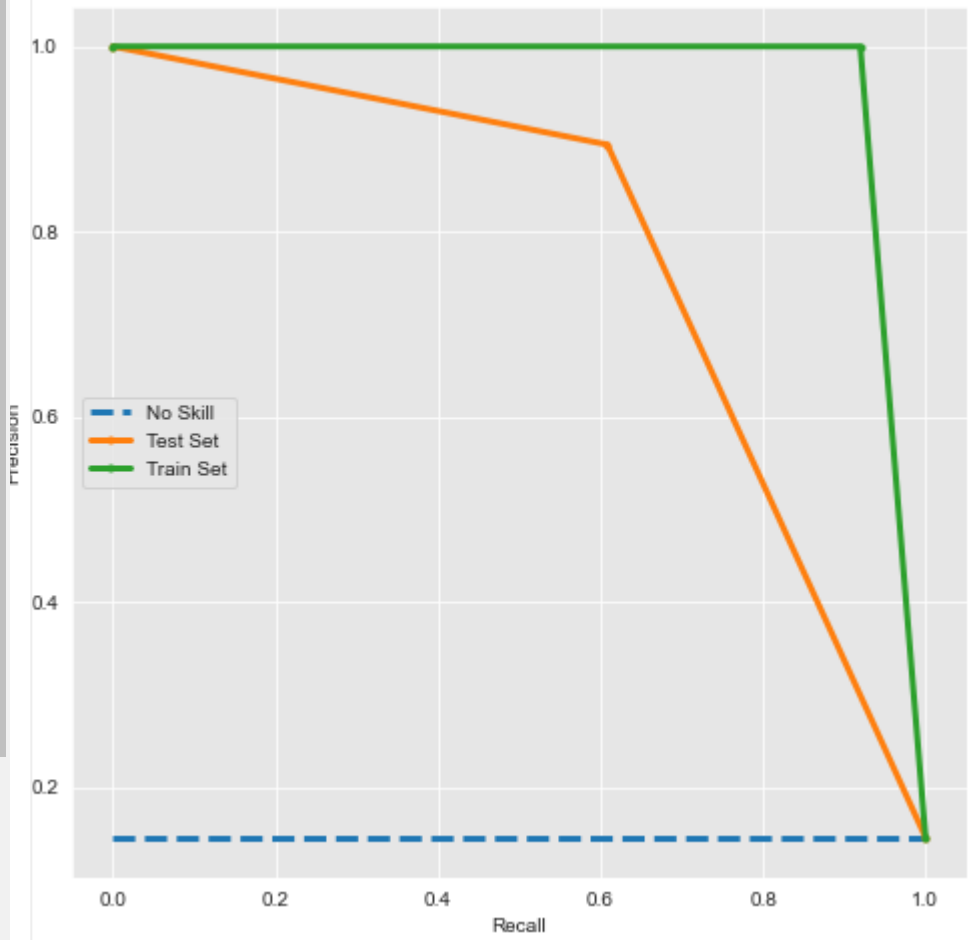
```
print(classification_report(y_test,y_pred_test))

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)

plot_feature_importances(rf_clf)
```


Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
              precision    recall  f1-score   support

       False       0.94      0.99      0.96       570
        True       0.89      0.61      0.72        97

    accuracy                           0.93       667
   macro avg       0.92      0.80      0.84       667
eighted avg       0.93      0.93      0.93       667

ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
No Churn     2280.0    0.0  2280.0
   Churn       31.0  355.0   386.0
     All     2311.0  355.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
No Churn      563.0    7.0  570.0
   Churn       38.0   59.0   97.0
     All      601.0   66.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       0.99      1.00      0.99      2280
        True       1.00      0.92      0.96       386

    accuracy                           0.99      2666
   macro avg       0.99      0.96      0.98      2666
eighted avg       0.99      0.99      0.99      2666


est set
              precision    recall  f1-score   support

       False       0.94      0.99      0.96       570
        True       0.89      0.61      0.72        97

    accuracy                           0.93       667
```

```
   macro avg       0.92      0.80      0.84       667
weighted avg       0.93      0.93      0.93       667

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

Cohen's Kappa for train and test set:
 0.9514 0.6871
f2 score for train and test set:
 0.9347 0.6498
oc auc score for train and test set:
 0.9598 0.798
ean Cross Validation Score:
0.9466
```

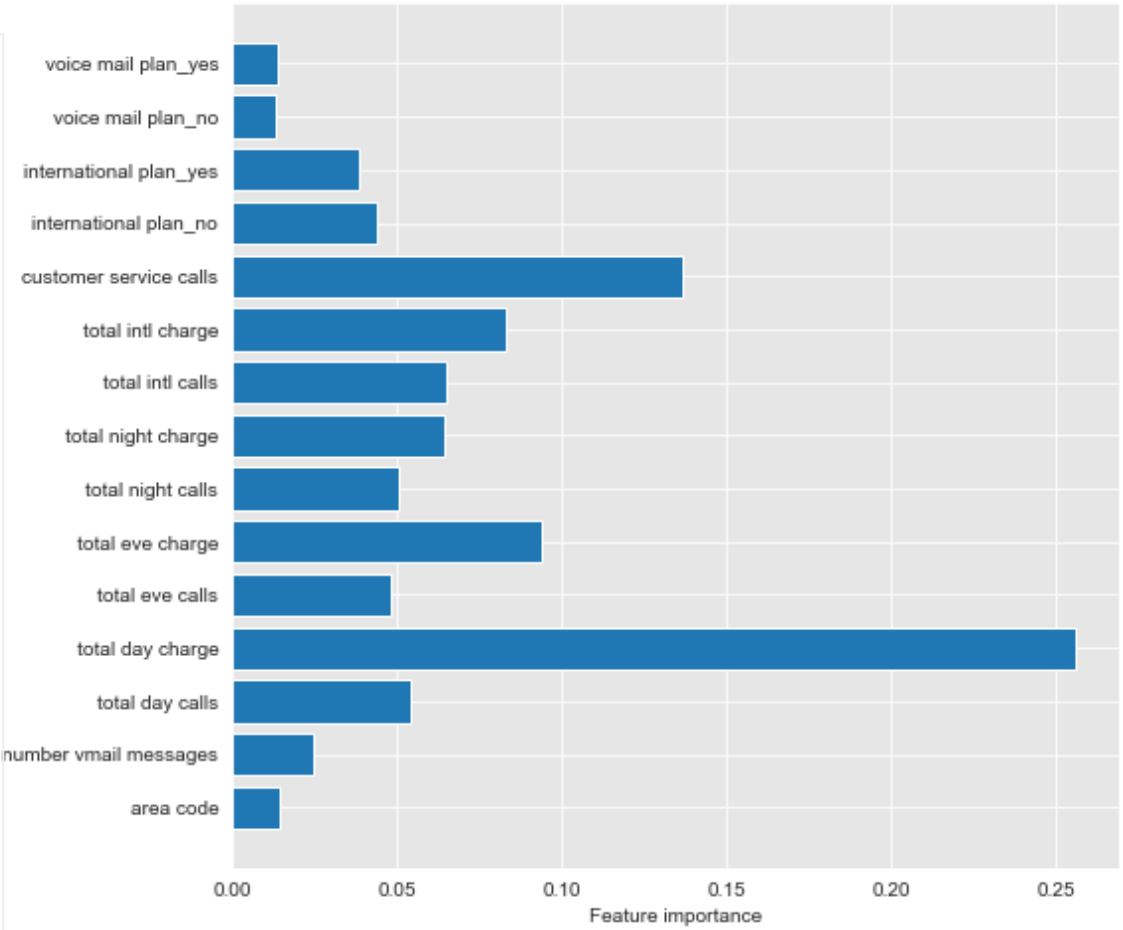


Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best



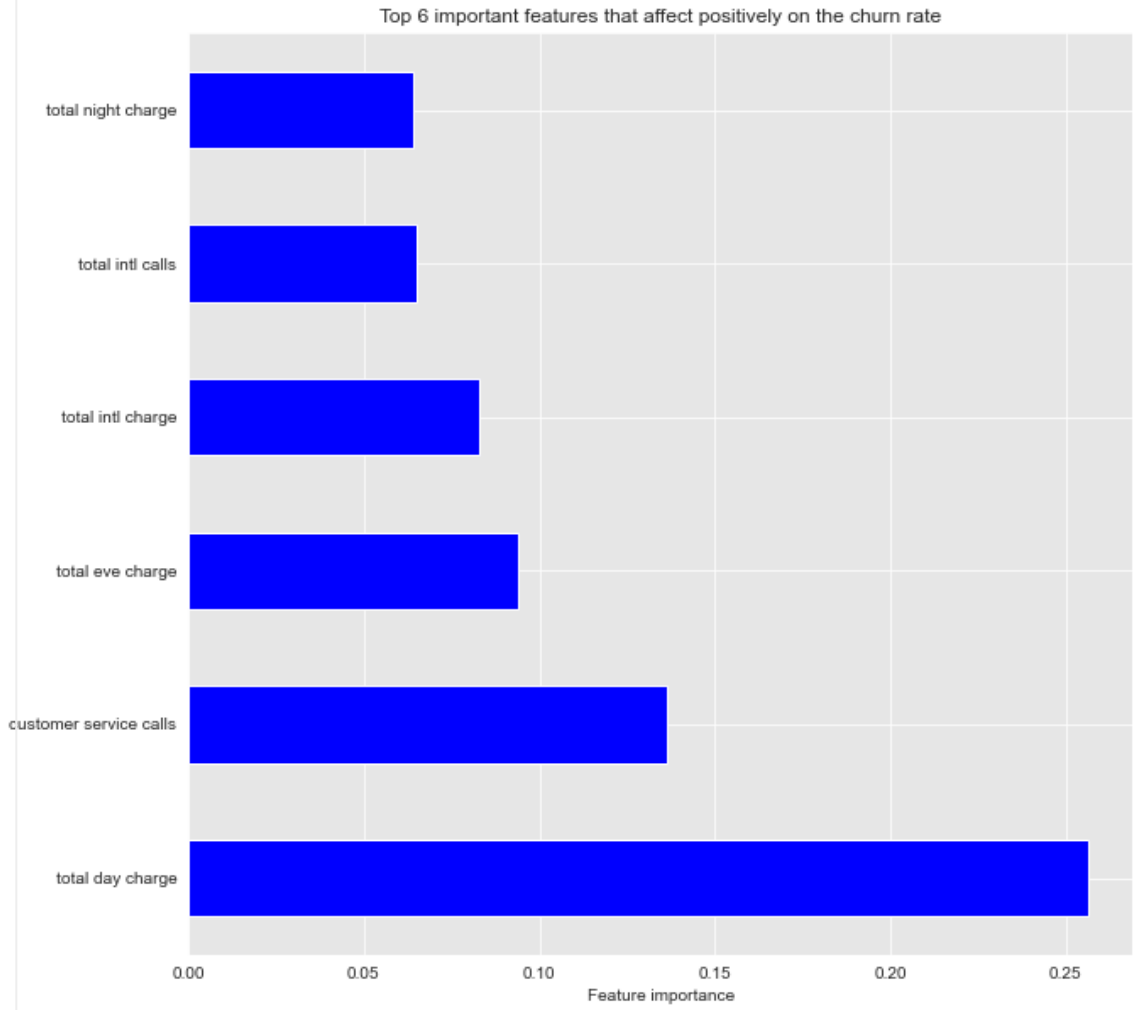
In [81]:

```
feature_importance = rf_clf.feature_importances_
print (rf_clf.feature_importances_)
feat_importances = pd.Series(rf_clf.feature_importances_, index=X.colum
feat_importances = feat_importances.nlargest(6)
feat_importances.plot(kind='barh' , figsize=(10,10), color="b")

plt.xlabel('Feature importance')
plt.ylabel('Positive Churn Factors')
plt.title('Top 6 important features that affect positively on the churr
```

```
0.01450957 0.02484146 0.05424423 0.25617375 0.04835243 0.09392077
0.05054068 0.06424145 0.06487218 0.08277946 0.13643413 0.04379005
0.03817828 0.01335585 0.01376572]
```

Out[81]:

```
ext(0.5, 1.0, 'Top 6 important features that affect positively on the chur
rate')
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

9.3 Results & Comments

We have a precision of 0.61 and recall of 0.89 for the test set. We have some overfitting. It means we are able to detect the churn customers 61% but 89% of the customers we say 'churn' was true.

The top 5 factors affecting te churn rate:

1) Total day charge 2) Customer service calls 3) Total evening charge 4) Total international charge 5) T al international calls 6) Total night charge

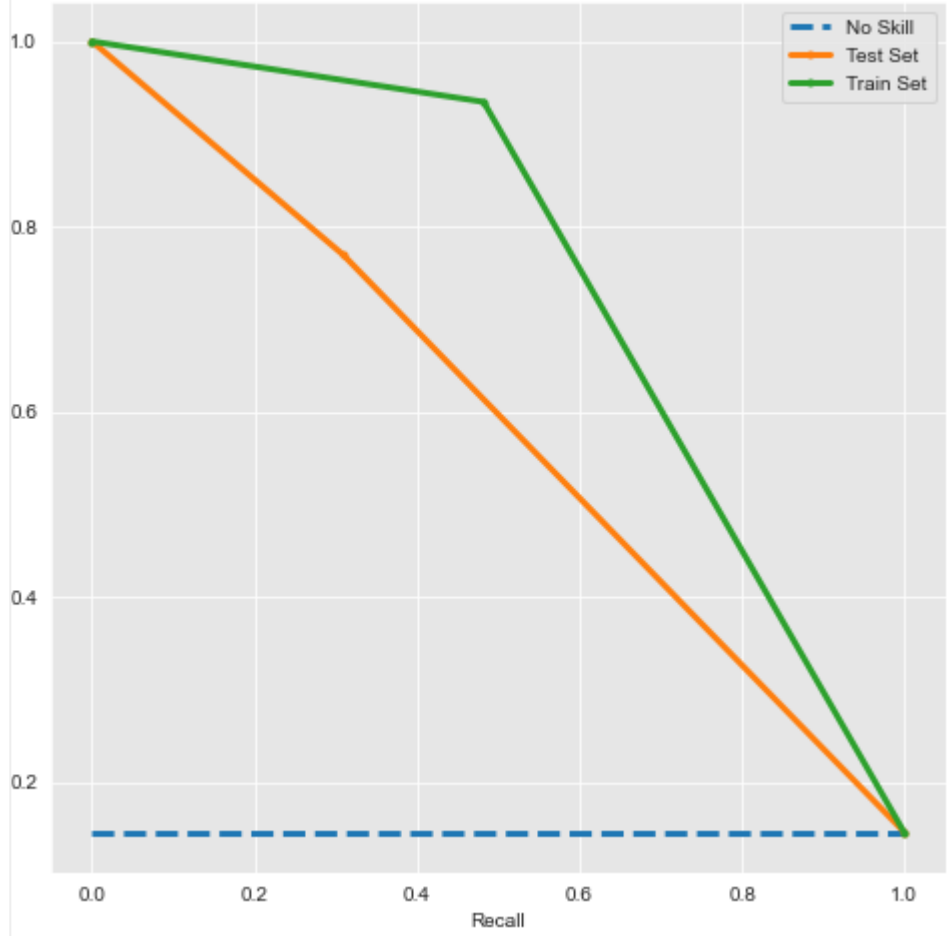
10 KNN Classifier

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploratio
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparam
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparam
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select B
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

In [82]:

```
#Instantiate KNeighborsClassifier
clf= KNeighborsClassifier()

# Fit the classifier
clf.fit(scaled_X_train, y_train)

# Predict on the test set
test_preds = clf.predict(scaled_X_test)
train_preds=clf.predict(scaled_X_train)




plot_pr_rc_curve(y_test, test_preds, y_train, train_preds)
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

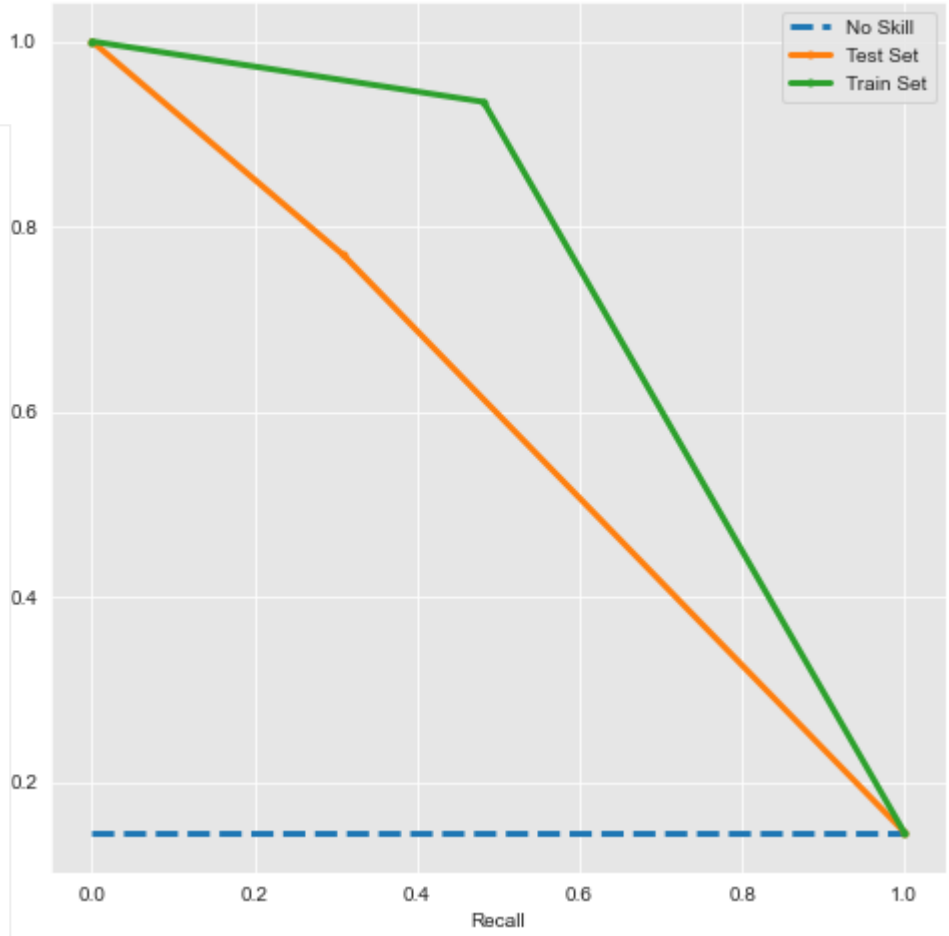
In [83]:
```
1 model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, train_
```

```
MODEL EVALUATION METRICS:
 -----------------------------------------------------
Confusion Matrix for train & test set:

   Predicted  No Churn  Churn     All
0    Actual       NaN    NaN     NaN
  No Churn    2267.0   13.0  2280.0
     Churn     200.0  186.0   386.0
       All    2467.0  199.0  2666.0

   Predicted  No Churn  Churn    All
     Actual       NaN    NaN    NaN
  No Churn     561.0    9.0  570.0
     Churn      67.0   30.0   97.0
       All     628.0   39.0  667.0


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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       0.92      0.99      0.96      2280
        True       0.93      0.48      0.64       386

    accuracy                           0.92      2666
   macro avg       0.93      0.74      0.80      2666
eighted avg       0.92      0.92      0.91      2666


est set
              precision    recall  f1-score   support

       False       0.89      0.98      0.94       570
        True       0.77      0.31      0.44        97

    accuracy                           0.89       667
   macro avg       0.83      0.65      0.69       667
eighted avg       0.88      0.89      0.86       667

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

ohen's Kappa for train and test set:
 0.5961 0.3903
2 score for train and test set:
 0.5336 0.3513
oc auc score for train and test set:
 0.7381 0.6467
ean Cross Validation Score:
.8614
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparam
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparam
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

In [84]:
```
plot_pr_rc_curve(y_test, test_preds, y_train, train_preds)
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

10 Tuning & Optimization (Iterate over n values)

In [85]:
```
def find_best_k(scaled_X_train, y_train, scaled_X_test, y_test, min_k=1
    best_k = 0
    best_score = 0.0
    for k in range(min_k, max_k+1, 2):
        knn = KNeighborsClassifier(n_neighbors=k)
        knn.fit(scaled_X_train, y_train)
        preds = knn.predict(scaled_X_test)
        f1 = f1_score(y_test, preds)
        if f1 > best_score:
            best_k = k
            best_score = f1

    print("Best Value for k: {}".format(best_k))
    print("F1-Score: {}".format(best_score))
```

In [86]:
```
1 find_best_k(scaled_X_train, y_train, scaled_X_test, y_test)
```

```
Best Value for k: 3
F1-Score: 0.4583333333333334
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

10.1.1 Select Best K for KNN Machine Learning Model

10.1.1.1 K=3

In [87]:

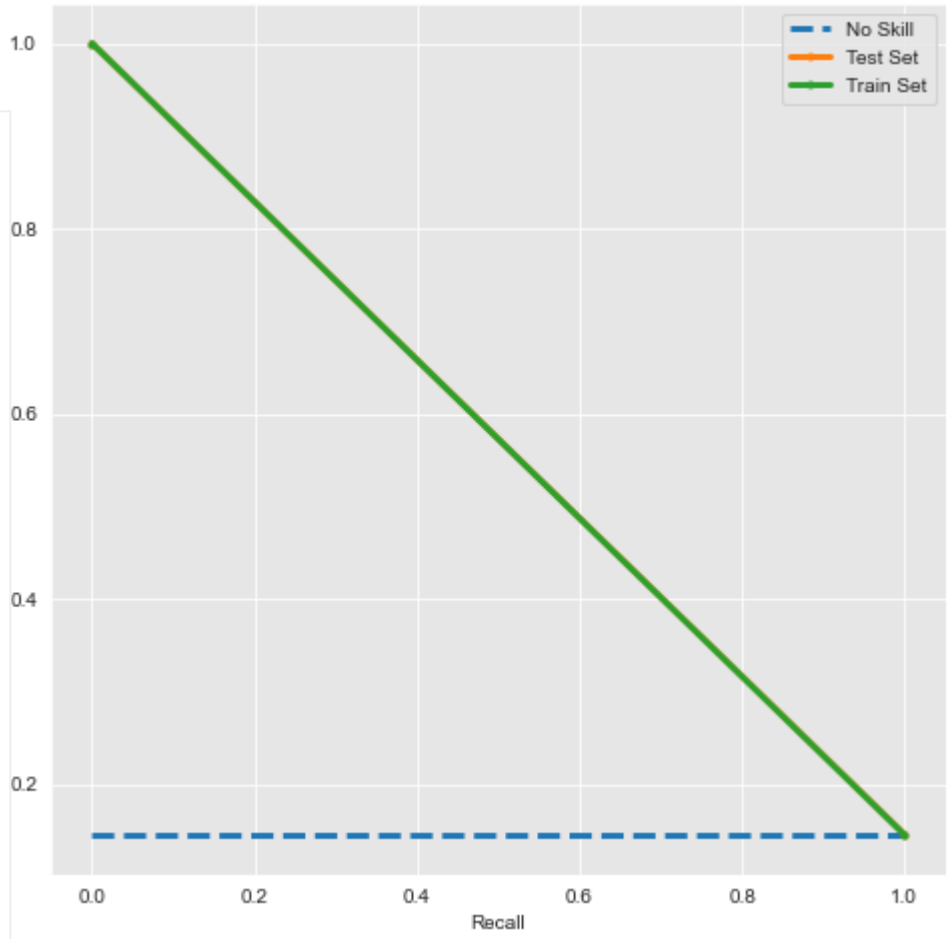
```
clf = KNeighborsClassifier(n_neighbors=3)
clf.fit(X_train, y_train)
train_preds = clf.predict(scaled_X_train)
test_preds = clf.predict(scaled_X_test)
model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, train_
plot_pr_rc_curve(y_test, test_preds, y_train, train_preds)

```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

 Predicted  No Churn  Churn     All
    Actual       NaN    NaN     NaN
  No Churn    2280.0    0.0  2280.0
     Churn     386.0    0.0   386.0
       All    2666.0    0.0  2666.0

 Predicted  No Churn  Churn    All
    Actual       NaN    NaN    NaN
  No Churn     570.0    0.0  570.0
     Churn      97.0    0.0   97.0
       All     667.0    0.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       0.86      1.00      0.92      2280
        True       0.00      0.00      0.00       386

    accuracy                           0.86      2666
   macro avg       0.43      0.50      0.46      2666
eighted avg       0.73      0.86      0.79      2666


est set
              precision    recall  f1-score   support

       False       0.85      1.00      0.92       570
        True       0.00      0.00      0.00        97

    accuracy                           0.85       667
   macro avg       0.43      0.50      0.46       667
eighted avg       0.73      0.85      0.79       667

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

ohen's Kappa for train and test set:
 0.0 0.0
2 score for train and test set:
 0.0 0.0
oc auc score for train and test set:
 0.5 0.5
```

```
Mean Cross Validation Score:
 0.8437
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results &
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [88]:

```
KNN_clf_score = cross_val_score(clf, scaled_X_train, y_train, cv=10)
mean_KNN_clf_score = np.mean(KNN_clf_score)


print(f"Mean Cross Validation Score: {mean_KNN_clf_score :.2%}")

```

```
ean Cross Validation Score: 89.05%
```

10.2 Iterate over 1 < n < 26

In [89]:

```
k_range = range(1, 26)

for k in k_range:
    clf = KNeighborsClassifier(n_neighbors=k)
    clf.fit(scaled_X_train, y_train)
    y_pred_train = clf.predict(scaled_X_train)
    y_pred_test = clf.predict(scaled_X_test)

    print('------------')
    print(k)
    print('\nClassification Report for train & test set\n',
          '\nTrain set\n',
          classification_report(y_train, y_pred_train),
          '\n\nTest set\n',
          classification_report(y_test, y_pred_test))
    print('-----------------------------------------------\n')

    print("f2 score for train and test set: \n ",
          round(fbeta_score(y_train, y_pred_train, 2.0), 4),
          round(fbeta_score(y_test, y_pred_test, 2.0), 4))
```

```
-----------


lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       1.00      1.00      1.00      2280
        True       1.00      1.00      1.00       386

    accuracy                           1.00      2666
   macro avg       1.00      1.00      1.00      2666
eighted avg       1.00      1.00      1.00      2666


est set
              precision    recall  f1-score   support

       False       0.00      0.00      0.00       570
```

10.1.1.1 K=1

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [90]:

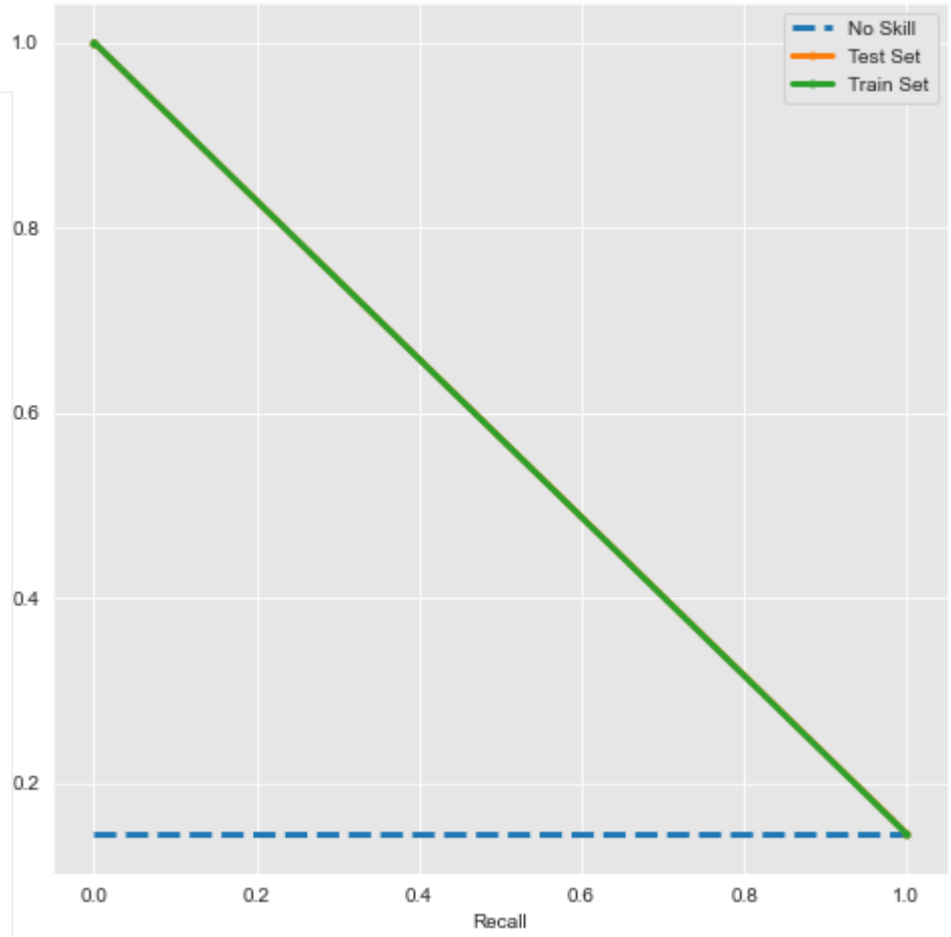
```
clf = KNeighborsClassifier(n_neighbors=1)
clf.fit(X_train, y_train)
train_preds = clf.predict(scaled_X_train)
test_preds = clf.predict(scaled_X_test)
model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, train_
plot_pr_rc_curve(y_test, test_preds, y_train, train_preds)

```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

 Predicted  No Churn  Churn     All
    Actual       NaN    NaN     NaN
  No Churn    2280.0    0.0  2280.0
     Churn     386.0    0.0   386.0
       All    2666.0    0.0  2666.0

 Predicted  No Churn  Churn    All
    Actual       NaN    NaN    NaN
  No Churn     570.0    0.0  570.0
     Churn      97.0    0.0   97.0
       All     667.0    0.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       0.86      1.00      0.92      2280
        True       0.00      0.00      0.00       386

    accuracy                           0.86      2666
   macro avg       0.43      0.50      0.46      2666
eighted avg       0.73      0.86      0.79      2666


est set
              precision    recall  f1-score   support

       False       0.85      1.00      0.92       570
        True       0.00      0.00      0.00        97

    accuracy                           0.85       667
   macro avg       0.43      0.50      0.46       667
eighted avg       0.73      0.85      0.79       667

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

ohen's Kappa for train and test set:
 0.0 0.0
2 score for train and test set:
 0.0 0.0
oc auc score for train and test set:
 0.5 0.5
```

```
Mean Cross Validation Score:
 0.7942
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results &
11 XGBoost
11.1 Results &
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results &
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

10 Results & Comments

The ean cross validation is around 85%. This model performed poorly even for the optimal sele ed K (K=1 or 3) with poor recall snd precision for True Churn.

In [93]:

```
1 ! pip install  xgboost
```

```
equirement already satisfied: xgboost in c:\users\mirnamamaranda\anaconda3
lib\site-packages (1.3.3)
equirement already satisfied: scipy in c:\users\mirnamamaranda\anaconda3\l
b\site-packages (from xgboost) (1.4.1)
equirement already satisfied: numpy in c:\users\mirnamamaranda\anaconda3\l
b\site-packages (from xgboost) (1.19.2)
```

11 XGBoost

In [ ]:

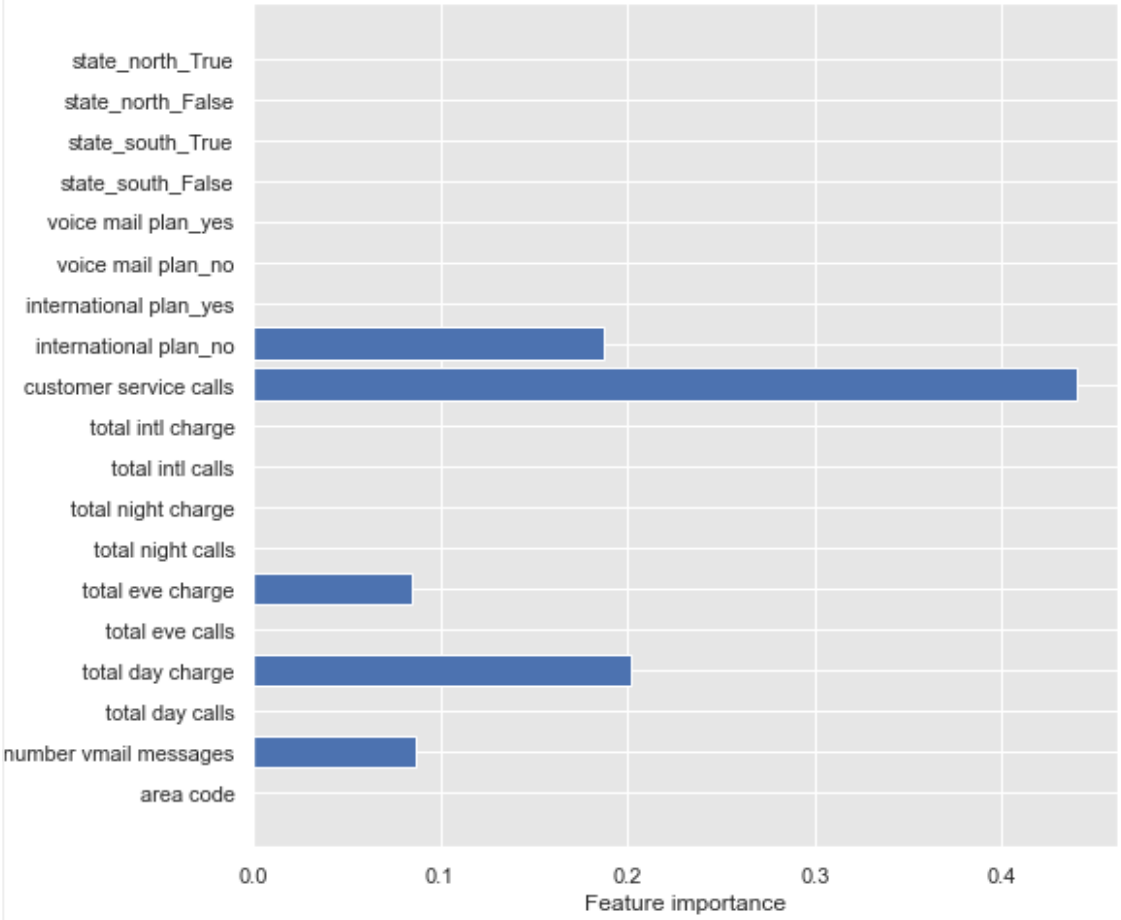
```
from xgboost import XGBClassifier



clf = XGBClassifier(objective='binary:logistic',
                    nthread=4,
                    scale_pos_weight=3,
                    seed=42,
                    max_depth=3,
                    n_estimators=140,
                    learning_rate=0.005)

clf.fit(scaled_X_train, y_train)
y_pred_train = clf.predict(scaled_X_train)
y_pred_test = clf.predict(scaled_X_test)
```

In [ ]:

```
model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred
plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)


```

In [399]:

```
plot_feature_importances(clf)
```



Contents

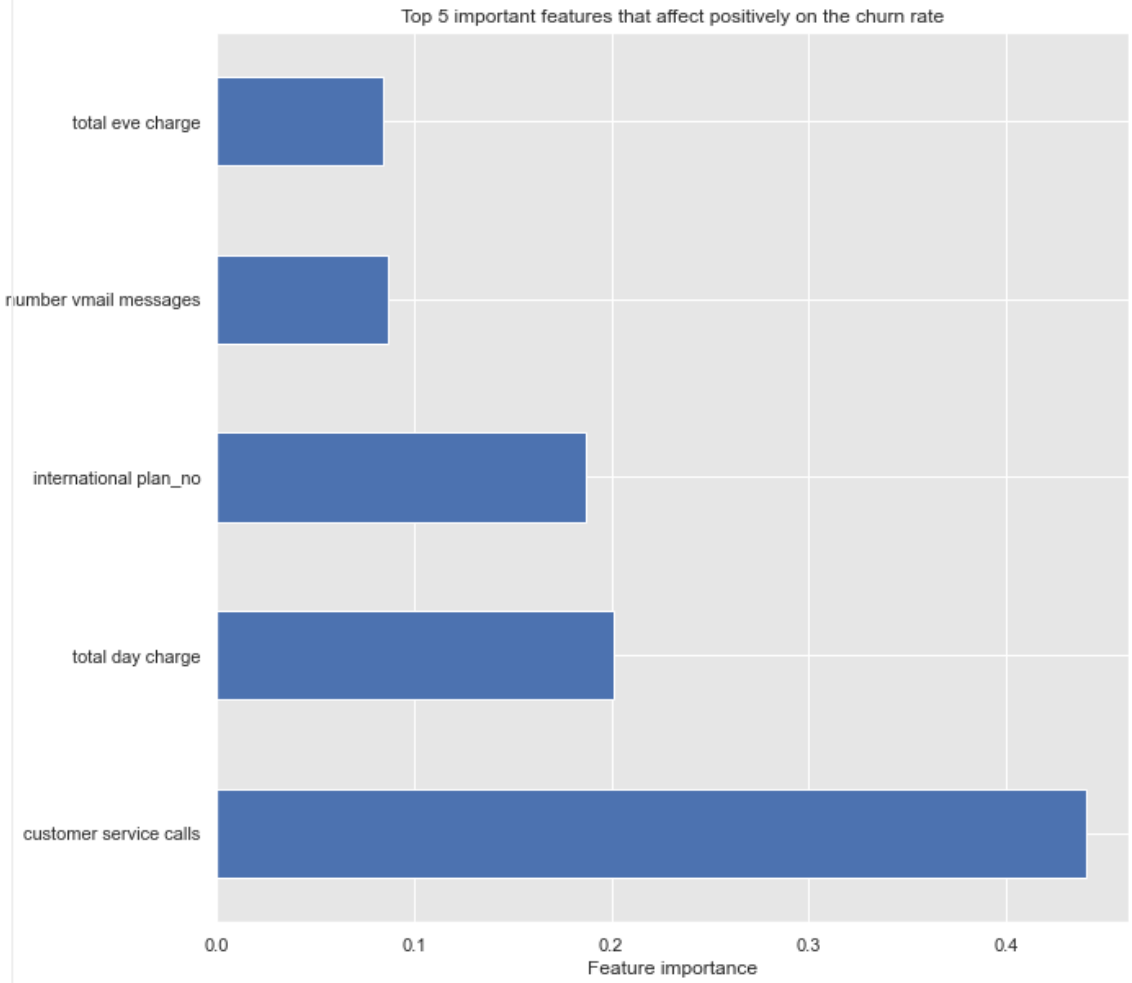
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [401]:

```
feature_importance = clf.feature_importances_
print (clf.feature_importances_)
feat_importances = pd.Series(clf.feature_importances_, index=X.columns)
feat_importances = feat_importances.nlargest(5)
feat_importances.plot(kind='barh' , figsize=(10,10), color="b")

plt.xlabel('Feature importance')
plt.ylabel('Positive Churn Factors')
plt.title('Top 5 important features that affect positively on the churr
```

```
0.         0.08669046 0.         0.20160858 0.         0.08463372
0.         0.         0.         0.         0.4402261  0.18684117
0.         0.         0.         0.         0.         0.
0.        ]
```

Out[401]: `ext(0.5, 1.0, 'Top 5 important features that affect positively on the chur rate')`



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

11 Results & comments

The mean cross validation is 88.69%. We have a precision of 0.62 and recall of 0.74 for the test we don't have overfitting. It means we are able to detect the 74% of churn customers but 62% of the customers we say 'churn' was true.

The top 5 factors affecting te churn rate:

1) Customer service calls

2) Total day charge

3) Interna ltional plan_no

4) N nber voice messages

5) T l evening charge

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

12 Gaussian NB

In [95]:

```
nb = GaussianNB()
nb_model=nb.fit(scaled_X_train, y_train)
y_pred_train = nb_model.predict(scaled_X_train)
y_pred_test = nb_model.predict(scaled_X_test)

```

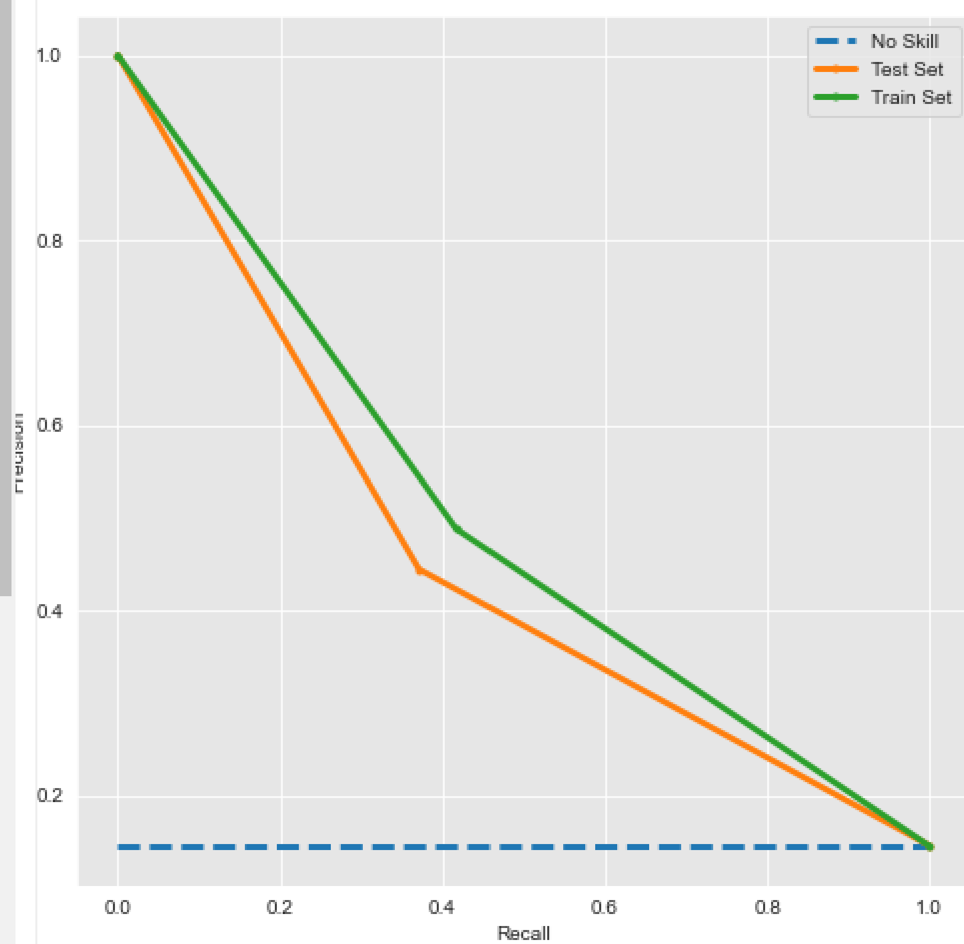
In [96]:
```
model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_trai

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
MODEL EVALUATION METRICS:
 ------------------------------------------------------
Confusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
No Churn    2280.0    0.0  2280.0
   Churn       0.0  386.0   386.0
     All    2280.0  386.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
No Churn     570.0    0.0  570.0
   Churn       0.0   97.0   97.0
     All     570.0   97.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       1.00      1.00      1.00      2280
        True       1.00      1.00      1.00       386

    accuracy                           1.00      2666
   macro avg       1.00      1.00      1.00      2666
eighted avg       1.00      1.00      1.00      2666


est set
              precision    recall  f1-score   support

       False       1.00      1.00      1.00       570
        True       1.00      1.00      1.00        97

    accuracy                           1.00       667
   macro avg       1.00      1.00      1.00       667
eighted avg       1.00      1.00      1.00       667

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

ohen's Kappa for train and test set:
 1.0 1.0
2 score for train and test set:
 1.0 1.0
oc auc score for train and test set:
 1.0 1.0
14:57:27] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
efault evaluation metric used with the objective 'binary:logistic' was cha
ged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
estore the old behavior.
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

```
[14:57:27] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:57:27] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:57:27] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[14:57:27] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'binary:logistic' was changed from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Mean Cross Validation Score:
0.8869
```



Contents

1 Abstract
2 Business Probler
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparam
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Comment
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test sp
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [82]:
```
1 nb_model.get_params
```

Out[82]: <bound method BaseEstimator.get_params of GaussianNB()>

12 Results & Comments

The ean cross validation is 88.7%. We have a precision of 1 and recall of 1 for the test set. We don have overfitting. It means we are able to detect the 100% of churn customers and 100% of the stomers we say 'churn' was true.

13 AdaBoostClassifier

In [97]:

```
from sklearn.ensemble import AdaBoostClassifier


ada = AdaBoostClassifier(n_estimators=120,random_state=5,learning_rate=
ada_model=ada.fit(scaled_X_train,y_train)

y_pred_train = ada_model.predict(scaled_X_train)
y_pred_test = ada_model.predict(scaled_X_test)

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_trai

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

 Predicted  No Churn  Churn     All
    Actual       NaN    NaN     NaN
 No Churn    2280.0    0.0  2280.0
    Churn       0.0  386.0   386.0
      All    2280.0  386.0  2666.0

 Predicted  No Churn  Churn    All
    Actual       NaN    NaN    NaN
 No Churn     570.0    0.0  570.0
    Churn       0.0   97.0   97.0
      All     570.0   97.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       1.00      1.00      1.00      2280
        True       1.00      1.00      1.00       386

    accuracy                           1.00      2666
   macro avg       1.00      1.00      1.00      2666
eighted avg       1.00      1.00      1.00      2666


est set
              precision    recall  f1-score   support

       False       1.00      1.00      1.00       570
        True       1.00      1.00      1.00        97

    accuracy                           1.00       667
   macro avg       1.00      1.00      1.00       667
eighted avg       1.00      1.00      1.00       667

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

ohen's Kappa for train and test set:
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparam
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparam
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

```
  1.0 1.0
f2 score for train and test set:
  1.0 1.0
roc auc score for train and test set:
  1.0 1.0
[14:58:28] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was cha
nged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
restore the old behavior.
14:58:28] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
efault evaluation metric used with the objective 'binary:logistic' was cha
ged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
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14:58:28] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
efault evaluation metric used with the objective 'binary:logistic' was cha
ged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
estore the old behavior.
14:58:29] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
efault evaluation metric used with the objective 'binary:logistic' was cha
ged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
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14:58:29] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
efault evaluation metric used with the objective 'binary:logistic' was cha
ged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
estore the old behavior.
ean Cross Validation Score:
0.8869
```
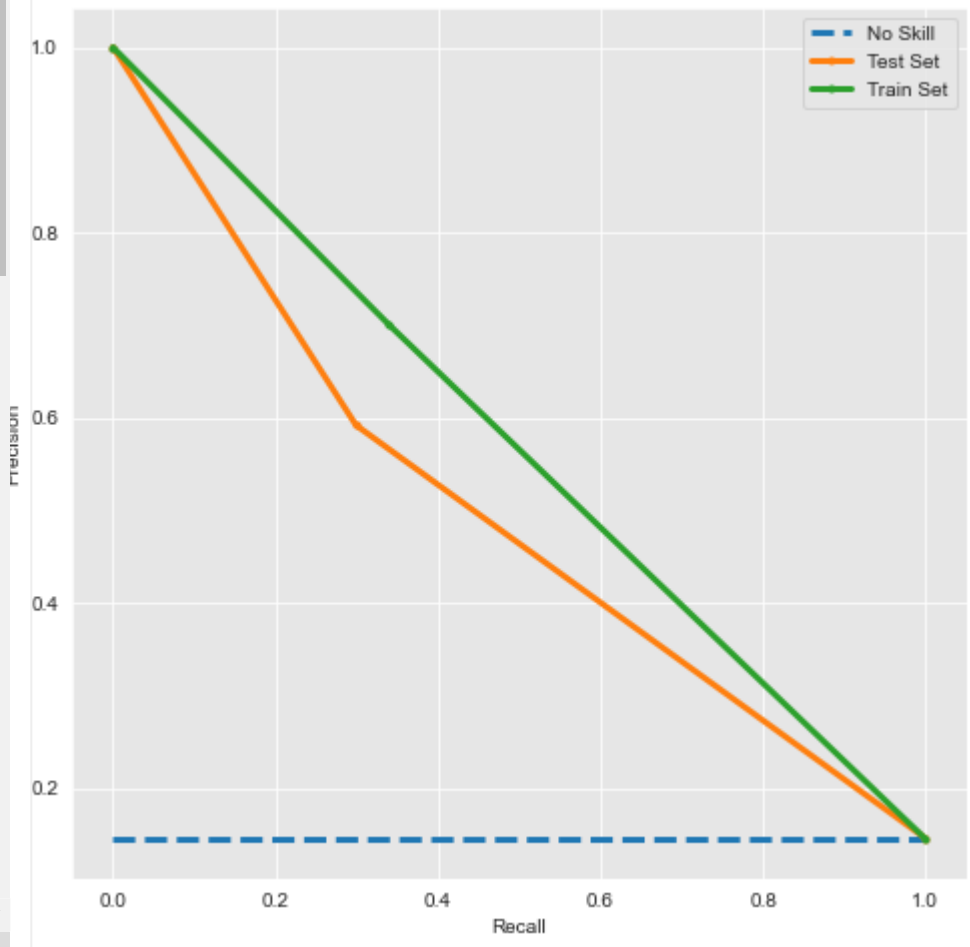



Contents

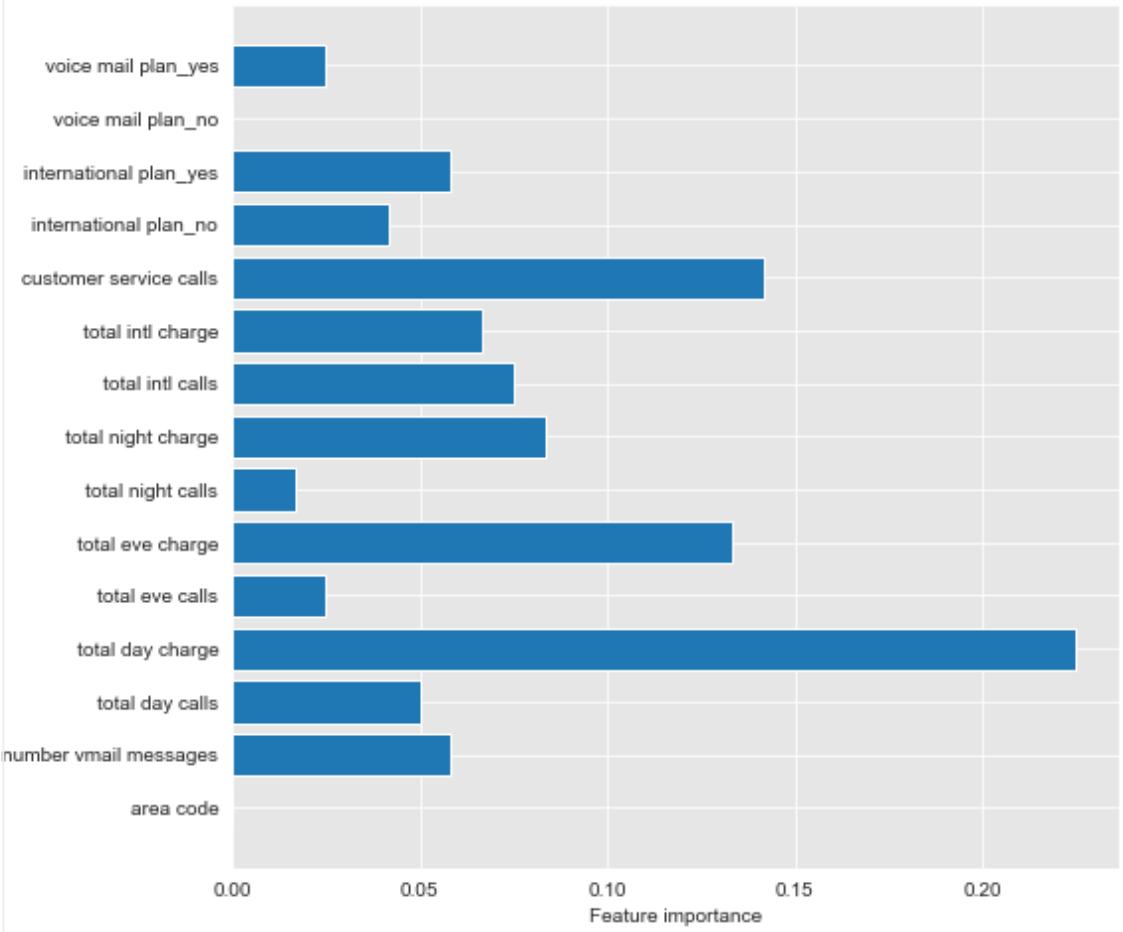
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [98]:

```
1 plot_feature_importances(ada_model)
```



In [99]:

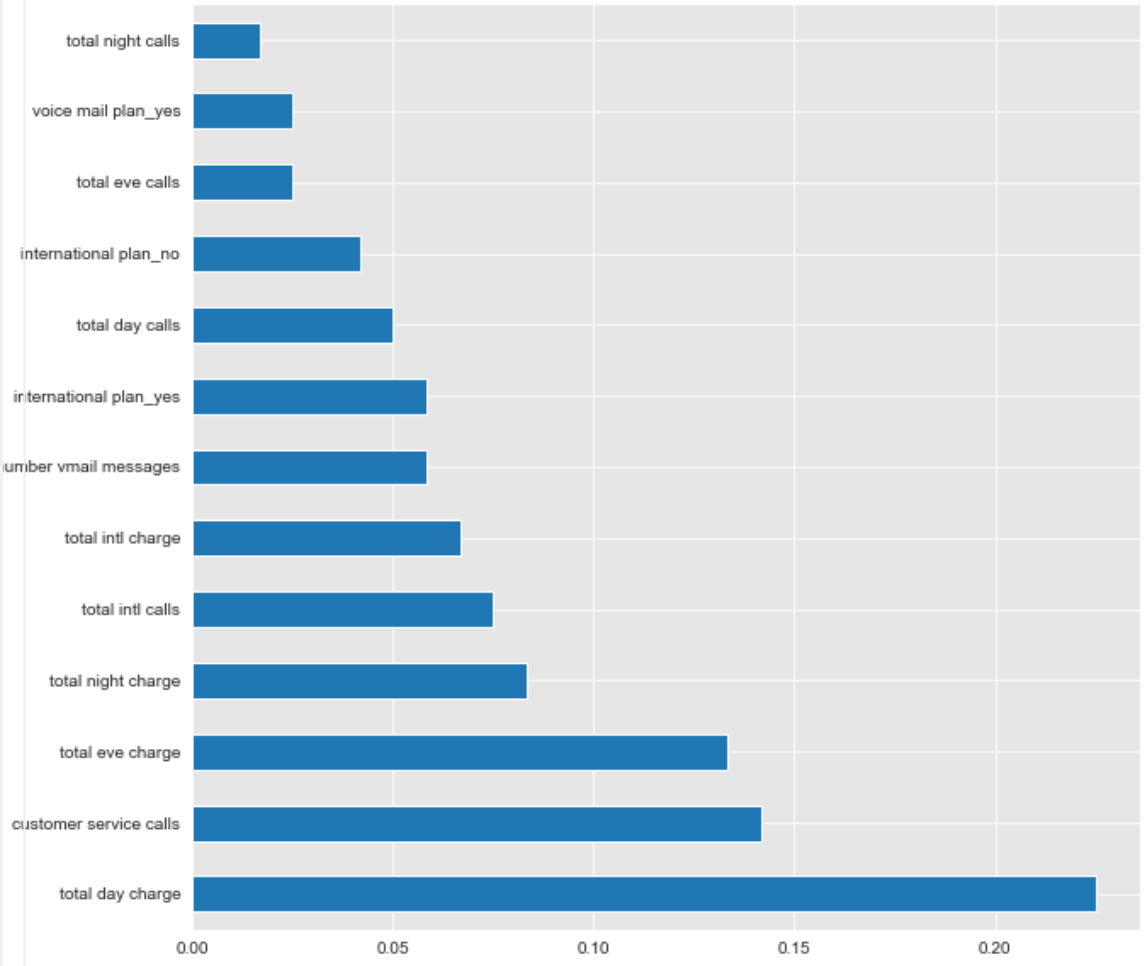
```
# Get Feature Importance from the classifier
feature_importance = ada_model.feature_importances_
print (ada_model.feature_importances_)
feat_importances = pd.Series(ada_model.feature_importances_, index=X.cc
feat_importances = feat_importances.nlargest(13)
feat_importances.plot(kind='barh' , figsize=(10,10))
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
[0.         0.05833333 0.05       0.225      0.025      0.13333333
 0.01666667 0.08333333 0.075      0.06666667 0.14166667 0.04166667
 0.05833333 0.         0.025     ]
```

Out[99]: <AxesSubplot:>



Contents
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building mat
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select B
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

13.1 Results & Comments

The mean cross validation is 88.7%. We have a precision of 1 and recall of 1 for the test set. We don have overfitting. It means we are able to detect the 100% of churn customers and 100% of the stomers we say 'churn' was true.

The ost important churn factors:

1) T l day charge

2) C tomer service calls

3) T l evening charge

4) T l International calls

5) T l night charge

12 Gradient Boosting Classifier

In [187]:

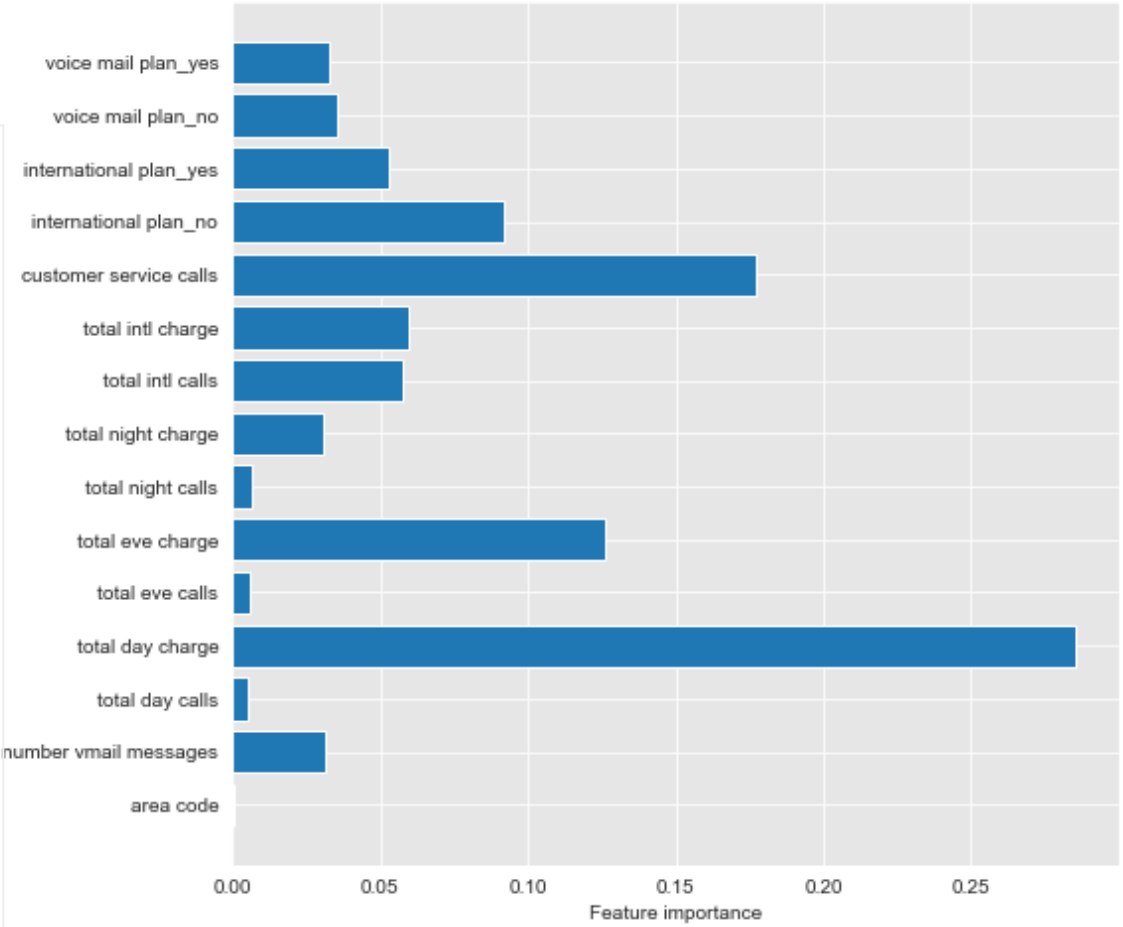
```
# Gradient Boosting
from sklearn.ensemble import GradientBoostingClassifier

gb = GradientBoostingClassifier(learning_rate=0.1,n_estimators=150,rand
gb_model=gb.fit(scaled_X_train,y_train)



y_pred_train = gb_model.predict(scaled_X_train)
y_pred_test = gb_model.predict(scaled_X_test)

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_trai
roc_curve_and_auc(gb_model, scaled_X_train, scaled_X_test, y_train, y_t

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
No Churn     2284.0    0.0  2284.0
   Churn        0.0  382.0   382.0
     All     2284.0  382.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
No Churn      566.0    0.0  566.0
   Churn        0.0  101.0  101.0
     All      566.0  101.0  667.0

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

lassification Report for train & test set
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [101]:
```
1 plot_feature_importances(gb_model)
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

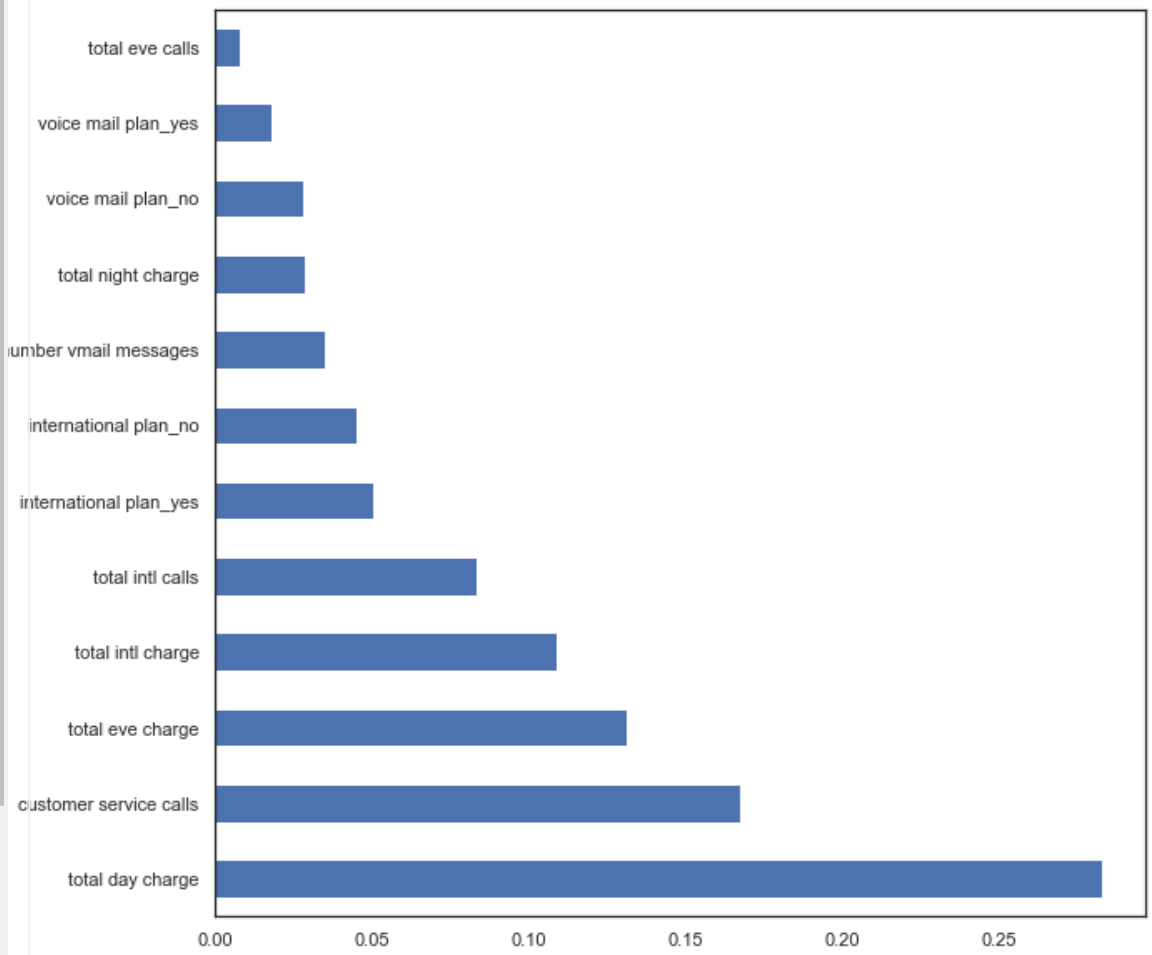
In [188]:
```
# Get Feature Importance from the classifier
feature_importance = gb_model.feature_importances_
print (gb_model.feature_importances_)
feat_importances = pd.Series(gb_model.feature_importances_, index=X.col
feat_importances = feat_importances.nlargest(12)
feat_importances.plot(kind='barh' , figsize=(10,10))
```


Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results &
14 Gradient Boosti
14.1 Results &
15 SVM Classifier
15.1 Tuning &
15.1.1 Hypertu
15.1.1.1 Bes


```
[0.00174112 0.03503597 0.00639164 0.28248003 0.00768167 0.13115795
 0.00619365 0.02847671 0.08348926 0.108813   0.16733934 0.04515022
 0.05019546 0.02789222 0.01796176]
```

Out[188]: <AxesSubplot:>



14 Results & comments

The mean cross validation is 88.7%. We have a precision of 1 and recall of 1 for the test set. We don't have overfitting. It means we are able to detect the 100% of churn customers and 100% of the customers we say 'churn' was true.

The most important churn factors:

1) Total day charge

2) Customer service calls

3) Total evening charge

4) Total International charge

5) T al international calls

Contents

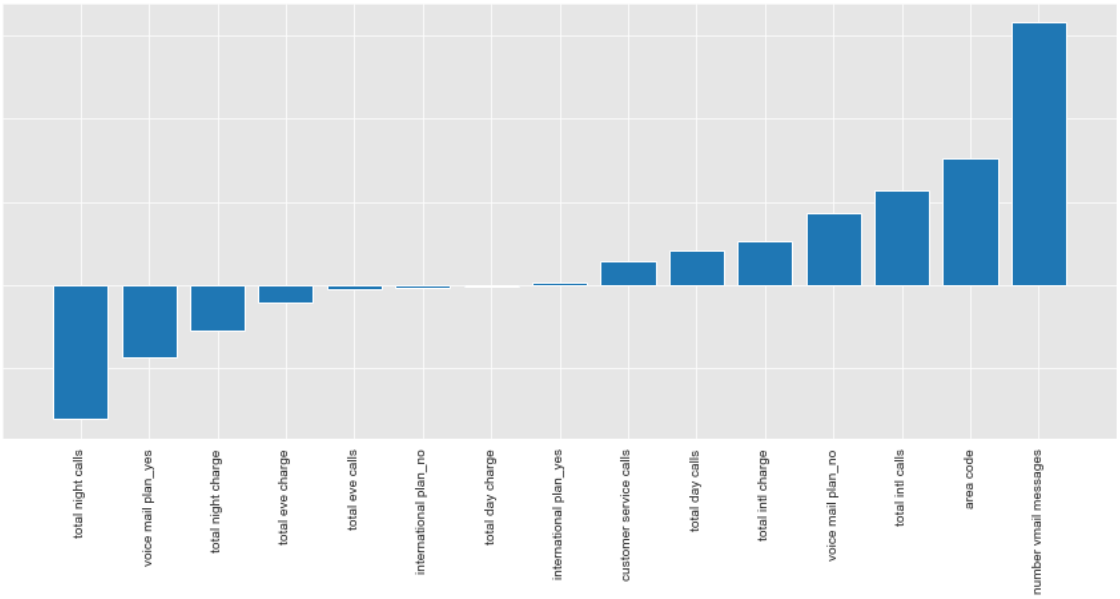
1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Decision Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

15 SVM Classifier

In [103]:
```
#SV M Classifier
#Make a sample to run SVM faster

sample_X_train = scaled_X_train.sample(n=1000)
sample_y_train = y_train.sample(n=1000)
```

In [104]:
```
#SVM Classifier (Balanced Class Weight)
svc = SVC(kernel='linear', class_weight='balanced')
svc.fit(sample_X_train, sample_y_train)
y_pred_train = svc.predict(sample_X_train)
y_pred_test = svc.predict(scaled_X_test)
```

In [105]:
```
plot_coefficients(svc)
```



In [106]:
```
1 model_evaluation(sample_X_train, scaled_X_test, sample_y_train, y_test,
```

```
MODEL EVALUATION METRICS:
 -----------------------------------------------------
Confusion Matrix for train & test set:

  Predicted  No Churn  Churn     All
0    Actual       NaN    NaN     NaN
  No Churn     510.0  328.0   838.0
     Churn      85.0   77.0   162.0
       All     595.0  405.0  1000.0

  Predicted  No Churn  Churn    All
     Actual       NaN    NaN    NaN
  No Churn     347.0  223.0  570.0
     Churn      65.0   32.0   97.0
       All     412.0  255.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       0.86      0.61      0.71       838
        True       0.19      0.48      0.27       162

    accuracy                           0.59      1000
   macro avg       0.52      0.54      0.49      1000
eighted avg       0.75      0.59      0.64      1000


est set
              precision    recall  f1-score   support

       False       0.84      0.61      0.71       570
        True       0.13      0.33      0.18        97

    accuracy                           0.57       667
   macro avg       0.48      0.47      0.44       667
eighted avg       0.74      0.57      0.63       667

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

ohen's Kappa for train and test set:
 0.0523 -0.0366
2 score for train and test set:
 0.3656 0.2488
oc auc score for train and test set:
 0.542 0.4693
15:00:57] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
efault evaluation metric used with the objective 'binary:logistic' was cha
ged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
estore the old behavior.
15:00:57] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
efault evaluation metric used with the objective 'binary:logistic' was cha
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

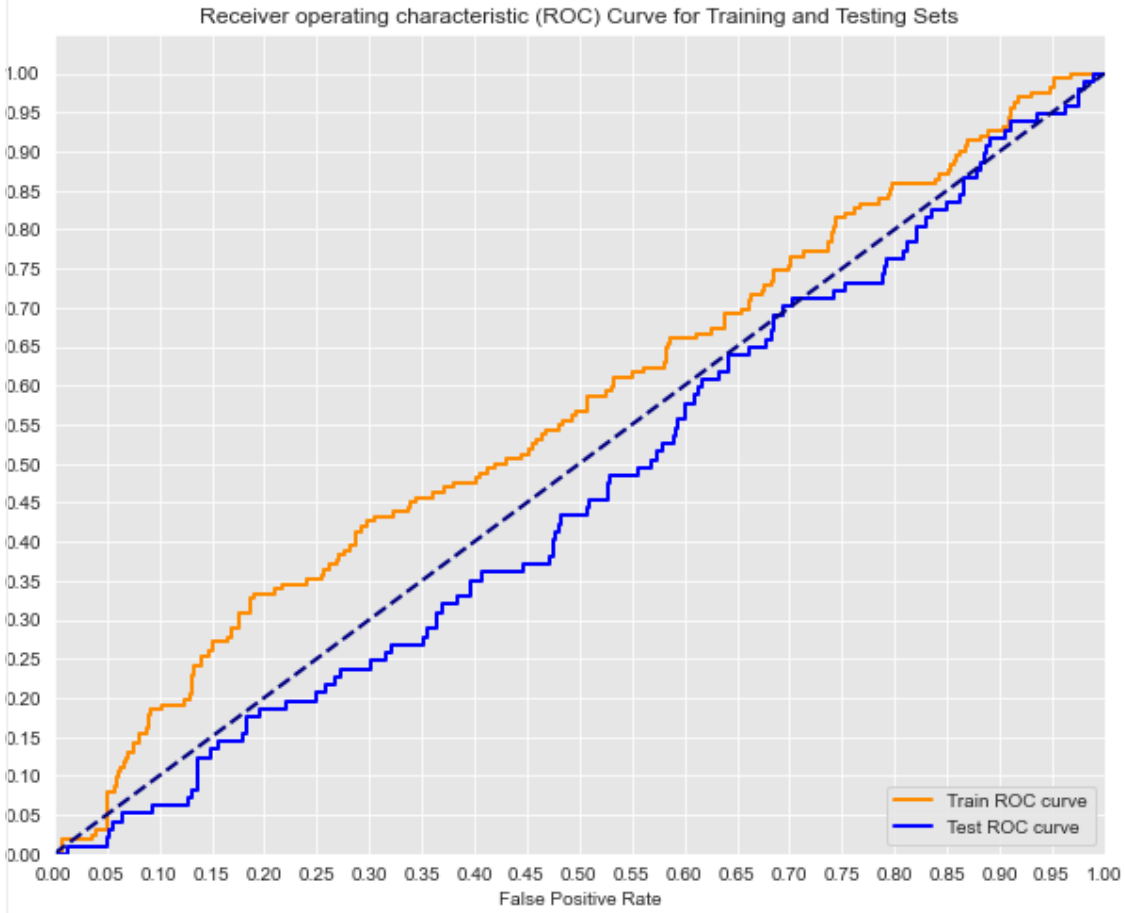
```
nged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
restore the old behavior.
[15:00:57] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was cha
nged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
restore the old behavior.
[15:00:58] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was cha
nged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
restore the old behavior.
[15:00:58] WARNING: ..\src\learner.cc:1061: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was cha
nged from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to
restore the old behavior.
ean Cross Validation Score:
0.8869
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop highly
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

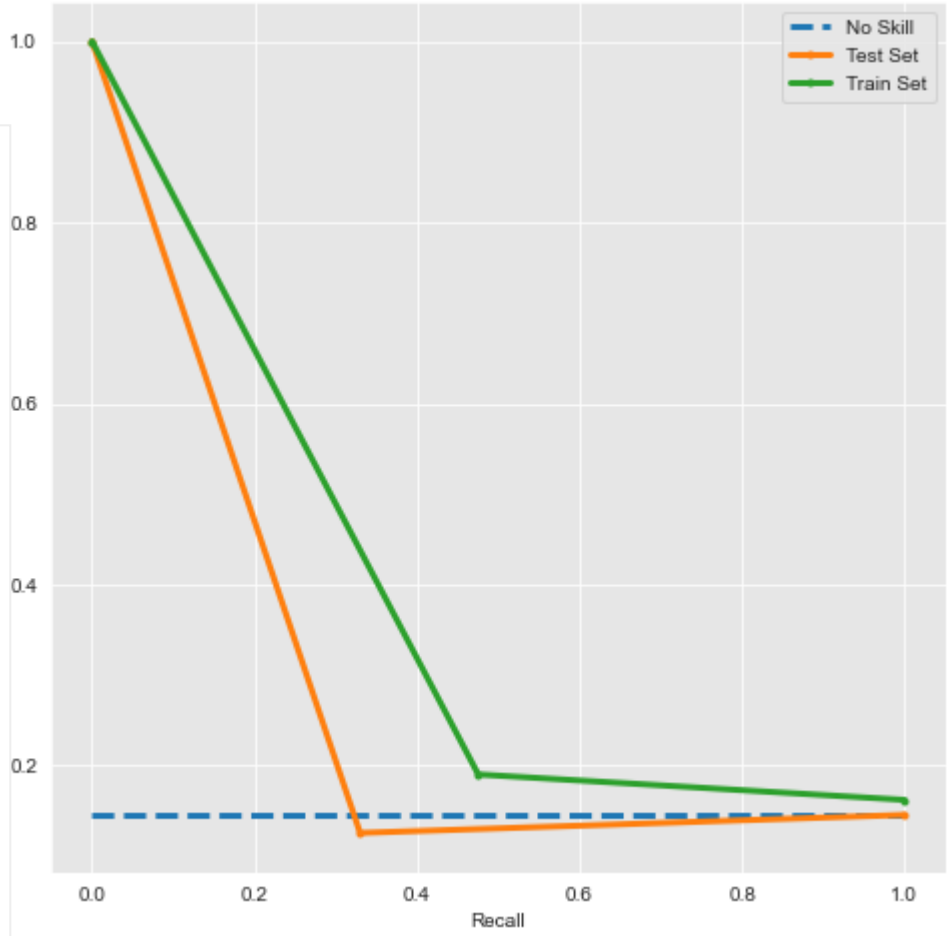
In [107]:

```
1 roc_curve_and_auc(svc, sample_X_train, scaled_X_test, sample_y_train, y
```




```
aining AUC: 0.56507
esting AUC: 0.46609
```

In [108]:
```
1 plot_pr_rc_curve(y_test, y_pred_test, sample_y_train, y_pred_train)
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=5
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

15 Tuning & Optimization

15.1 Hypertuning of SVM Classifier throgh GridSearhCV

In [109]:

```
#SVM Classifier (balanced class weight and gridsearch)

param_grid = {'C': [0.1, 1, 10, 100, 1000],
              'gamma': [1, 0.1, 0.01, 0.001, 0.0001],
              'kernel': ['rbf', "linear"]}

svc2 = GridSearchCV(SVC(class_weight = 'balanced'), param_grid, refit=T


svc2.fit(scaled_X_train, y_train)
y_pred_train = svc2.predict(scaled_X_train)
y_pred_test = svc2.predict(X_test)

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred

roc_curve_and_auc(svc2, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)

svc2.best_params_
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
 No Churn    2154.0  126.0  2280.0
    Churn      37.0  349.0   386.0
      All    2191.0  475.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
 No Churn     570.0    0.0  570.0
    Churn      97.0    0.0   97.0
      All     667.0    0.0  667.0

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

lassification Report for train & test set
```

In [432]:

```
svc2.best_params_
```

Out[432]:

```
'C': 1, 'gamma': 0.1, 'kernel': 'rbf'}
```

15.1.1 Best paramets for SVM Classifier

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results &
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [115]:

```
param_grid2 = {'C': [1],
               'gamma': [ 0.01],
               'kernel': ['rbf']}

svc3 = GridSearchCV(SVC(class_weight = 'balanced'), param_grid2, refit=

svc3.fit(scaled_X_train, y_train)
y_pred_train = clf.predict(scaled_X_train)
y_pred_test = clf.predict(scaled_X_test)

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred

roc_curve_and_auc(svc3, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
 No Churn    1995.0  289.0  2284.0
    Churn     340.0   42.0   382.0
      All    2335.0  331.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
 No Churn     502.0   64.0  566.0
    Churn      94.0    7.0  101.0
      All     596.0   71.0  667.0

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

lassification Report for train & test set
```

15 Results & Comments

The ean cross validation is 95.02%. We have a precision of 0.10 and recall of 0.07 for the test set. his model performed poorly even after parameter optimization

In [439]:

```
! pip install delayed
```

```
ollecting delayed
 Downloading delayed-0.11.0b1-py2.py3-none-any.whl (19 kB)
ollecting hiredis
 Downloading hiredis-2.0.0-cp38-cp38-win_amd64.whl (18 kB)
ollecting redis
 Downloading redis-3.5.3-py2.py3-none-any.whl (72 kB)
nstalling collected packages: hiredis, redis, delayed
uccessfully installed delayed-0.11.0b1 hiredis-2.0.0 redis-3.5.3
```

15.2.1 SVM with RFE

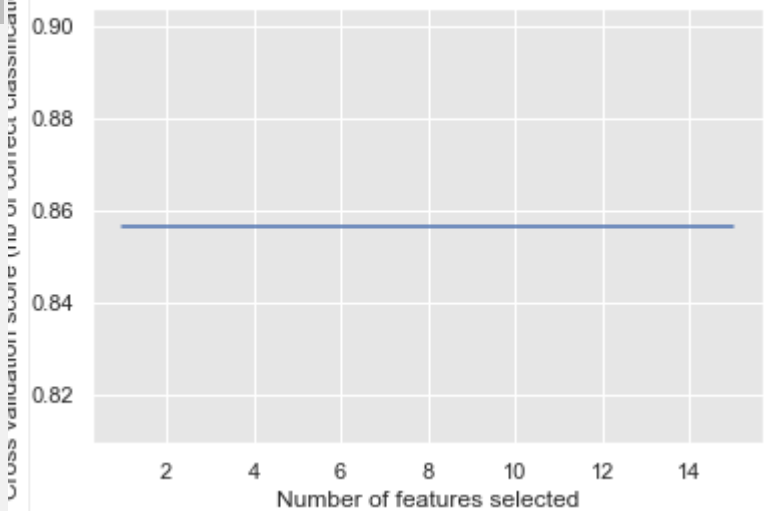
Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=
10.1.2 Iterate
10.1.2.1 K=
10.2 Results &
11 XGBoost
11.1 Results &
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [153]:

```
from sklearn.svm import SVC
from sklearn.model_selection import StratifiedKFold
from sklearn.feature_selection import RFECV
from sklearn.datasets import make_classification


# Build a classification task using 3 informative features


# Create the RFE object and compute a cross-validated score.
svc = SVC(kernel="linear")
# The "accuracy" scoring is proportional to the number of correct
# classifications

min_features_to_select = 1  # Minimum number of features to consider
rfecv = RFECV(estimator=svc, step=1, cv=StratifiedKFold(2),
              scoring='accuracy',
              min_features_to_select=min_features_to_select)
rfecv.fit(scaled_X_train, y_train)

print("Optimal number of features : %d" % rfecv.n_features_)

# Plot number of features VS. cross-validation scores
plt.figure()
plt.xlabel("Number of features selected")
plt.ylabel("Cross validation score (nb of correct classifications)")
plt.plot(range(min_features_to_select,
               len(rfecv.grid_scores_) + min_features_to_select),
         rfecv.grid_scores_)
plt.show()
```

```
ptimal number of features : 1
```



In [154]:

```
rfecv.support_
```

Out[154]:

```
array([False,  True, False, False, False, False, False, False, False,
       False, False, False, False, False, False])
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [155]:
```
1 pd.DataFrame(data=rfecv.support_.reshape(1,-1), columns= X.columns)
```

Out[155]:

	area code	number vmail messages	total day calls	total day charge	total eve calls	total eve charge	total night calls	total night charge	total intl calls	cha
0	False	True	False	False	False	False	False	False	False	

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Oppt
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [156]:
```
1 rfecv.ranking_
```

Out[156]:
```
array([10,  1,  8,  7,  9,  4, 13, 15, 11, 14,  5, 12,  6,  3,  2])
```

In [157]:
```
1 pd.DataFrame(data=rfecv.ranking_.reshape(1,-1), columns= X.columns)
```

Out[157]:

	area code	number vmail messages	total day calls	total day charge	total eve calls	total eve charge	total night calls	total night charge	total intl calls	cha
0	10	1	8	7	9	4	13	15	11	

15.2 SVM with SelectKBest

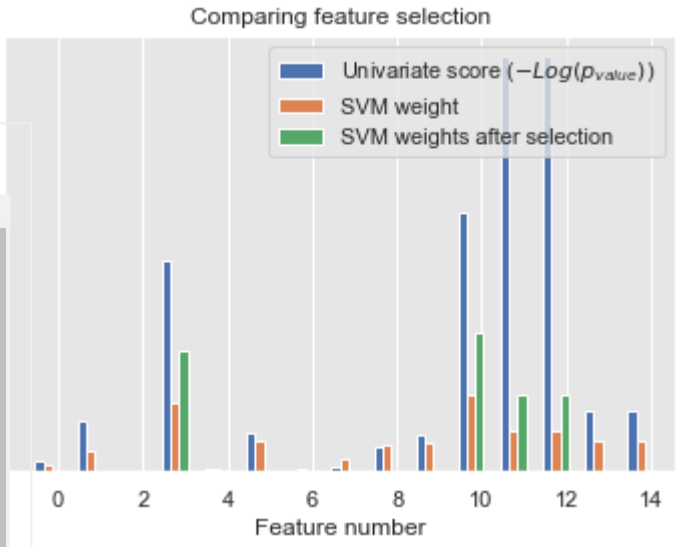
In [158]:

```
from sklearn.feature_selection import f_regression, mutual_info_regress

from sklearn.svm import LinearSVC
from sklearn.pipeline import make_pipeline
from sklearn.feature_selection import SelectKBest, f_classif


plt.figure(1)
plt.clf()

X_indices = np.arange(X.shape[-1])

# #############################################################################
# Univariate feature selection with F-test for feature scoring
# We use the default selection function to select the four
# most significant features
selector = SelectKBest(f_classif, k=4)
selector.fit(scaled_X_train, y_train)
scores = -np.log10(selector.pvalues_)
scores /= scores.max()
plt.bar(X_indices - .45, scores, width=.2,
        label=r'Univariate score ($-Log(p_{value})$)')

# #############################################################################
# Compare to the weights of an SVM
clf = make_pipeline( LinearSVC())
clf.fit(scaled_X_train, y_train)
print('Classification accuracy without selecting features: {:.3f}'
      .format(clf.score(scaled_X_test, y_test)))

svm_weights = np.abs(clf[-1].coef_).sum(axis=0)
svm_weights /= svm_weights.sum()

plt.bar(X_indices - .25, svm_weights, width=.2, label='SVM weight')

clf_selected = make_pipeline(
        SelectKBest(f_classif, k=4), LinearSVC())

clf_selected.fit(scaled_X_train, y_train)
print('Classification accuracy after univariate feature selection: {:.3
      .format(clf_selected.score(scaled_X_test, y_test)))

svm_weights_selected = np.abs(clf_selected[-1].coef_).sum(axis=0)
svm_weights_selected /= svm_weights_selected.sum()

plt.bar(X_indices[selector.get_support()] - .05, svm_weights_selected,
        width=.2, label='SVM weights after selection')


plt.title("Comparing feature selection")
plt.xlabel('Feature number')
plt.yticks(())
plt.axis('tight')
plt.legend(loc='upper right')
plt.show()
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

```
Classification accuracy without selecting features: 0.853
Classification accuracy after univariate feature selection: 0.844
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results &
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [159]:

```
y_pred_test= clf_selected.predict(scaled_X_test)
print(classification_report(y_test, y_pred_test))
```

```
              precision    recall  f1-score   support

       False       0.86      0.98      0.91       566
        True       0.41      0.07      0.12       101

    accuracy                           0.84       667
   macro avg       0.63      0.53      0.52       667
eighted avg       0.79      0.84      0.79       667
```

15 Results & Comments

The VC classifiers performed poorly even with RFE and SELECTK.

In [163]:

```
! pip install sklearn.ensemble
```

```
RROR: Could not find a version that satisfies the requirement sklearn.ense
ble (from versions: none)
RROR: No matching distribution found for sklearn.ensemble
```

16 Stacking

In [160]:

```
from  sklearn.ensemble  import StackingClassifier
from sklearn.ensemble import GradientBoostingClassifier
#Stacking

#Using Decisoin Tree, Random Forest, Gradient Boosting as base learners

log_model = LogisticRegression()
dt_model = DecisionTreeClassifier(random_state=5,max_depth=10)
rf_model = RandomForestClassifier(n_estimators=100,random_state=5,max_d
gb_model = GradientBoostingClassifier(learning_rate=0.01,n_estimators=1


clf= StackingClassifier(estimators=[('tree', dt_model),('forest', rf_mo



clf.fit(scaled_X_train,y_train)

y_pred_train = clf.predict(scaled_X_train)
y_pred_test = clf.predict(scaled_X_test)

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred

roc_curve_and_auc(clf, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)

```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
No Churn     2284.0    0.0  2284.0
   Churn       55.0  327.0   382.0
     All     2339.0  327.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
No Churn      560.0    6.0  566.0
   Churn       26.0   75.0  101.0
     All      586.0   81.0  667.0


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

lassification Report for train & test set
```

In [50]:
```
1 clf.get_params
```

Out[50]:
```
<bound method _BaseHeterogeneousEnsemble.get_params of StackingClassifier(e
stimators=[('tree',
                                DecisionTreeClassifier(max_depth=10,
                                                       random_state=5)),
                               ('forest',
                                RandomForestClassifier(max_depth=10,
                                                       random_state=5)),
                               ('gb',
                                GradientBoostingClassifier(learning_rate=0.
1,
                                                           n_estimators=12
,
                                                           random_state=
))],
                   final_estimator=LogisticRegression())>
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot E
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimizatio
7.2 Best perform
7.3 Results C
8 Descion Tree Cl
8.1 Hyperpara
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparam
9.2 Best Para
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

In [51]:
```
1 clf.final_estimator
```

Out[51]:
```
ogisticRegression()
```

16 Results & Comments

The ean cross validation is 95%. We have a precision of 0.93 and recall of 0.74 for the test set. We n't have overfitting. It means we are able to detect the 74% of churn customers and 93% of the stomers we say 'churn' was true.

17 SGDClassifier (Lasso & Ridge regularizations)

In [161]:

```
#SCDClassifier (balanced class weight)

scd = SGDClassifier(penalty='elasticnet', class_weight='balanced')
scd.fit(scaled_X_train, y_train)
y_pred_train = scd.predict(scaled_X_train)
y_pred_test = scd.predict(scaled_X_test)


model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred
roc_curve_and_auc(scd, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)

```


Contents

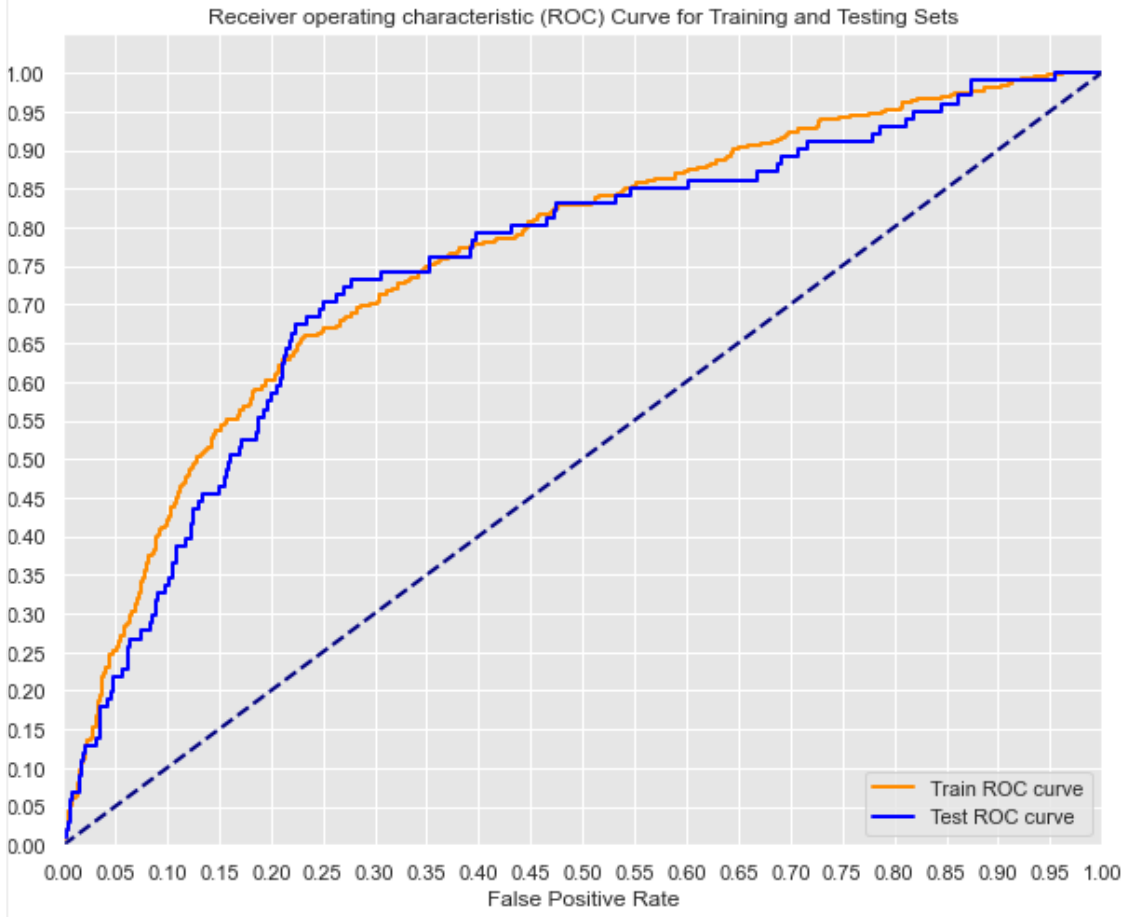
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

 Predicted  No Churn   Churn     All
    Actual       NaN     NaN     NaN
  No Churn    1356.0   928.0  2284.0
     Churn      77.0   305.0   382.0
       All    1433.0  1233.0  2666.0

 Predicted  No Churn  Churn    All
    Actual       NaN    NaN    NaN
  No Churn     354.0  212.0  566.0
     Churn      19.0   82.0  101.0
       All     373.0  294.0  667.0

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

lassification Report for train & test set

rain set
              precision    recall  f1-score   support

       False       0.95      0.59      0.73      2284
        True       0.25      0.80      0.38       382

    accuracy                           0.62      2666
   macro avg       0.60      0.70      0.55      2666
eighted avg       0.85      0.62      0.68      2666


est set
              precision    recall  f1-score   support

       False       0.95      0.63      0.75       566
        True       0.28      0.81      0.42       101

    accuracy                           0.65       667
   macro avg       0.61      0.72      0.58       667
eighted avg       0.85      0.65      0.70       667

-----------------------------------------------------
```

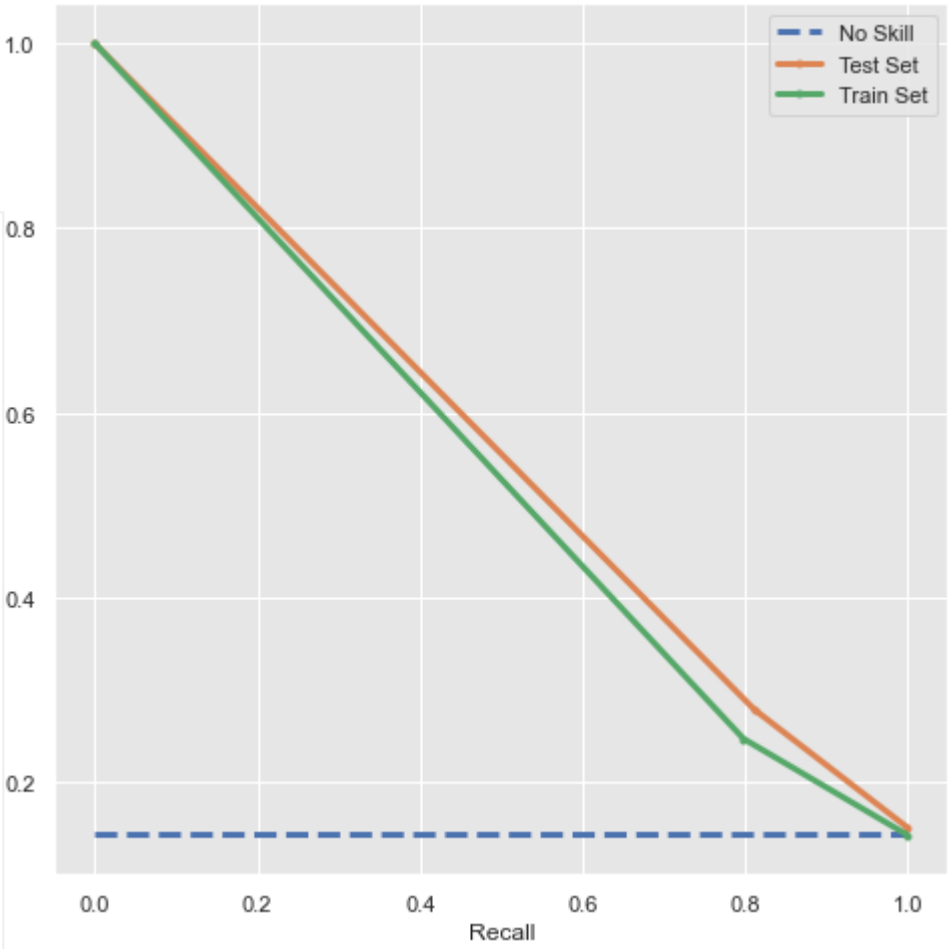
```
Cohen's Kappa for train and test set:
  0.2034 0.245
f2 score for train and test set:
  0.5523 0.5874
roc auc score for train and test set:
  0.6961 0.7187
Mean Cross Validation Score:
 0.9502
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best



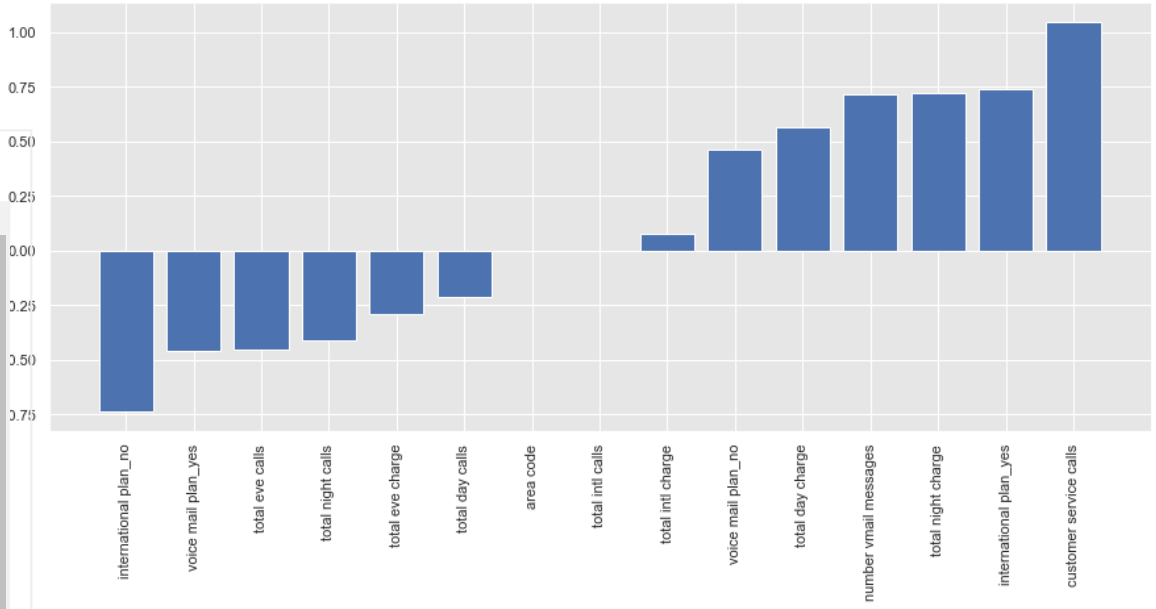

```
raining AUC: 0.76274
esting AUC: 0.74873
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [162]:
```
1 plot_coefficients(scd)
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select B
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results &
12 Gaussian N
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

17 Results & Comments

The ean cross validation is 95%. We have a precision of 0.28 and recall of 0.81 for the test set. We n't have overfitting. It means we are able to detect the 81% of churn customers and 28% of the stomers we say 'churn' was true.

18 Logistic Regession - RandomizedSearchCV

In [164]:
```
from sklearn.model_selection import RandomizedSearchCV
from scipy.stats import uniform

logistic = LogisticRegression(solver='saga', tol=1e-2, max_iter=200,
                              random_state=0)
distributions = dict(C=uniform(loc=0, scale=4),
                     penalty=['l2', 'l1'])
clf = RandomizedSearchCV(logistic, distributions, random_state=0)
search = clf.fit(scaled_X_train, y_train)

search.best_params_
```

Out[164]:
```
{'C': 1.75034884505077, 'penalty': 'l2'}
```

In [165]:
```
logistic = LogisticRegression(solver='saga', tol=1e-2, max_iter=200,
                              random_state=0)
distributions = dict(C=[1.5], penalty=['l2'])

clf = RandomizedSearchCV(logistic, distributions, random_state=0)
search = clf.fit(scaled_X_train, y_train)
```

In [44]:
```
y_pred_train = clf.predict(scaled_X_train)
y_pred_test = clf.predict(scaled_X_test)


model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred
roc_curve_and_auc(clf, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
No Churn    2498.0   72.0  2570.0
   Churn     337.0   92.0   429.0
     All    2835.0  164.0  2999.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
No Churn     273.0    7.0  280.0
   Churn      43.0   11.0   54.0
     All     316.0   18.0  334.0

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

lassification Report for train & test set
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building appl
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

18 Results & Comments

This model had a mean cross validation of 85.66%. Only 20% of the time the churn was true with precision.

19 SGDClassifier - RandomizedSearchCV

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [167]:

```
from time import time
import scipy.stats as stats
from sklearn.utils.fixes import loguniform

from sklearn.model_selection import GridSearchCV, RandomizedSearchCV
from sklearn.datasets import load_digits
from sklearn.linear_model import SGDClassifier

# build a classifier
clf = SGDClassifier(loss='hinge', penalty='elasticnet',
                    fit_intercept=True)


# Utility function to report best scores
def report(results, n_top=3):
    for i in range(1, n_top + 1):
        candidates = np.flatnonzero(results['rank_test_score'] == i)
        for candidate in candidates:
            print("Model with rank: {0}".format(i))
            print("Mean validation score: {0:.3f} (std: {1:.3f})"
                  .format(results['mean_test_score'][candidate],
                          results['std_test_score'][candidate]))
            print("Parameters: {0}".format(results['params'][candidate]
            print("")


# specify parameters and distributions to sample from
param_dist = {'average': [True, False],
              'l1_ratio': stats.uniform(0, 1),
              'alpha': loguniform(1e-4, 1e0)}

# run randomized search
n_iter_search = 20
random_search = RandomizedSearchCV(clf, param_distributions=param_dist,
                                   n_iter=n_iter_search)

start = time()
random_search.fit(scaled_X_train, y_train)
print("RandomizedSearchCV took %.2f seconds for %d candidates"
      " parameter settings." % ((time() - start), n_iter_search))
report(random_search.cv_results_)

```

```
andomizedSearchCV took 0.88 seconds for 20 candidates parameter setting
.
odel with rank: 1
ean validation score: 0.863 (std: 0.006)
arameters: {'alpha': 0.0006626483822186211, 'average': False, 'l1_rati
': 0.503491101662517}

odel with rank: 2
ean validation score: 0.860 (std: 0.008)
arameters: {'alpha': 0.0005634122292363634, 'average': False, 'l1_rati
': 0.7403534721013764}

odel with rank: 3
ean validation score: 0.857 (std: 0.001)
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparam
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparam
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & O
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & O
15.1.1 Hypertu
15.1.1.1 Best

```
Parameters: {'alpha': 0.04172285339373269, 'average': False, 'l1_ratio':
0.6586706021204276}

Model with rank: 3
Mean validation score: 0.857 (std: 0.001)
Parameters: {'alpha': 0.062422867830419115, 'average': False, 'l1_ratio':
0.9302673127586086}

Model with rank: 3
ean validation score: 0.857 (std: 0.001)
arameters: {'alpha': 0.07482750672804837, 'average': False, 'l1_ratio':
.8430808042120077}

odel with rank: 3
ean validation score: 0.857 (std: 0.001)
arameters: {'alpha': 0.18281454383299717, 'average': False, 'l1_ratio':
.3788213628609819}

odel with rank: 3
ean validation score: 0.857 (std: 0.001)
arameters: {'alpha': 0.03808645305940271, 'average': False, 'l1_ratio':
.3697350025208 65}

odel with rank: 3
ean validation score: 0.857 (std: 0.001)
arameters: {'alpha': 0.020721941661317956, 'average': False, 'l1_ratio':
.2931709072344363}

odel with rank: 3
ean validation score: 0.857 (std: 0.001)
arameters: {'alpha': 0.0034212589075411893, 'average': False, 'l1_rati
': 0.6651574325714098}
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results &
10 KNN Classifier
10.1 Tuning & Op
10.1.1 SelectB
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

19 Tuning & Optimization

In [168]:
```
1 random_search.best_params_
```

Out[168]:
```
'alpha': 0.0006626483822186211,
'average': False,
'l1_ratio': 0.503491101662517}
```

In [169]:

```
# build a classifier
clf = SGDClassifier(loss='hinge', penalty='elasticnet',
                    fit_intercept=True)
param_dist = {'alpha': [0.0006626483822186211], 'average': [False], 'l1

# run randomized search
n_iter_search = 20
random_search = RandomizedSearchCV(clf, param_distributions=param_dist,
                                   n_iter=n_iter_search)

start = time()
rs=random_search.fit(scaled_X_train, y_train)
print("RandomizedSearchCV took %.2f seconds for %d candidates"
      " parameter settings." % ((time() - start), n_iter_search))
report(random_search.cv_results_)
```

```
andomizedSearchCV took 0.08 seconds for 20 candidates parameter settings.
odel with rank: 1
ean validation score: 0.858 (std: 0.002)
arameters: {'l1_ratio': 0.503491101662517, 'average': False, 'alpha': 0.00
6626483822186211}
```

In [170]:

```
y_pred_train = rs.predict(scaled_X_train)
y_pred_test = rs.predict(scaled_X_test)


model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred
roc_curve_and_auc(rs, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn  Churn     All
   Actual       NaN    NaN     NaN
No Churn     2284.0    0.0  2284.0
   Churn      381.0    1.0   382.0
     All     2665.0    1.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
No Churn      566.0    0.0  566.0
   Churn      101.0    0.0  101.0
     All      667.0    0.0  667.0

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

lassification Report for train & test set
```

19 2 Results & Comments

This model performed poorly.

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

20 Data Interpretation

20.1 Most Important features Accoring to DecisionTree Model

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select B
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [189]:

```
dt_param_grid2 = {
    'criterion': ['gini'],
    'max_depth': [ 6],
    'min_samples_split': [4],
    'min_samples_leaf': [10]
}

dt_grid_search2 = GridSearchCV(tree_clf, dt_param_grid2, cv=10, return_

# Fit to the data

clf=dt_grid_search2 .fit(scaled_X_train, y_train)



#Examine best parameters

# Mean training score
dt_gs_training_score2 = np.mean(clf.cv_results_['mean_train_score'])

# Mean test score
dt_gs_testing_score2 = clf.score(scaled_X_test, y_test)


print(f"Mean Training Score: {dt_gs_training_score2 :.2%}")
print(f"Mean Test Score: {dt_gs_testing_score2 :.2%}")

# Model Performance
# Test set predictions
y_pred_test =clf.predict(scaled_X_test)
y_pred_train =clf.predict(scaled_X_train)

print(classification_report(y_test,y_pred_test))

model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred



plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)

plot_feature_importances(tree_clf)
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
ean Training Score: 95.15%
ean Test Score: 93.85%
              precision    recall  f1-score   support

       False       0.94      0.99      0.96       566
        True       0.89      0.67      0.77       101

    accuracy                           0.94       667
   macro avg       0.92      0.83      0.87       667
eighted avg       0.94      0.94      0.93       667

ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:
```

	Predicted	No Churn	Churn	All
0	Actual	NaN	NaN	NaN
1	No Churn	2262.0	22.0	2284.0
2	Churn	104.0	278.0	382.0

20.1.1 Top 5 Important Features Affecting Churn Rate

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

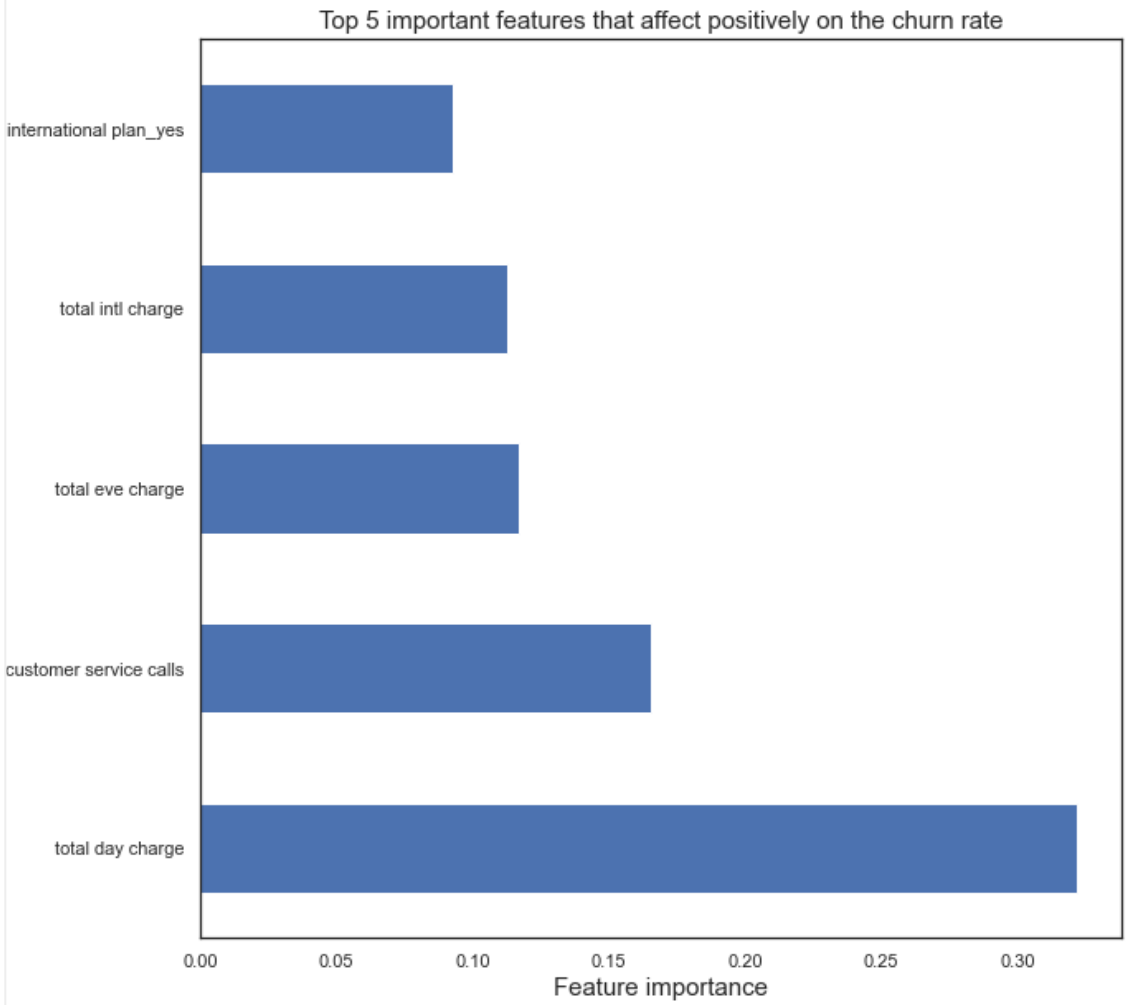
In [196]:

```
feature_importance = tree_clf.feature_importances_
print (tree_clf.feature_importances_)
feat_importances = pd.Series(tree_clf.feature_importances_, index=X.col
feat_importances = feat_importances.nlargest(5)
feat_importances.plot(kind='barh' , figsize=(10,10), color="b")

plt.xlabel('Feature importance', fontsize=15)
plt.ylabel('Positive Churn Factors', fontsize=15)
plt.title('Top 5 important features that affect positively on the churr
```

```
0.         0.         0.         0.32193796 0.0134261  0.11687289
0.00422496 0.02131784 0.08281552 0.11242512 0.1652558  0.
0.0928464  0.         0.0688774 ]
```

Out[196]:

```
ext(0.5, 1.0, 'Top 5 important features that affect positively on the chur
rate')
```



20.2 Top Positive and Negative Features According to Logistic Regression

In [178]:

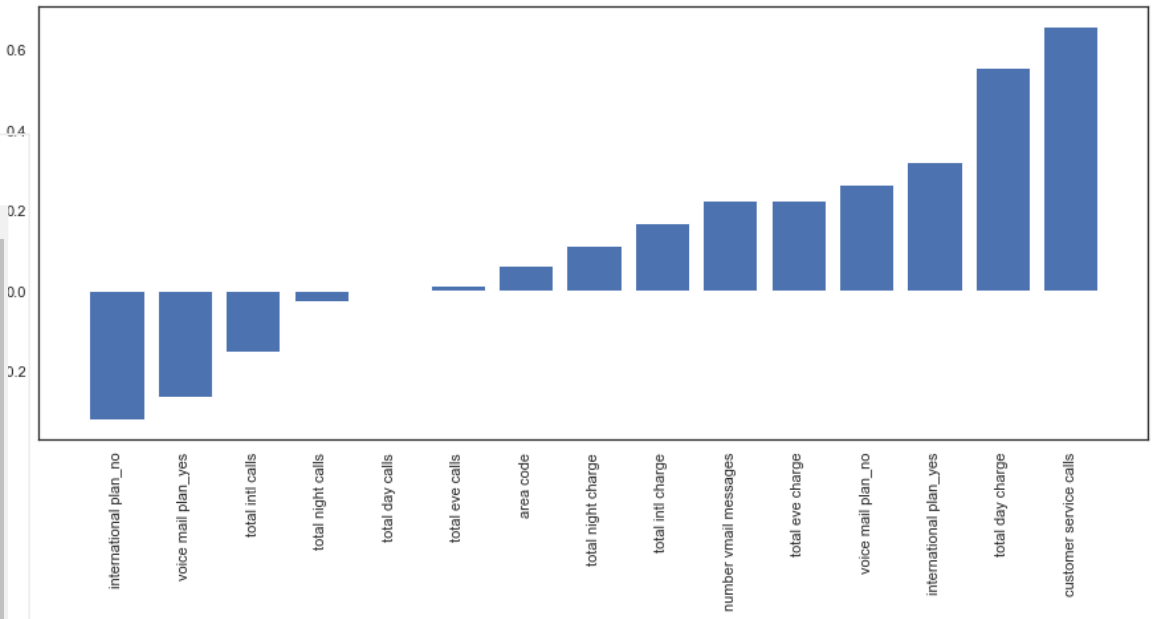
```
lr = LogisticRegression(fit_intercept=False, C=100,
                        solver='liblinear', class_weight='balanced')
lr.fit(scaled_X_train, y_train)
y_pred_train = lr.predict(scaled_X_train)
y_pred_test = lr.predict(scaled_X_test)


model_evaluation(scaled_X_train, scaled_X_test, y_train, y_test, y_pred

roc_curve_and_auc(lr, scaled_X_train, scaled_X_test, y_train, y_test)

plot_pr_rc_curve(y_test, y_pred_test, y_train, y_pred_train)
```

```
ODEL EVALUATION METRICS:
-----------------------------------------------------
onfusion Matrix for train & test set:

Predicted  No Churn   Churn     All
   Actual       NaN     NaN     NaN
 No Churn    1426.0   858.0  2284.0
    Churn      48.0   334.0   382.0
      All    1474.0  1192.0  2666.0

Predicted  No Churn  Churn    All
   Actual       NaN    NaN    NaN
 No Churn     357.0  209.0  566.0
    Churn      10.0   91.0  101.0
      All     367.0  300.0  667.0


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

lassification Report for train & test set
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [179]:
```
1 plot_coefficients(lr)
```



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Decision Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [180]:
```
1 lr.coef_.round(2)
```

Out[180]:
```
rray([[ 0.06,  0.23,  0.  ,  0.56,  0.01,  0.23, -0.03,  0.11, -0.15,
        0.17,  0.66, -0.32,  0.32,  0.26, -0.26]])
```

In [181]:
```
1 from collections import OrderedDict
2 coefficients =pd.Series(lr.coef_[0], index=X.columns.values).to_dict()
3
4 abs_coefficients = {k: abs(v) for k, v in coefficients.items()}
5 coefs_ranked =OrderedDict(sorted(coefficients.items(), key=lambda kv: k
6 top_5 = list(coefs_ranked)[:5]
7 print("The 5 most important coefficients are:")
8 print(" / ".join(top_5))
```

```
ne 5 most important coefficients are:
nternational plan_no / voice mail plan_yes / total intl calls / total nigh
 calls / total day calls
```

In [182]:
```
1 coefs_pos = {k: abs(v) for k, v in coefs_ranked.items() if v > 0}
2 coefs_neg = {k: abs(v) for k, v in coefs_ranked.items() if v < 0}
3 coefs_pos = OrderedDict(sorted(coefs_pos.items(), key=lambda kv: kv[1],
```

20. 1 Top Negative Factors affectig Churn Rate

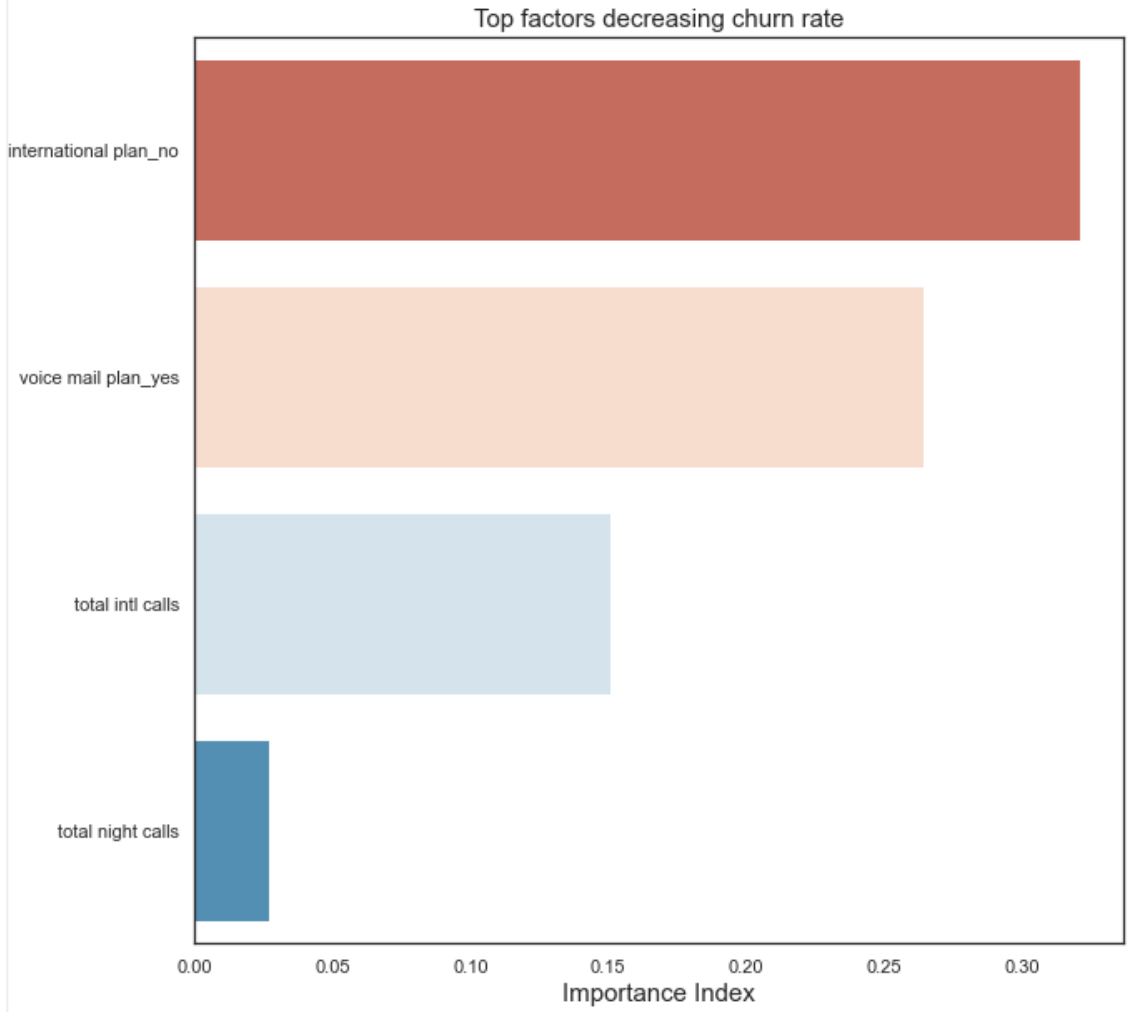
In [183]:

```
1 sns.set(rc={"figure.figsize":(10,10)})
2 sns.set_style("white")
3 sns.barplot(x=list(coefs_neg.values()), y=list(coefs_neg.keys()), palet
4 plt.title('Top factors decreasing churn rate', fontsize=15)
5 plt.xlabel("Importance Index", fontsize=15)
6 plt.ylabel('Churn Factors', fontsize=15)
7 print("\n\nBiggest Negative Factors on Churn")
```

Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hyp
15.1.1.1 Best


```
iggest Negative Factors on Churn
```



20 2 Top Positive Fators Affectig Churn Rate

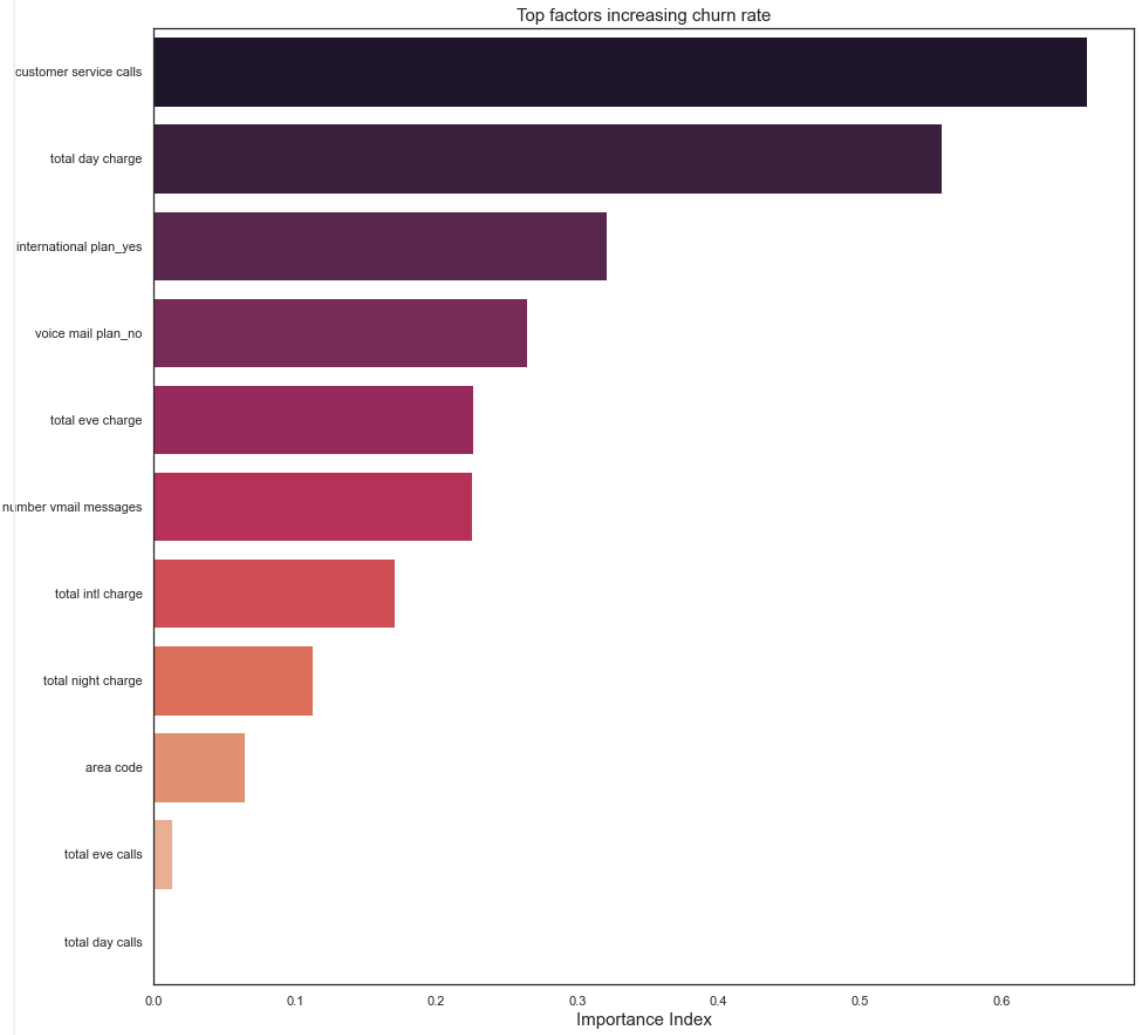
In [184]:

```
sns.set(rc={"figure.figsize":(15,15)})
sns.set_style("white")
sns.barplot(x=list(coefs_pos.values()), y=list(coefs_pos.keys()), palet
plt.title('Top factors increasing churn rate', fontsize=15)
plt.xlabel("Importance Index", fontsize=15)
plt.ylabel('Churn Factors', fontsize=15)
print("\n\nBiggest Positive Factors on Churn rate")
```

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results &
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best


```
iggest Positive Factors on Churn rate
```



21 Conclusion

The est performing machine learnng model to predict the churn rate is for Stacking Classifier with reca of 74% and precision of 93%. However, we can not interpret this model and extract the imp ant features.

NB aussian, Adaboost and Gradient Boost Classifier had the optimal recall and precision of 100

We decided to use DecisionTree classifier which performed well with 65% recall and 87% precision to intepret the data and extract the features.

Adaboost and GradientBoost, DecisionTree and RandoForest intpreted the data similarly.

Factors that contibute to churn of customers are:

```
1)Total day charge of calls,
)customer service calls,
)Total evening charge,
)Total International Charge,
)Total International calls,
```

Fac s that contribute to the retention of customers and churn prevention are:

```
) International plan = no
) Voice mail plan = yes
) Total International calls
```

21 Increasing churn factors

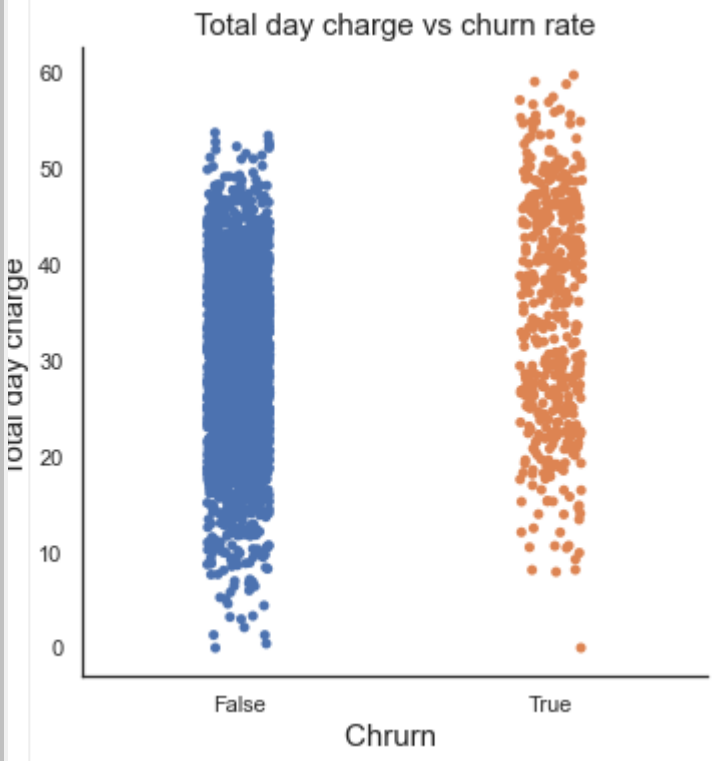
21.1 Total day charge

Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results C
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & C
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & c
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & c
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [146]:

```
sns.set_style("white")
g=sns.catplot(data=df, x="churn", y="total day charge")
plt.title('Total day charge vs churn rate', fontsize=15)
plt.xlabel("Chrurn ", fontsize=15)
plt.ylabel('Total day charge ', fontsize=15)

spots = zip(g.ax.patches)
for spot in spots:
    height = spot[0].get_height()
    g.ax.text(spot[0].get_x(), height+3, '{:1.2f}'.format(churn.value_c
```

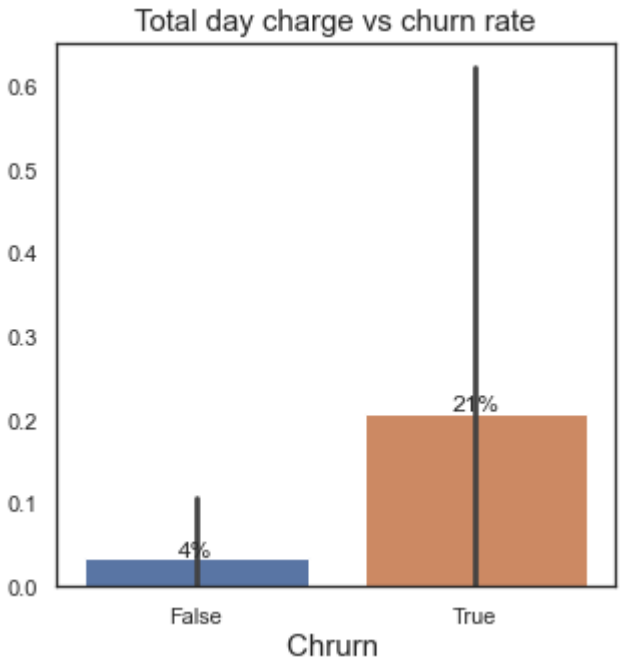


Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [214]:

```
sns.set(rc={"figure.figsize":(5,5)})
sns.set_style("white")
ax=sns.barplot( x="churn", y="total day charge", data=df, estimator=lam
sns.set(rc={"figure.figsize":(5,5)})
plt.title('Total day charge vs churn rate', fontsize=15)
plt.xlabel("Chrurn ", fontsize=15)
plt.ylabel('Total day charge $ (*100)', fontsize=15)
for p in ax.patches:
    width = p.get_width()
    height = p.get_height()
    x, y = p.get_xy()
    ax.annotate(f'{height:.0%}', (x + width/2, y + height*1.02), ha='ce
```

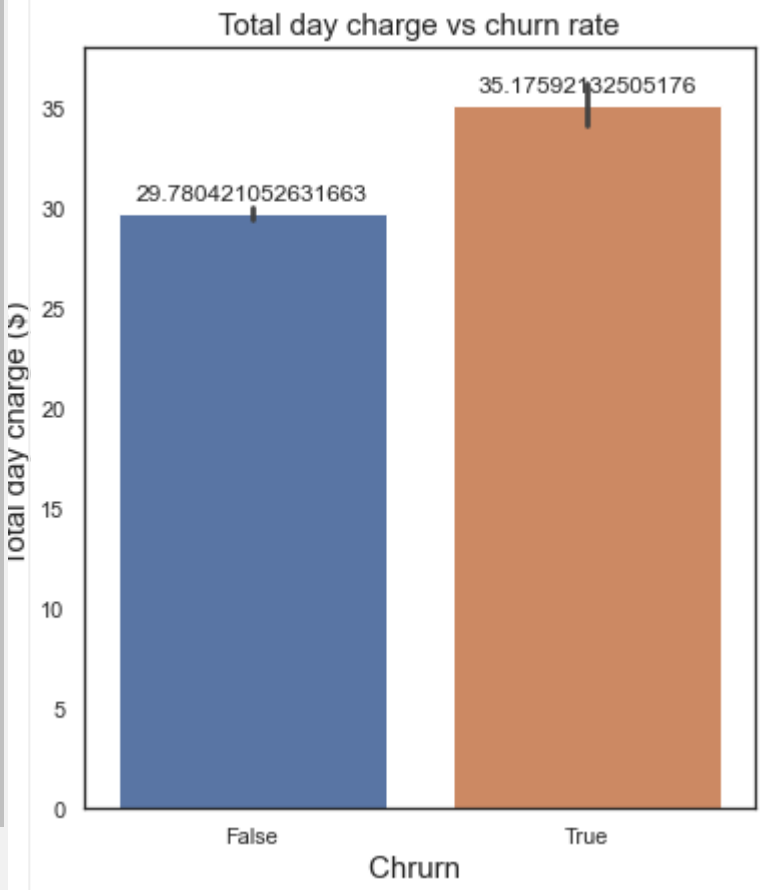


Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [219]:

```
sns.set(rc={"figure.figsize":(6,7)})
sns.set_style("white")
ax=sns.barplot(data=df, x="churn", y="total day charge")
plt.title('Total day charge vs churn rate', fontsize=15)
plt.xlabel("Chrurn ", fontsize=15)
plt.ylabel('Total day charge ($) ', fontsize=15)
for p in ax.patches:
    width = p.get_width()
    height = p.get_height()
    x, y = p.get_xy()
    ax.annotate(f'{height}', (x + width/2, y + height*1.02), ha='center
```



Contents

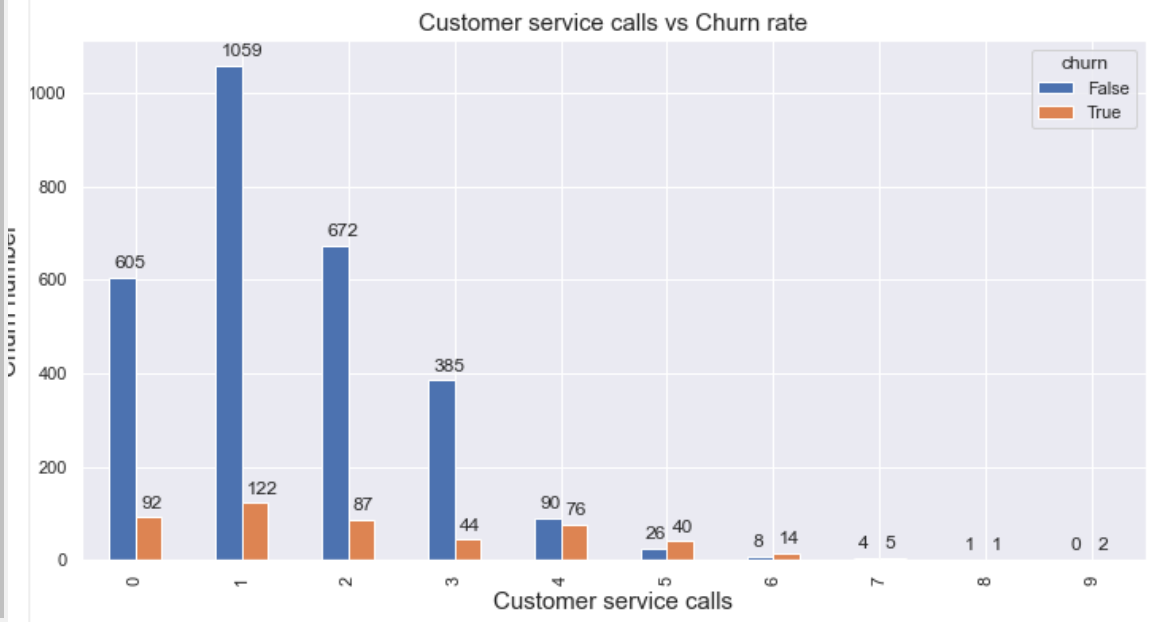
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

Contents
1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

21.1.2 Customer service calls

In [216]:
```
cs=df.groupby(["customer service calls", "churn"]).size().unstack().plo
for i in cs.patches:
    cs.text(i.get_x()+0.05, i.get_height()+20,int(i.get_height()))

plt.xlabel('Customer service calls', fontsize=15)
plt.ylabel('Churn number', fontsize=15)
plt.title('Customer service calls vs Churn rate', fontsize=15)
```

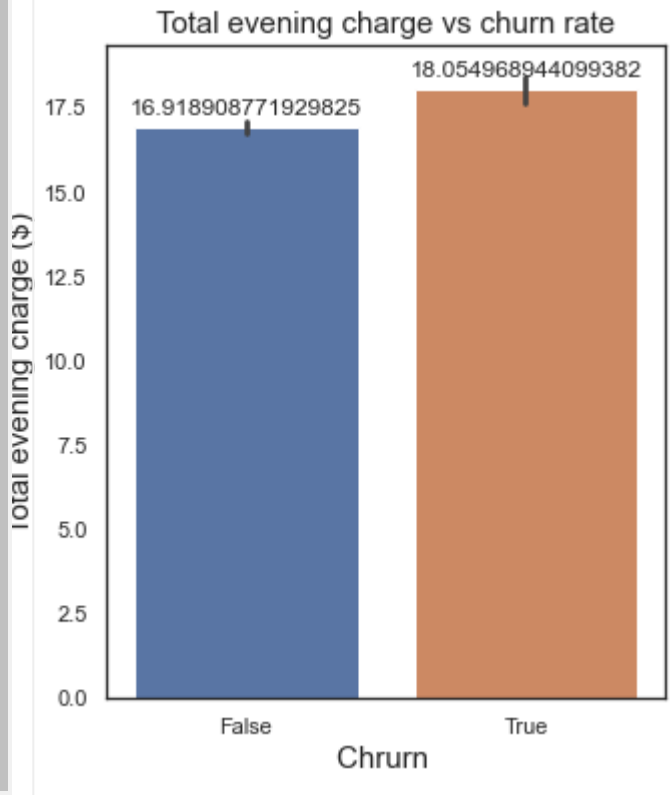
Out[216]:
```
ext(0.5, 1.0, 'Customer service calls vs Churn rate')
```



21.1.3 Total evening charge

In [220]:

```
sns.set(rc={"figure.figsize":(5,6)})
sns.set_style("white")
ax=sns.barplot(data=df, x="churn", y="total eve charge")
plt.title('Total evening charge vs churn rate', fontsize=15)
plt.xlabel("Chrurn ", fontsize=15)
plt.ylabel('Total evening charge ($)', fontsize=15)

for p in ax.patches:
    width = p.get_width()
    height = p.get_height()
    x, y = p.get_xy()
    ax.annotate(f'{height}', (x + width/2, y + height*1.02), ha='center
```



21.4 Total internatioanl charge

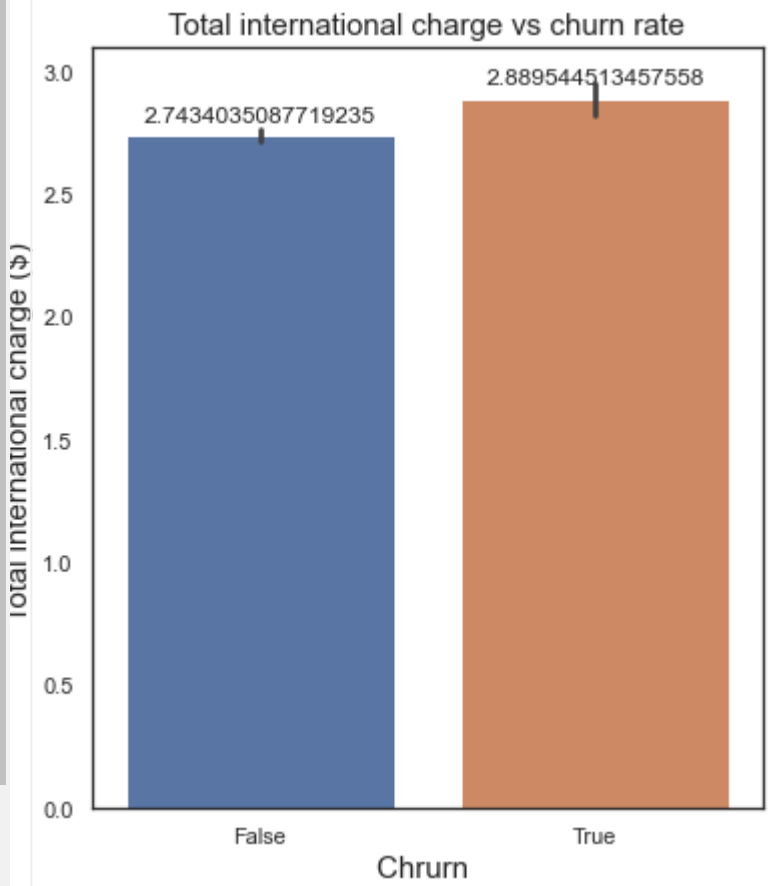
Contents
1 Abstract
2 Business Problei
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [223]:

```
sns.set(rc={"figure.figsize":(6,7)})
sns.set_style("white")
ax=sns.barplot(data=df, x="churn", y="total intl charge")
plt.title('Total international charge vs churn rate', fontsize=15)
plt.xlabel("Chrurn ", fontsize=15)
plt.ylabel('Total international charge ($) ', fontsize=15)

for p in ax.patches:
    width = p.get_width()
    height = p.get_height()
    x, y = p.get_xy()
    ax.annotate(f'{height}', (x + width/2, y + height*1.02), ha='center
```


Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best



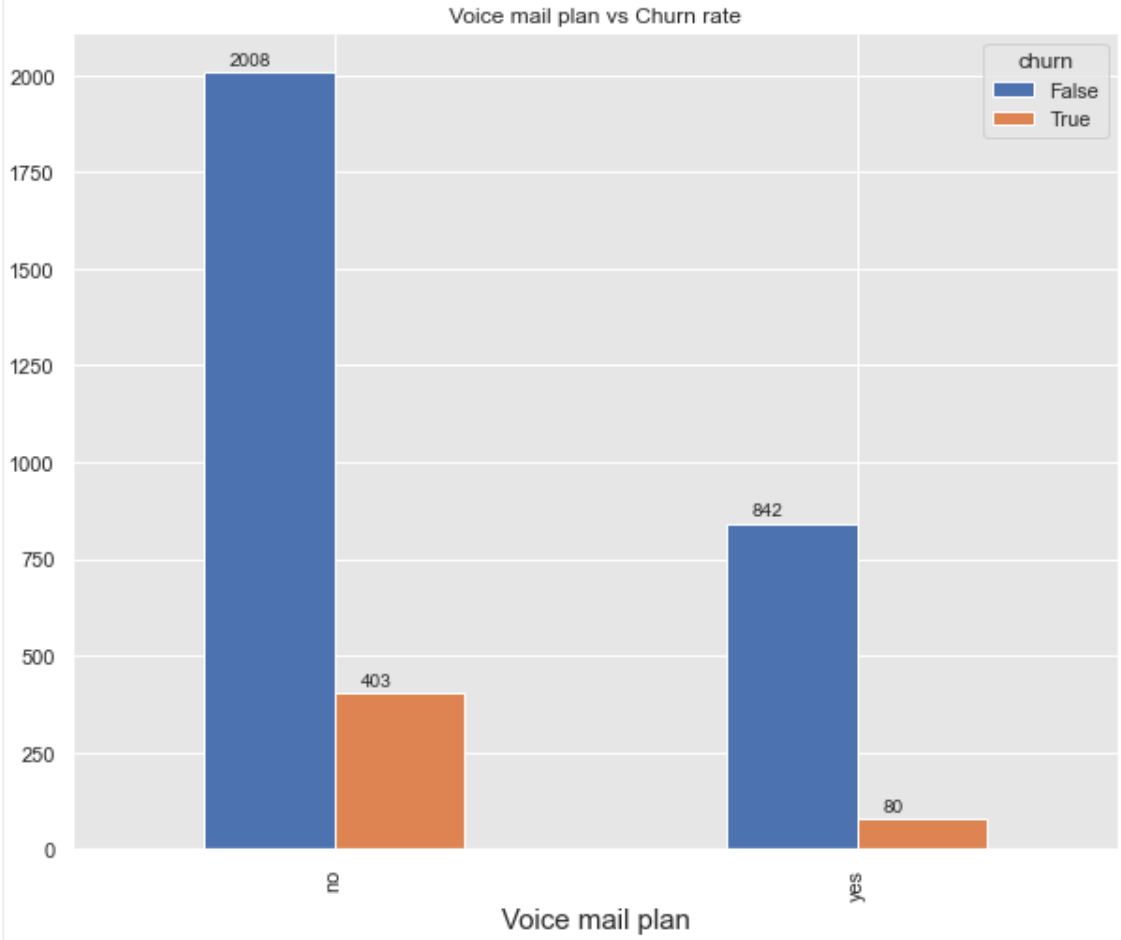
21 2 Decreasing churn factors

21 1 Voice mail plan

In [256]:

```
ax=df.groupby(["voice mail plan","churn"]).size().unstack().plot(kind='
for i in ax.patches:
    ax.text(i.get_x()+0.05, i.get_height()+20,str(i.get_height()))

plt.xlabel('Voice mail plan', fontsize=15)
plt.ylabel('Churn number', fontsize=15)
plt.title('Voice mail plan vs Churn rate')
```

Out[256]: ext(0.5, 1.0, 'Voice mail plan vs Churn rate')



Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best

In [228]:
```
1 df.columns
```

Out[228]:
```
Index(['area code', 'number vmail messages', 'total day calls',
       'total day charge', 'total eve calls', 'total eve charge',
       'total night calls', 'total night charge', 'total intl calls',
       'total intl charge', 'customer service calls', 'churn',
       'international plan_no', 'international plan_yes', 'voice mail plan_
no',
       'voice mail plan_yes'],
      dtype='object')
```

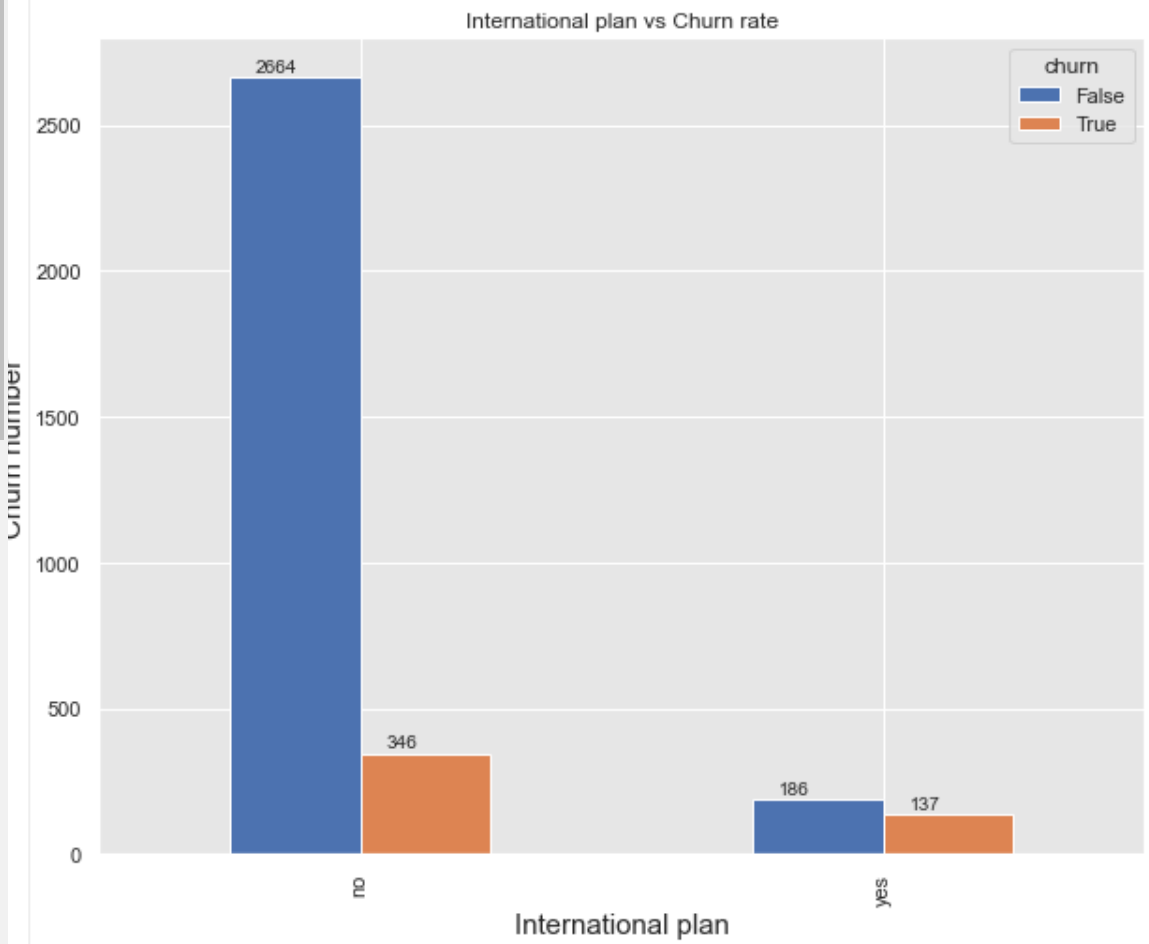
Contents

1 Abstract
2 Business Problem
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineering
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly co
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cla
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hyperpa
15.1.1.1 Best

21 2 International plan

In [113]:
```
1 ac=df.groupby(['international plan',"churn"]).size().unstack().plot(kir
2 for i in ac.patches:
3     ac.text(i.get_x()+0.05, i.get_height()+20,str(i.get_height()))
4 plt.xlabel('International plan', fontsize=15)
5 plt.ylabel('Churn number', fontsize=15)
6 plt.title('International plan vs Churn rate')
```

Out[113]:
```
ext(0.5, 1.0, 'International plan vs Churn rate')
```



22 Recomendations

1) Decrease call charge for day and special charges for evening calls.

2) Have a better international plan.

3) Customer service calls is a measure usually for bad experience. Look what are the main causes of cmplaints and improve the quality of phone service.

4) Keep up the good work with the voice mail plan which is the best feature that keeps customers in the company.

5) C npete with other companies on this strongly recommended feature"voice mail plan" which can tract customers from competeing rivals

2 Future Work

Mor mportant data is needed to predict the churn ofcustomers.

1) C npetitor Information

2) I rnet package information

3) C ntract Information

5) F ment method

6) C nplaint data

7) F ure data

In [ ]:

```
1
```


Contents

1 Abstract
2 Business Proble
3 Import Libaries
4 Load Data
5 Data Exploration
6 Data Engineerin
6.1 Group state
6.1.1 Commen
6.2 Drop unnece
6.3 Drop higly c
6.4 One Hot Enc
6.5 Train test spl
6.6 Standarize F
6.7 Building anal
7 Logistic Regress
7.1 Optimization
7.2 Best perform
7.3 Results Com
8 Descion Tree Cl
8.1 Hyperparame
8.1.1 Select Be
8.2 Results Com
9 Random Forest
9.1 Hyperparame
9.2 Best Parame
9.3 Results & Co
10 KNN Classifier
10.1 Tuning & Op
10.1.1 Select E
10.1.1.1 K=3
10.1.2 Iterate
10.1.2.1 K=1
10.2 Results & C
11 XGBoost
11.1 Results & co
12 Gaussian NB
12.1 Results & C
13 AdaBoostClassi
13.1 Results & C
14 Gradient Boosti
14.1 Results & co
15 SVM Classifier
15.1 Tuning & Op
15.1.1 Hypertu
15.1.1.1 Best