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Master Lab Course - Big Data Machine Learning

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In [4]:
```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
from keras.layers import *
from tensorflow.keras.layers.experimental import preprocessing
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
from scipy.stats import norm
from sklearn.preprocessing import StandardScaler
import scipy.stats as stats
import sklearn.linear_model as linear_model
from sklearn.model_selection import KFold
from IPython.display import HTML, display
from sklearn.manifold import TSNE
from sklearn.cluster import KMeans
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler
from scipy import stats
import warnings
warnings.filterwarnings('ignore')
%matplotlib inline
import os
import sys
import IPython
from six.moves import urllib
import datetime
from glob import glob
```

```
Using TensorFlow backend.
```

Step1
(Aufgabe 1) Analyse the data--> get feeling on the data

- Building System with only one Folder Data(Bearing1_4)

In [2]:
```
#1# MeasurementData_Bearing1_4_acc_00001.csv
df = pd.read_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_zip/measurement
#dataset = dataset[0].str.split(';', expand = True)
df.columns = ['Stunde', 'Minute', 'Sekunde', 'Mikrosekunde', 'Horiz Beschl', 'Vert B
print(df)
print(df.shape)
```

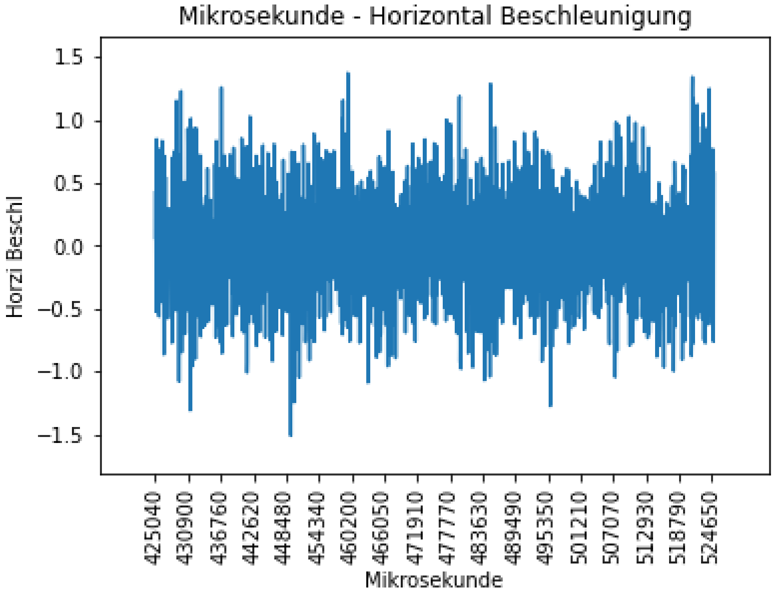
```
      Stunde  Minute  Sekunde  Mikrosekunde  Horiz Beschl  Vert Beschl
0          8       8        0      425040.0         0.065       -0.058
1          8       8        0      425080.0         0.438        0.179
2          8       8        0      425120.0        -0.079        0.646
3          8       8        0      425160.0        -0.523       -0.411
4          8       8        0      425200.0        -0.146       -0.387
...      ...     ...      ...           ...           ...          ...
2555       8       8        0      524840.0        -0.102        0.438
2556       8       8        0      524880.0        -0.556        0.386
2557       8       8        0      524920.0        -0.762        0.371
2558       8       8        0      524960.0         0.015        0.136
2559       8       8        0      525000.0         0.580        0.265

[2560 rows x 6 columns]
(2560, 6)
```

Step2
(Aufgabe 1)Plot: Mikrosekunde - Horizontal Beschleunigung

In [3]:
```
x = df['Mikrosekunde']
print(x)

y = df['Horiz Beschl']
print(y)


#title & labels
plt.title('Mikrosekunde - Horizontal Beschleunigung')
plt.xlabel('Mikrosekunde')
plt.ylabel('Horzi Beschl')


#print only very 150
plt.plot(x,y)
plt.xticks(x[::150],  rotation='vertical')
plt.margins(0.1)
plt.show()
```

```
0       425040.0
1       425080.0
2       425120.0
3       425160.0
4       425200.0
          ...
2555    524840.0
2556    524880.0
2557    524920.0
2558    524960.0
2559    525000.0
Name: Mikrosekunde, Length: 2560, dtype: float64
0       0.065
1       0.438
2      -0.079
3      -0.523
4      -0.146
         ...
2555   -0.102
2556   -0.556
```

```
2557   -0.762
2558    0.015
2559    0.580
Name: Horiz Beschl, Length: 2560, dtype: float64
```



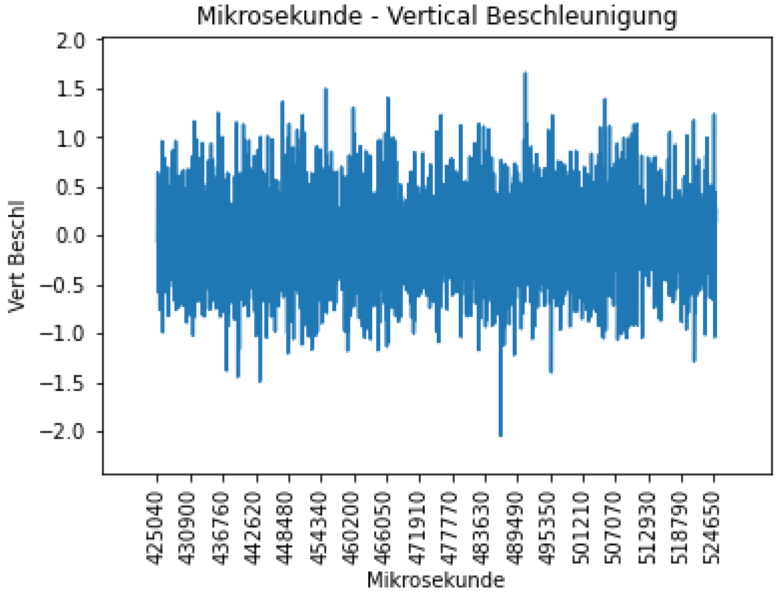
Step3
(Aufgabe 1)Plot: Mikrosekunde - Vertical Beschleunigung

In [4]:

```
x = df['Mikrosekunde']
print(x)

y = df['Vert Beschl']
print(y)


#title & labels
plt.title('Mikrosekunde - Vertical Beschleunigung')
plt.xlabel('Mikrosekunde')
plt.ylabel('Vert Beschl')


#print only very 150
plt.plot(x,y)
plt.xticks(x[::150],  rotation='vertical')
plt.margins(0.1)
plt.show()
```

```
0       425040.0
1       425080.0
2       425120.0
3       425160.0
4       425200.0
          ...
2555    524840.0
2556    524880.0
2557    524920.0
2558    524960.0
2559    525000.0
Name: Mikrosekunde, Length: 2560, dtype: float64
0      -0.058
1       0.179
2       0.646
3      -0.411
4      -0.387
```

```
        ...
2555    0.438
2556    0.386
2557    0.371
2558    0.136
2559    0.265
Name: Vert Beschl, Length: 2560, dtype: float64
```



Step4
Create func1 --> to generate 'state_df'

In [5]:

```
### create function: get each csv's label + filename ###
def get_state_filename(key, file_path_str):
    label_folder_files = sorted(glob(file_path_str))
    label_folder_files

    #create dict
    state_dict = {}
    state_list = []

    #for i in range(len(label_folder_files)):
    for i in range(len(label_folder_files)):
        filename = label_folder_files[i]
        df_      = pd.read_csv(filename, delimiter=',', header=None)
        df_      = df_.drop(df_.columns[0], axis=1)
        df_      = df_.drop([0])
        df_.columns = ['file', 'state']
        #df_filename = df_['file']
        #df_label    = df_['state']
        state_list.append(df_)
        #replace 1 with 0/ replace 2 with 1(only 2 labels)

        #state_dict['{}'.format(i)] = [df_filename, df_label]
        #state_dict[key[i]] = [df_filename, df_label]

    return state_list#state_dict
```

In [6]:

```
folder_files = sorted(glob('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bd
folder_files
```

Out[6]:

```
['C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00001.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00002.csv',
```

```
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00003.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00004.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00005.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00006.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00007.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00008.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00009.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00010.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00011.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00012.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00013.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00014.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00015.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00016.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00017.csv',
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data/measurement_data/Bearing1_4\\acc_00018.csv',
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data/measurement_data/Bearing1_4\\acc_00019.csv',
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data/measurement_data/Bearing1_4\\acc_00020.csv',
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data/measurement_data/Bearing1_4\\acc_00021.csv',
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data/measurement_data/Bearing1_4\\acc_00022.csv',
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data/measurement_data/Bearing1_4\\acc_00023.csv',
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data/measurement_data/Bearing1_4\\acc_00024.csv',
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data/measurement_data/Bearing1_4\\acc_00025.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00026.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00027.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00028.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00029.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00030.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00031.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00032.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00033.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00034.csv',
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data/measurement_data/Bearing1_4\\acc_00035.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00036.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
```

```
data/measurement_data/Bearing1_4\\acc_00037.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00038.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00039.csv',
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data/measurement_data/Bearing1_4\\acc_00040.csv',
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data/measurement_data/Bearing1_4\\acc_00043.csv',
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data/measurement_data/Bearing1_4\\acc_00049.csv',
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data/measurement_data/Bearing1_4\\acc_00052.csv',
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data/measurement_data/Bearing1_4\\acc_00054.csv',
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data/measurement_data/Bearing1_4\\acc_00056.csv',
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data/measurement_data/Bearing1_4\\acc_00061.csv',
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data/measurement_data/Bearing1_4\\acc_00062.csv',
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data/measurement_data/Bearing1_4\\acc_00071.csv',
```

```
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00072.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
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data/measurement_data/Bearing1_4\\acc_00076.csv',
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data/measurement_data/Bearing1_4\\acc_00077.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00078.csv',
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 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00080.csv',
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 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00082.csv',
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data/measurement_data/Bearing1_4\\acc_00084.csv',
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 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00086.csv',
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data/measurement_data/Bearing1_4\\acc_00087.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00088.csv',
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data/measurement_data/Bearing1_4\\acc_00946.csv',
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data/measurement_data/Bearing1_4\\acc_00947.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00948.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00949.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00950.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00951.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00952.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00953.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00954.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00955.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00956.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00957.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00958.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00959.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00960.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00961.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00962.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00963.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00964.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00965.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00966.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00967.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_
data/measurement_data/Bearing1_4\\acc_00968.csv',
```

```
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00969.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00970.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00971.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00972.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00973.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00974.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00975.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00976.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00977.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00978.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00979.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00980.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00981.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00982.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00983.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00984.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00985.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00986.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00987.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00988.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00989.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00990.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00991.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00992.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00993.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00994.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00995.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00996.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00997.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00998.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_00999.csv',
 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_projekt_7z/bdml_projekt_7z/measurement_data/measurement_data/Bearing1_4\\acc_01000.csv',
 ...]
```

Step5
Create func1 --> to generate 'df_new' (have not

stacking)

- to (Aufgabe 6): in this step will prepare extra features like: 'absolute mean value horizontal' & 'absolute mean value horizontal'. These features will be used to generate different datasets(df_features_0, df_features_1, df_features_2 and df_features_3) for training(see Step13).

In [7]:
```
def calculate_each_csv(file_path_str):
    folder_files = sorted(glob(file_path_str))

    #create empty lists
    abs_mean_h_list = []
    abs_mean_v_list = []
    mean_h_list     = []
    mean_v_list     = []
    stand_h_list    = []
    stand_v_list    = []
    max_h_list      = []
    min_h_list      = []
    max_v_list      = []
    min_v_list      = []
    time_deviation_list = []


    for i in range(len(folder_files)):
        filename = folder_files[i]
        #df = pd.read_csv(filename, delimiter=',', header=None)
        df = pd.read_csv(filename, sep=';|,')

        #add columns head
        df.columns  = ['Stunde', 'Minute', 'Sekunde', 'Mikrosekunde', 'Horiz Beschl'

        #calculate abs_mean_h, abs_mean_v, mean_h, mean_v, stand_h, stand_v, time_de
        abs_mean_h = df['Horiz Beschl'].abs().mean().round(5)
        abs_mean_v = df['Vert Beschl'].abs().mean().round(5)
        mean_h     = df['Horiz Beschl'].mean().round(5)
        mean_v     = df['Vert Beschl'].mean().round(5)
        stand_h    = df['Horiz Beschl'].std().round(5)
        stand_v    = df['Vert Beschl'].std().round(5)
        max_h      = df['Horiz Beschl'].max().round(5)
        min_h      = df['Horiz Beschl'].min().round(5)
        max_v      = df['Vert Beschl'].max().round(5)
        min_v      = df['Vert Beschl'].min().round(5)
        time_deviation = int(df['Mikrosekunde'].max() - df['Mikrosekunde'].min())

        #append to list
        abs_mean_h_list.append(abs_mean_h)
        abs_mean_v_list.append(abs_mean_v)
        mean_h_list.append(mean_h)
        mean_v_list.append(mean_v)
        stand_h_list.append(stand_h)
        stand_v_list.append(stand_v)
        max_h_list.append(max_h)
        min_h_list.append(min_h)
        max_v_list.append(max_v)
        min_v_list.append(min_v)
        time_deviation_list.append(time_deviation)

    #Create new dataframe
    df_new = pd.DataFrame({'abs_mean_h': abs_mean_h_list,
                           'abs_mean_v': abs_mean_v_list,
                           'mean_h'    :     mean_h_list,
                           'mean_v'    :     mean_v_list,
```

```
                                   'stand_h'    :    stand_h_list,
                                   'stand_v'    :    stand_v_list,
                                   'max_h'      :      max_h_list,
                                   'min_h'      :      min_h_list,
                                   'max_v'      :      max_v_list,
                                   'min_v'      :      min_v_list,
                                   'time_deviation': time_deviation_list
                                })

    return df_new
```

Step6
(Aufgabe 2) Only load bearing1_4 folder csv file

Goal is to plot 4 plots: (x axis, y axis) --> to analyse the tendency against time

- Plot_1: (time, Mean_h)
- Plot_2: (time, Mean_v)
- Plot_3: (time, StandardDeviation_h)
- Plot_4: (time, StardardDeviation_v)

In [8]:
```
#use function
key = ['Bearing1_4', 'Bearing1_5', 'Bearing1_6',
       'Bearing1_7', 'Bearing2_4', 'Bearing2_5',
       'Bearing2_6', 'Bearing2_7', 'Bearing3_3']
```

In [9]:
```
#1# Load only Bearing1_4_health_state csv files
state_list_B1_4 = get_state_filename(key, 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdm

#2#concatenate a list of dataframes together#
state_df_B1_4 = pd.concat(state_list_B1_4)
state_df_B1_4.reset_index(drop=True, inplace=True)

print('state_df_B1_4')
print(state_df_B1_4)
print(state_df_B1_4.shape)

#3# reduce from 3 to 2 classes
state_df_B1_4['state'] = state_df_B1_4['state'].replace({'0': 0, '1': 0, '2': 1})
state_df_B1_4['state']

print()
print('state_df_B1_4_reduced')
print(state_df_B1_4)

#calculat frequency
state_df_B1_4['state'].value_counts()


#4# Load only Bearing1_4 folder csv files --> generate dataframe
Bearing1_4_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing1_4_df')
print(Bearing1_4_df)


#5# concate 'features df' & 'label df'
B1_4_df = pd.concat([state_df_B1_4, Bearing1_4_df], axis=1)
print(B1_4_df)
```

```
print(B1_4_df.shape)
print(B1_4_df.columns.values)
B1_4_df['state'].value_counts()


#6# drop columns 'file' & 'time_deviation'
B1_4_df = B1_4_df.drop(columns=['file', 'time_deviation'], axis=1)
B1_4_df
```

```
state_df_B1_4
                file state
0     acc_00001.csv     0
1     acc_00002.csv     0
2     acc_00003.csv     0
3     acc_00004.csv     0
4     acc_00005.csv     0
...             ...   ...
1423  acc_01424.csv     2
1424  acc_01425.csv     2
1425  acc_01426.csv     2
1426  acc_01427.csv     2
1427  acc_01428.csv     2

[1428 rows x 2 columns]
(1428, 2)

state_df_B1_4_reduced
                file  state
0     acc_00001.csv      0
1     acc_00002.csv      0
2     acc_00003.csv      0
3     acc_00004.csv      0
4     acc_00005.csv      0
...             ...    ...
1423  acc_01424.csv      1
1424  acc_01425.csv      1
1425  acc_01426.csv      1
1426  acc_01427.csv      1
1427  acc_01428.csv      1

[1428 rows x 2 columns]
Bearing1_4_df
      abs_mean_h  abs_mean_v   mean_h   mean_v   stand_h   stand_v   max_h  \
0        0.32318     0.35930  0.00636  0.00167   0.40337   0.45502   1.373
1        0.31214     0.36394 -0.00900  0.00669   0.39068   0.45886   1.299
2        0.31035     0.38840 -0.00622 -0.00830   0.39190   0.49150   1.313
3        0.33253     0.38023 -0.00582 -0.00175   0.41586   0.47481   1.508
4        0.31086     0.40921 -0.00202  0.00663   0.38677   0.51172   1.334
...          ...         ...      ...      ...       ...       ...     ...
1423     7.86718    11.04806  0.04985 -0.32804  10.54333  14.54749  48.128
1424     7.91047    10.61781 -0.11316 -0.03484  10.55686  14.07207  48.128
1425     8.29157    10.74766 -0.16524  0.06929  11.10476  14.19700  48.128
1426     8.14881    11.08156 -0.14566  0.26825  10.89777  14.59728  48.128
1427     7.18050     8.18296  0.17245  0.76412   9.33412  10.48393  48.128

        min_h   max_v   min_v  time_deviation
0      -1.511   1.658  -2.045           99920
1      -1.446   1.537  -1.685           99920
2      -1.505   2.161  -1.872           99920
3      -1.476   1.637  -2.033           99920
4      -1.225   1.967  -1.690           99920
...       ...     ...     ...             ...
1423  -41.133  47.849 -47.843           99920
1424  -39.357  47.849 -47.843           99920
1425  -46.942  47.849 -47.843           99920
1426  -48.148  47.849 -47.843           99920
1427  -41.573  47.849 -41.680           99920

[1428 rows x 11 columns]
```

```
               file  state  abs_mean_h  abs_mean_v   mean_h   mean_v  \
0     acc_00001.csv      0     0.32318     0.35930  0.00636  0.00167
1     acc_00002.csv      0     0.31214     0.36394 -0.00900  0.00669
2     acc_00003.csv      0     0.31035     0.38840 -0.00622 -0.00830
3     acc_00004.csv      0     0.33253     0.38023 -0.00582 -0.00175
4     acc_00005.csv      0     0.31086     0.40921 -0.00202  0.00663
...             ...    ...         ...         ...      ...      ...
1423  acc_01424.csv      1     7.86718    11.04806  0.04985 -0.32804
1424  acc_01425.csv      1     7.91047    10.61781 -0.11316 -0.03484
1425  acc_01426.csv      1     8.29157    10.74766 -0.16524  0.06929
1426  acc_01427.csv      1     8.14881    11.08156 -0.14566  0.26825
1427  acc_01428.csv      1     7.18050     8.18296  0.17245  0.76412

       stand_h   stand_v   max_h   min_h   max_v   min_v  time_deviation
0      0.40337   0.45502   1.373  -1.511   1.658  -2.045           99920
1      0.39068   0.45886   1.299  -1.446   1.537  -1.685           99920
2      0.39190   0.49150   1.313  -1.505   2.161  -1.872           99920
3      0.41586   0.47481   1.508  -1.476   1.637  -2.033           99920
4      0.38677   0.51172   1.334  -1.225   1.967  -1.690           99920
...        ...       ...     ...     ...     ...     ...             ...
1423  10.54333  14.54749  48.128 -41.133  47.849 -47.843           99920
1424  10.55686  14.07207  48.128 -39.357  47.849 -47.843           99920
1425  11.10476  14.19700  48.128 -46.942  47.849 -47.843           99920
1426  10.89777  14.59728  48.128 -48.148  47.849 -47.843           99920
1427   9.33412  10.48393  48.128 -41.573  47.849 -41.680           99920

[1428 rows x 13 columns]
(1428, 13)
['file' 'state' 'abs_mean_h' 'abs_mean_v' 'mean_h' 'mean_v' 'stand_h'
 'stand_v' 'max_h' 'min_h' 'max_v' 'min_v' 'time_deviation']
```

Out[9]:

	state	abs_mean_h	abs_mean_v	mean_h	mean_v	stand_h	stand_v	max_h	min_h	max_
0	0	0.32318	0.35930	0.00636	0.00167	0.40337	0.45502	1.373	-1.511	1.65
1	0	0.31214	0.36394	-0.00900	0.00669	0.39068	0.45886	1.299	-1.446	1.53
2	0	0.31035	0.38840	-0.00622	-0.00830	0.39190	0.49150	1.313	-1.505	2.16
3	0	0.33253	0.38023	-0.00582	-0.00175	0.41586	0.47481	1.508	-1.476	1.63
4	0	0.31086	0.40921	-0.00202	0.00663	0.38677	0.51172	1.334	-1.225	1.96
...	...	...	...	...	...	...	...	...	...	
1423	1	7.86718	11.04806	0.04985	-0.32804	10.54333	14.54749	48.128	-41.133	47.84
1424	1	7.91047	10.61781	-0.11316	-0.03484	10.55686	14.07207	48.128	-39.357	47.84
1425	1	8.29157	10.74766	-0.16524	0.06929	11.10476	14.19700	48.128	-46.942	47.84
1426	1	8.14881	11.08156	-0.14566	0.26825	10.89777	14.59728	48.128	-48.148	47.84
1427	1	7.18050	8.18296	0.17245	0.76412	9.33412	10.48393	48.128	-41.573	47.84

1428 rows × 11 columns

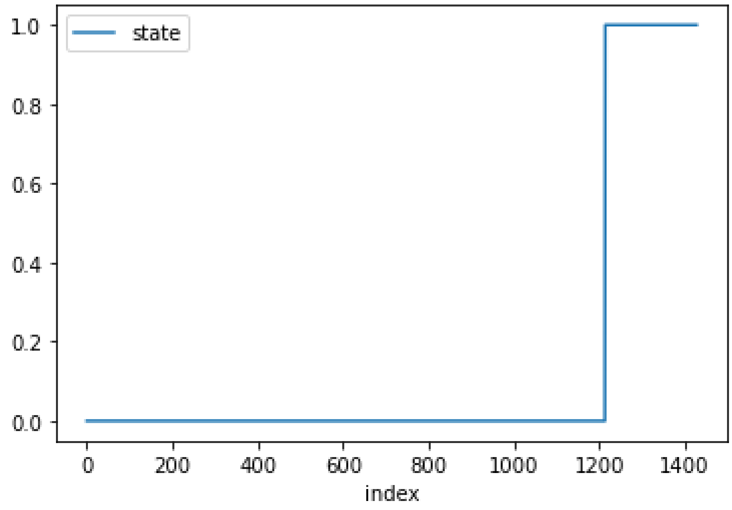
(Aufgabe 2)Plotting

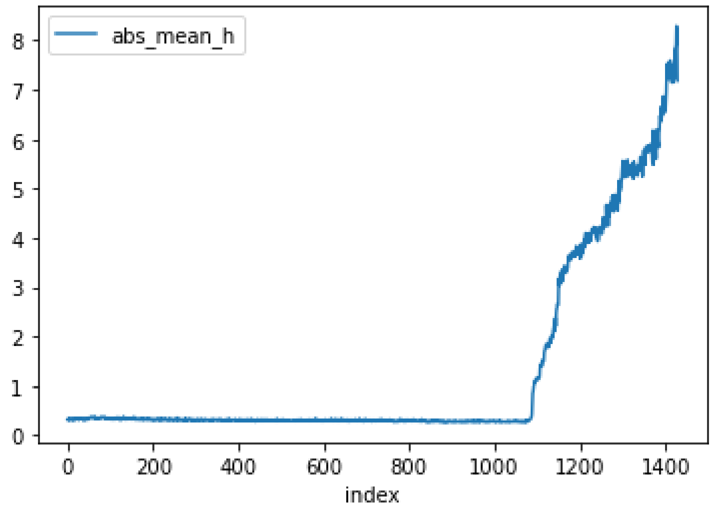
- Plot_0: (time, state)
- Plot_1: (time, Abs_Mean_h)
- Plot_2: (time, Abs_Mean_v)
- Plot_3: (time, Mean_h)
- Plot_4: (time, Mean_v)

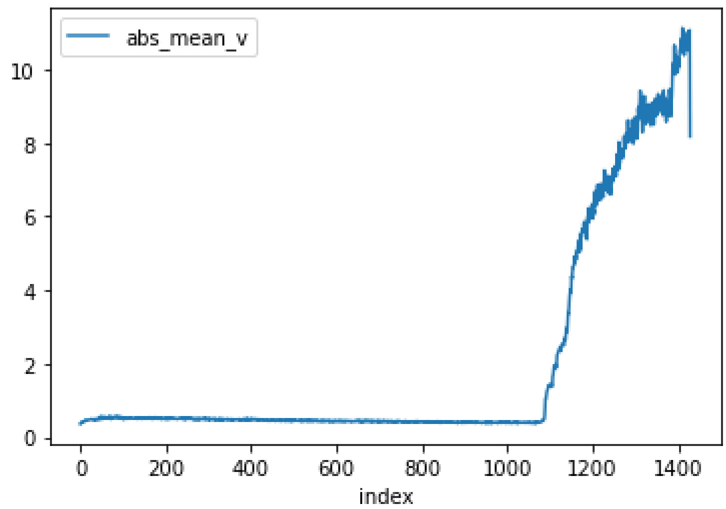
In [10]:

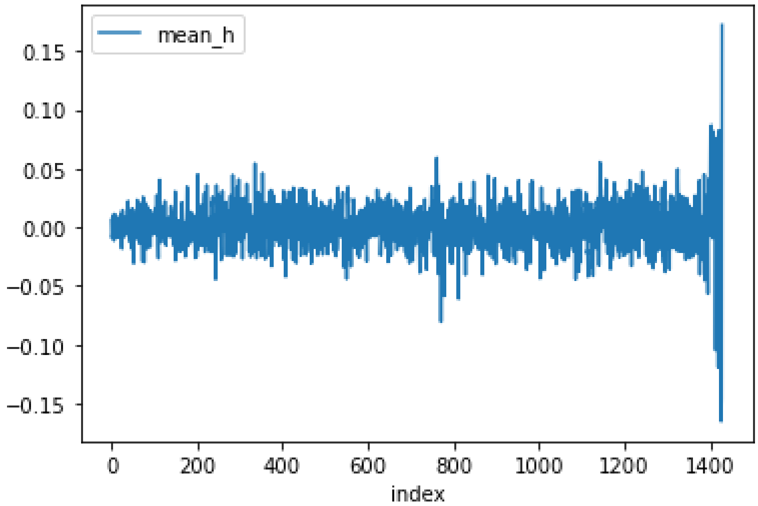
```
# here use index as Zeitliche Verlauf
# Plot_0: (time, state)
B1_4_df.reset_index().plot(x='index', y='state')
print(B1_4_df)
plt.show()

# Plot_1: (time, Abs_Mean_h)
B1_4_df.reset_index().plot(x='index', y='abs_mean_h')
plt.show()


# Plot_2: (time, Abs_Mean_v)
B1_4_df.reset_index().plot(x='index', y='abs_mean_v')
plt.show()


# Plot_3: (time, Mean_h)
B1_4_df.reset_index().plot(x='index', y='mean_h')
plt.show()

# Plot_4: (time, Mean_v)
B1_4_df.reset_index().plot(x='index', y='mean_v')
plt.show()
```

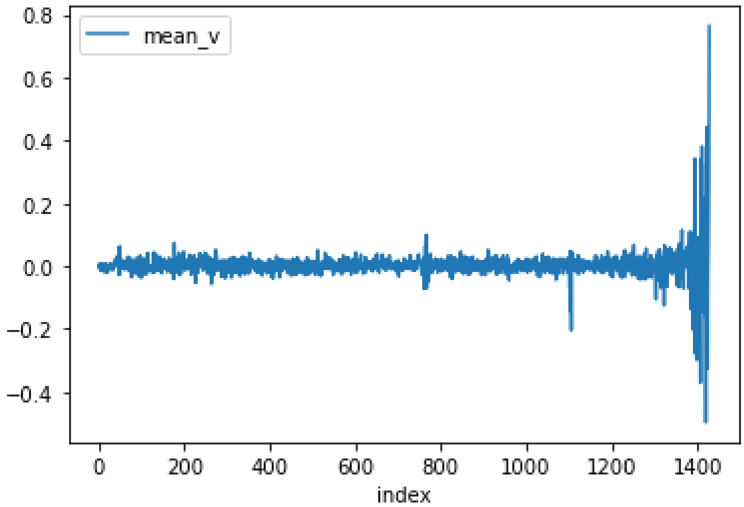
```
      state  abs_mean_h  abs_mean_v   mean_h   mean_v   stand_h   stand_v  \
0         0     0.32318     0.35930  0.00636  0.00167   0.40337   0.45502
1         0     0.31214     0.36394 -0.00900  0.00669   0.39068   0.45886
2         0     0.31035     0.38840 -0.00622 -0.00830   0.39190   0.49150
3         0     0.33253     0.38023 -0.00582 -0.00175   0.41586   0.47481
4         0     0.31086     0.40921 -0.00202  0.00663   0.38677   0.51172
...     ...         ...         ...      ...      ...       ...       ...
1423      1     7.86718    11.04806  0.04985 -0.32804  10.54333  14.54749
1424      1     7.91047    10.61781 -0.11316 -0.03484  10.55686  14.07207
1425      1     8.29157    10.74766 -0.16524  0.06929  11.10476  14.19700
1426      1     8.14881    11.08156 -0.14566  0.26825  10.89777  14.59728
1427      1     7.18050     8.18296  0.17245  0.76412   9.33412  10.48393

       max_h   min_h   max_v   min_v
0      1.373  -1.511   1.658  -2.045
1      1.299  -1.446   1.537  -1.685
2      1.313  -1.505   2.161  -1.872
3      1.508  -1.476   1.637  -2.033
4      1.334  -1.225   1.967  -1.690
...      ...     ...     ...     ...
1423  48.128 -41.133  47.849 -47.843
1424  48.128 -39.357  47.849 -47.843
1425  48.128 -46.942  47.849 -47.843
1426  48.128 -48.148  47.849 -47.843
1427  48.128 -41.573  47.849 -41.680

[1428 rows x 11 columns]
```


state
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
1400
index


abs_mean_h
8
7
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
index


abs_mean_v
10
8
6
4
2
0
0
200
400
600
800
1000
1200
1400
index





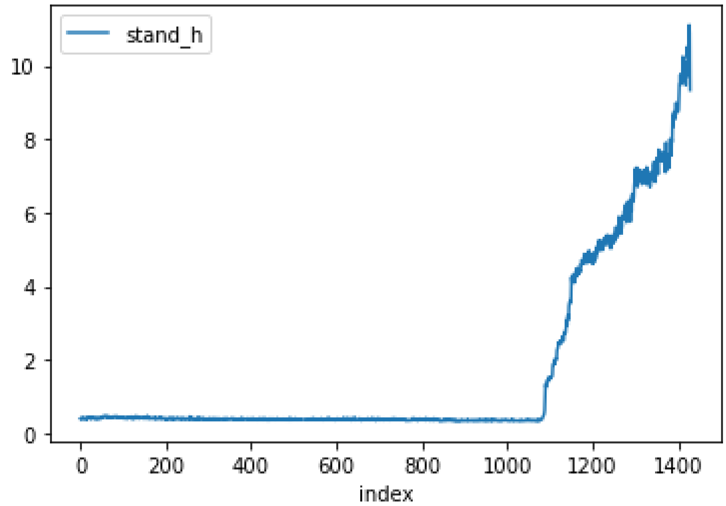
(Aufgabe 2)Plotting

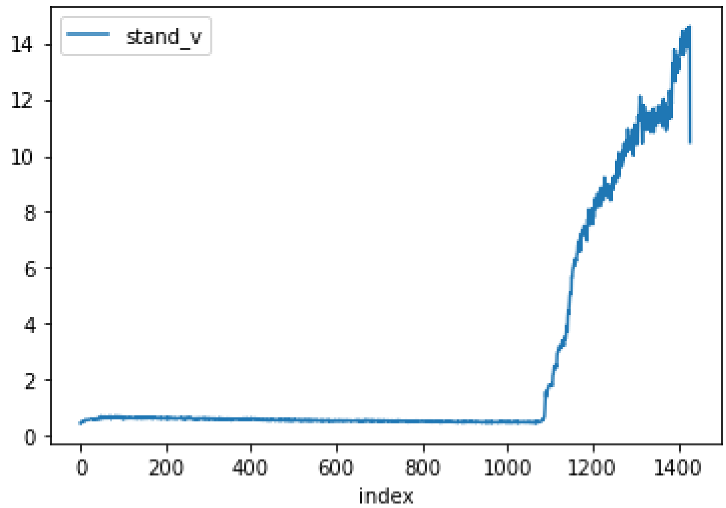
- Plot_5: (time, stand_h)
- Plot_6: (time, stand_v)
- Plot_7: (time, max_h)
- Plot_8: (time, min_h)
- Plot_9: (time, max_v)
- Plot_10: (time, min_v)

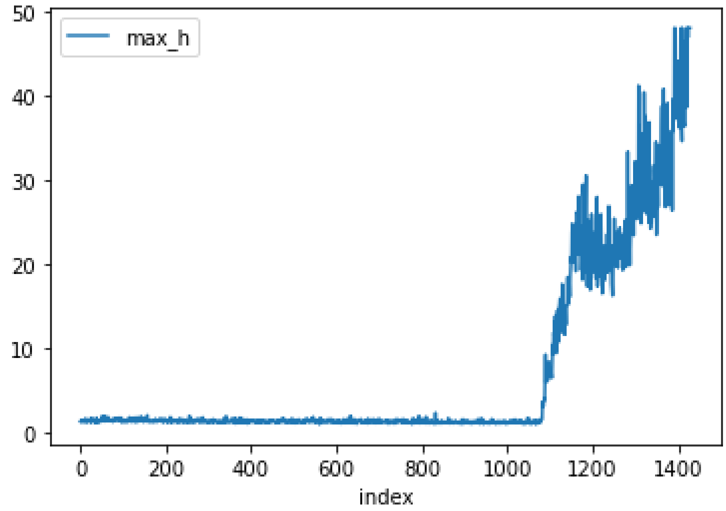
In [11]:
```
# here use index as Zeitliche Verlauf
# Plot_5: (time, stand_h)
B1_4_df.reset_index().plot(x='index', y='stand_h')
print(B1_4_df)
plt.show()

# Plot_6: (time, stand_v)
B1_4_df.reset_index().plot(x='index', y='stand_v')
plt.show()

# Plot_7: (time, max_h)
B1_4_df.reset_index().plot(x='index', y='max_h')
plt.show()

# Plot_8: (time, min_h)
B1_4_df.reset_index().plot(x='index', y='min_h')
plt.show()

# Plot_9: (time, max_v)
```

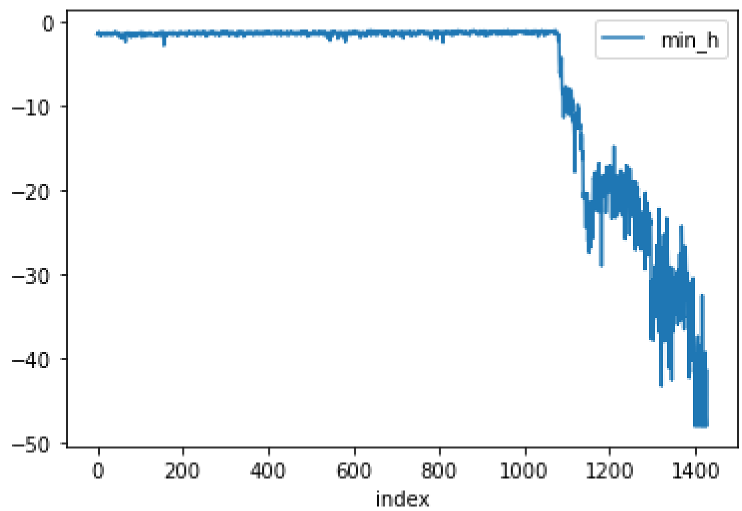
```
B1_4_df.reset_index().plot(x='index', y='max_v')
plt.show()

# Plot_10: (time, min_v)
B1_4_df.reset_index().plot(x='index', y='min_v')
plt.show()
```

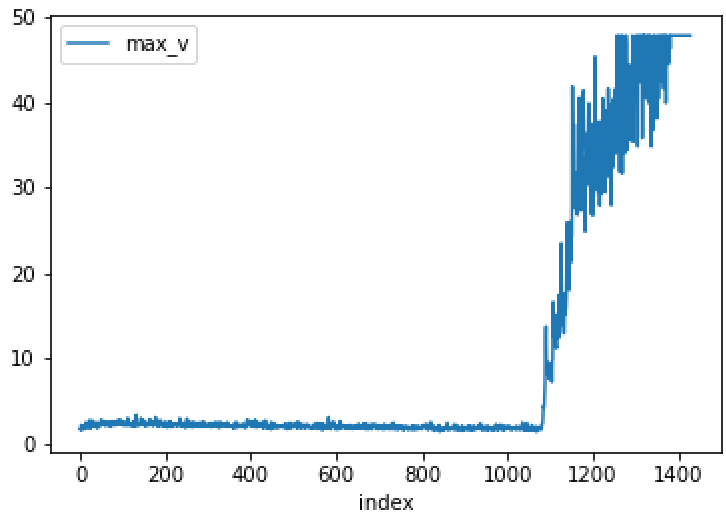
```
      state  abs_mean_h  abs_mean_v   mean_h   mean_v   stand_h   stand_v  \
0         0     0.32318     0.35930  0.00636  0.00167   0.40337   0.45502
1         0     0.31214     0.36394 -0.00900  0.00669   0.39068   0.45886
2         0     0.31035     0.38840 -0.00622 -0.00830   0.39190   0.49150
3         0     0.33253     0.38023 -0.00582 -0.00175   0.41586   0.47481
4         0     0.31086     0.40921 -0.00202  0.00663   0.38677   0.51172
...     ...         ...         ...      ...      ...       ...       ...
1423      1     7.86718    11.04806  0.04985 -0.32804  10.54333  14.54749
1424      1     7.91047    10.61781 -0.11316 -0.03484  10.55686  14.07207
1425      1     8.29157    10.74766 -0.16524  0.06929  11.10476  14.19700
1426      1     8.14881    11.08156 -0.14566  0.26825  10.89777  14.59728
1427      1     7.18050     8.18296  0.17245  0.76412   9.33412  10.48393

       max_h   min_h   max_v   min_v
0      1.373  -1.511   1.658  -2.045
1      1.299  -1.446   1.537  -1.685
2      1.313  -1.505   2.161  -1.872
3      1.508  -1.476   1.637  -2.033
4      1.334  -1.225   1.967  -1.690
...      ...     ...     ...     ...
1423  48.128 -41.133  47.849 -47.843
1424  48.128 -39.357  47.849 -47.843
1425  48.128 -46.942  47.849 -47.843
1426  48.128 -48.148  47.849 -47.843
1427  48.128 -41.573  47.849 -41.680

[1428 rows x 11 columns]
```

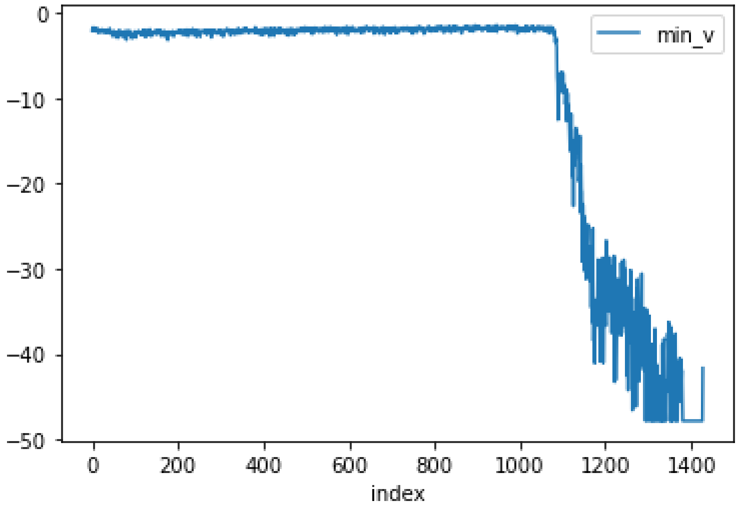





max_h
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
index


min_h
0
−10
−20
−30
−40
−50
0
200
400
600
800
1000
1200
1400
index


max_v
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
index



Analysis Summary on the 11 plotting above:

- all the features('state', 'abs_mean_h', 'abs_mean_v', 'mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v') increase their amplitude, as the time increase.

Step7
(Aufgabe 3) Generate 'State_df'

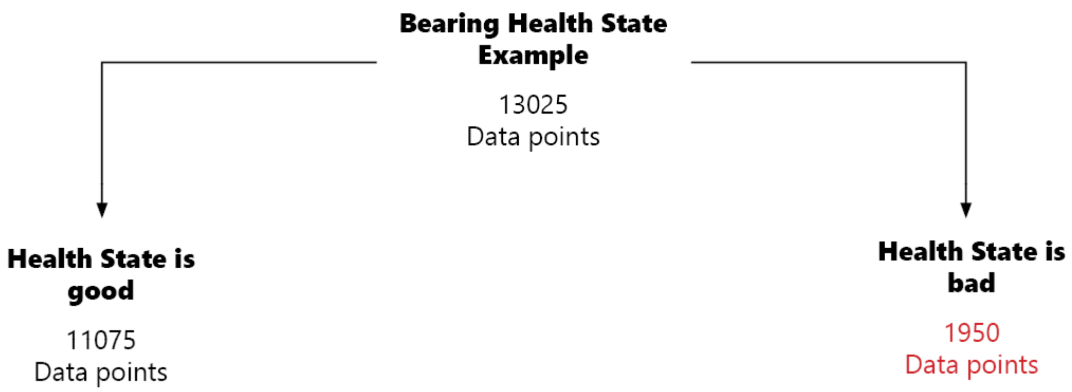
In [12]:
```
#use function
key = ['Bearing1_4', 'Bearing1_5', 'Bearing1_6',
       'Bearing1_7', 'Bearing2_4', 'Bearing2_5',
       'Bearing2_6', 'Bearing2_7', 'Bearing3_3']

#1#
state_list = get_state_filename(key, 'C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_pro

#2#concatenate a list of dataframes together#
state_df = pd.concat(state_list)
state_df.reset_index(drop=True, inplace=True)

print('state_df')
print(state_df)
print(state_df.shape)
```

```
state_df
                file  state
0      acc_00001.csv      0
1      acc_00002.csv      0
2      acc_00003.csv      0
3      acc_00004.csv      0
4      acc_00005.csv      0
...              ...    ...
13020  acc_00430.csv      2
13021  acc_00431.csv      2
13022  acc_00432.csv      2
13023  acc_00433.csv      2
13024  acc_00434.csv      2

[13025 rows x 2 columns]
(13025, 2)
```

Step8
(Aufgabe 3 & Aufgabe 4) Reduce the class Number from 3 --> 2

In [13]:
```
state_df['state'] = state_df['state'].replace({'0': 0, '1': 0, '2': 1})
state_df['state']

#calculat frequency
G,HW = state_df['state'].value_counts()
print(('Good: {}'.format(G),'HeavyWorn: {}'.format(HW)))
print('TotalNumber of csv files: ', G+HW)

#check value
state_df_new = state_df
print(state_df_new)
```

```
('Good: 11075', 'HeavyWorn: 1950')
TotalNumber of csv files:  13025
                 file  state
0      acc_00001.csv      0
1      acc_00002.csv      0
2      acc_00003.csv      0
3      acc_00004.csv      0
4      acc_00005.csv      0
...              ...    ...
13020  acc_00430.csv      1
13021  acc_00431.csv      1
13022  acc_00432.csv      1
13023  acc_00433.csv      1
13024  acc_00434.csv      1

[13025 rows x 2 columns]
```



Current analysis of the dataset: The dataset is imbalance(skewness). If we train a model on the dataset, since the number of data points of bearing with good health state is far more than bearing with bad health state, the model will be biased towards the target(health state is good), which has more data points

Step9
Import all the csv files from each folders

In [14]:
```
#generate Bearing1_4, 1_5 .....,3_3 df
Bearing1_4_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing1_4_df')
print(Bearing1_4_df)

Bearing1_5_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing1_5_df')
print(Bearing1_5_df)

Bearing1_6_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing1_6_df')
```

```
print(Bearing1_6_df)

Bearing1_7_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing1_7_df')
print(Bearing1_7_df)

Bearing2_4_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing2_4_df')
print(Bearing2_4_df)

Bearing2_5_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing2_5_df')
print(Bearing2_5_df)

Bearing2_6_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing2_6_df')
print(Bearing2_6_df)

Bearing2_7_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing2_7_df')
print(Bearing2_7_df)

Bearing3_3_df = calculate_each_csv('C:/TCW/01_Uni-Stuttgart/Big Data Labs/bdml_proje
print('Bearing3_3_df')
print(Bearing3_3_df)
```

```
Bearing1_4_df
      abs_mean_h  abs_mean_v   mean_h   mean_v   stand_h   stand_v   max_h  \
0        0.32318     0.35930  0.00636  0.00167   0.40337   0.45502   1.373
1        0.31214     0.36394 -0.00900  0.00669   0.39068   0.45886   1.299
2        0.31035     0.38840 -0.00622 -0.00830   0.39190   0.49150   1.313
3        0.33253     0.38023 -0.00582 -0.00175   0.41586   0.47481   1.508
4        0.31086     0.40921 -0.00202  0.00663   0.38677   0.51172   1.334
...          ...         ...      ...      ...       ...       ...     ...
1423     7.86718    11.04806  0.04985 -0.32804  10.54333  14.54749  48.128
1424     7.91047    10.61781 -0.11316 -0.03484  10.55686  14.07207  48.128
1425     8.29157    10.74766 -0.16524  0.06929  11.10476  14.19700  48.128
1426     8.14881    11.08156 -0.14566  0.26825  10.89777  14.59728  48.128
1427     7.18050     8.18296  0.17245  0.76412   9.33412  10.48393  48.128

       min_h   max_v   min_v  time_deviation
0     -1.511   1.658  -2.045           99920
1     -1.446   1.537  -1.685           99920
2     -1.505   2.161  -1.872           99920
3     -1.476   1.637  -2.033           99920
4     -1.225   1.967  -1.690           99920
...      ...     ...     ...             ...
1423 -41.133  47.849 -47.843           99920
1424 -39.357  47.849 -47.843           99920
1425 -46.942  47.849 -47.843           99920
1426 -48.148  47.849 -47.843           99920
1427 -41.573  47.849 -41.680           99920

[1428 rows x 11 columns]
Bearing1_5_df
      abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v   max_h  \
0        0.31656     0.28592  0.00337  0.00247  0.40077  0.35730   1.298
1        0.29740     0.28811  0.00306 -0.00153  0.37572  0.35934   1.304
2        0.31841     0.30212  0.00345 -0.00091  0.40191  0.37774   1.269
3        0.32935     0.29942 -0.00147  0.00045  0.41238  0.37716   1.597
4        0.31798     0.31392 -0.00231  0.00296  0.40293  0.39106   1.446
...          ...         ...      ...      ...      ...      ...     ...
2458     0.78944     1.30445  0.03493  0.00482  1.29052  1.73803  12.811
2459     0.84398     1.45504  0.01168 -0.00972  1.36539  1.92841  14.053
2460     0.81835     1.38848 -0.00267  0.01294  1.33530  1.84301  12.554
2461     0.85351     1.46709  0.00895  0.01178  1.33762  1.93461  11.680
2462     0.87393     1.42787 -0.00619 -0.00733  1.39689  1.87227  12.408
```

```
       min_h   max_v   min_v  time_deviation
0     -1.453   1.199  -1.267           99920
1     -1.497   1.200  -1.761           99920
2     -1.526   1.134  -1.548           99920
3     -1.476   1.362  -1.428           99920
4     -1.519   1.503  -1.280           99920
...      ...     ...     ...             ...
2458 -11.738  10.180  -9.822           99920
2459 -10.802  12.965 -11.127           99920
2460  -9.542  12.036  -9.387           99920
2461  -9.651   9.312  -9.242           99920
2462 -10.270   8.475 -10.039           99920

[2463 rows x 11 columns]
Bearing1_6_df
      abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v  max_h  \
0        0.37257     0.38361 -0.06606 -0.01485  0.47298  0.47783  2.624
1        0.31632     0.36760  0.01297 -0.00680  0.40038  0.46393  1.427
2        0.35554     0.38350  0.01390  0.00123  0.46514  0.47830  2.608
3        0.34022     0.39356  0.00497  0.02892  0.43168  0.49310  2.019
4        0.33125     0.37575 -0.00039  0.00013  0.42314  0.47254  1.429
...          ...         ...      ...      ...      ...      ...    ...
2443     0.87490     1.38792  0.00620  0.02769  1.21665  1.79190  9.150
2444     0.89719     1.44833 -0.00266  0.03269  1.24330  1.86343  8.220
2445     0.87763     1.47405  0.00005  0.02033  1.22909  1.88969  6.779
2446     0.90034     1.49086 -0.01635 -0.02096  1.25398  1.93002  8.926
2447     0.92454     1.51083  0.00252 -0.00651  1.29322  1.95317  9.142

      min_h  max_v  min_v  time_deviation
0    -1.999  1.496 -1.670           99920
1    -1.446  1.538 -1.798           99920
2    -2.430  2.065 -1.585           99920
3    -1.677  1.900 -1.587           99920
4    -1.835  1.724 -1.651           99920
...     ...    ...    ...             ...
2443 -9.473  7.928 -8.752           99920
2444 -7.802  9.422 -7.495           99920
2445 -7.761  9.861 -9.143           99920
2446 -6.655  6.896 -7.758           99920
2447 -6.718  7.531 -9.531           99920

[2448 rows x 11 columns]
Bearing1_7_df
      abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v   max_h  \
0        0.34329     0.31273  0.00293  0.00237  0.43816  0.39171   1.810
1        0.33470     0.32509  0.00376  0.00263  0.42173  0.40342   1.360
2        0.35733     0.33705  0.00337  0.00143  0.45234  0.41746   1.720
3        0.34796     0.33305  0.00390  0.00331  0.44031  0.41773   1.565
4        0.35848     0.34185 -0.00090  0.00256  0.45139  0.42716   1.707
...          ...         ...      ...      ...      ...      ...     ...
2254     1.34397     1.45088 -0.00368 -0.04778  1.92288  1.89814  11.379
2255     1.40360     1.47648 -0.01567 -0.05049  2.01051  1.99316  12.165
2256     1.52379     1.62926  0.00516  0.02603  2.24517  2.17954  16.516
2257     1.56360     1.67294  0.01408  0.00494  2.39805  2.29778  19.515
2258     1.59041     1.71820  0.02106  0.00458  2.36344  2.39131  21.336

       min_h   max_v   min_v  time_deviation
0     -1.749   1.497  -1.290          999961
1     -1.660   1.371  -1.403          999961
2     -1.467   1.394  -1.474          999961
3     -1.637   1.544  -1.352          999961
4     -1.587   1.740  -1.457          999961
...      ...     ...     ...             ...
2254 -12.913   8.733  -8.005          999961
2255 -13.152  12.401  -9.853          999961
2256 -15.311  10.585 -13.120          999961
2257 -16.872  17.698 -10.561          999961
2258 -16.490  21.531 -12.010          999961
```

```
[2259 rows x 11 columns]
Bearing2_4_df
     abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v  max_h  min_h  \
0       0.27088     0.19117  0.00659  0.00232  0.34133  0.23891  1.130 -1.142   
1       0.25441     0.19617  0.00147  0.00225  0.31824  0.24588  1.080 -1.098   
2       0.25801     0.20131  0.00314  0.00414  0.32686  0.25265  1.247 -1.086   
3       0.28052     0.20080  0.00313 -0.00293  0.34730  0.25432  1.147 -1.032   
4       0.27698     0.20619  0.00426  0.00260  0.35136  0.26060  1.288 -1.572   
..          ...         ...      ...      ...      ...      ...    ...    ...   
746     0.82048     0.74865  0.00660 -0.00958  1.08543  1.00420  4.100 -4.979   
747     0.89540     0.81136 -0.01702  0.01387  1.17412  1.06485  4.297 -4.621   
748     0.89061     0.89055  0.02332 -0.01391  1.19781  1.17173  4.999 -5.890   
749     1.12198     1.12363 -0.00320  0.00656  1.50681  1.53442  4.890 -7.899   
750     1.17333     1.18761  0.02301  0.00977  1.56361  1.59059  6.072 -8.510   

     max_v  min_v  time_deviation  
0    0.775 -0.781           99920  
1    0.832 -0.784           99920  
2    0.949 -0.824           99920  
3    0.887 -1.054           99920  
4    1.029 -1.415           99920  
..     ...    ...             ...  
746  6.962 -3.994           99920  
747  5.219 -4.402           99920  
748  6.456 -5.084           99920  
749  8.818 -6.483           99920  
750  8.523 -6.190           99920  

[751 rows x 11 columns]
Bearing2_5_df
      abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v  max_h  \
0        0.40556     0.17984  0.03310  0.00685  0.52770  0.22588  2.585   
1        0.51514     0.18593 -0.07174  0.00546  0.67926  0.23376  3.150   
2        0.47952     0.18504  0.02326  0.00641  0.61162  0.23121  3.631   
3        1.31519     0.18643  0.15630 -0.00824  1.49801  0.23518  4.940   
4        0.75188     0.19091 -0.01070  0.00356  0.87201  0.24063  2.273   
...          ...         ...      ...      ...      ...      ...    ...   
2306     0.25763     0.38221 -0.00420  0.01240  0.49188  1.09998  6.151   
2307     0.27392     0.41429 -0.02538 -0.01595  0.53793  1.18650  4.569   
2308     0.27781     0.39508  0.01833  0.01070  0.48899  1.03347  3.422   
2309     0.32881     0.48996  0.00408  0.00602  0.68726  1.48907  8.163   
2310     0.33551     0.51870 -0.00161 -0.00247  0.73462  1.66807  9.135   

       min_h   max_v   min_v  time_deviation  
0     -1.516   0.846  -0.743           99920  
1     -1.861   0.763  -0.816           99920  
2     -1.628   0.799  -0.805           99920  
3     -3.208   0.869  -0.907           99920  
4     -2.068   1.008  -0.714           99920  
...      ...     ...     ...             ...  
2306  -7.401  16.095 -26.881           99920  
2307  -9.218  14.997 -22.875           99920  
2308  -5.759  11.250 -18.679           99920  
2309  -8.879  21.732 -18.025           99920  
2310 -10.854  22.562 -19.973           99920  

[2311 rows x 11 columns]
Bearing2_6_df
     abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v  max_h  min_h  \
0       0.27303     0.26293 -0.00311 -0.00041  0.34436  0.33272  1.009 -1.248   
1       0.26749     0.27778  0.12070  0.06403  0.31395  0.34069  1.100 -0.935   
2       0.24945     0.27290  0.00198 -0.01052  0.31355  0.34022  1.153 -1.289   
3       0.24972     0.27219  0.00347  0.00293  0.31452  0.34328  1.106 -1.105   
4       0.24085     0.27095 -0.00548  0.00415  0.30021  0.33738  1.147 -0.912   
..          ...         ...      ...      ...      ...      ...    ...    ...   
696     0.85694     1.41641  0.04461 -0.00007  1.17250  1.88860  5.647 -5.538   
697     1.03927     1.75602 -0.00456  0.00442  1.38989  2.28945  5.436 -6.358   
698     1.03024     1.78191 -0.03349  0.00768  1.37195  2.31026  5.141 -6.090   
699     1.06220     1.74686  0.00827  0.00126  1.42372  2.30703  5.560 -6.053   
```

```
700     1.12649     1.74578  0.01531 -0.00417  1.49550  2.23694  6.465 -6.656

      max_v   min_v  time_deviation
0     1.198  -1.184           99920
1     1.107  -1.147           99920
2     1.725  -1.231           99920
3     1.224  -1.240           99920
4     1.092  -1.196           99920
..      ...     ...             ...
696   7.808  -8.333           99920
697  10.126 -10.669           99920
698  11.456  -8.147           99920
699  11.116  -9.630           99920
700   9.848 -10.082           99920

[701 rows x 11 columns]
Bearing2_7_df
     abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v   max_h  \
0       0.33031     0.28376  0.00186  0.00517  0.41297  0.35981   1.374
1       0.31915     0.28325 -0.00699  0.00482  0.40751  0.35601   1.430
2       0.32236     0.29040 -0.00427  0.00158  0.40778  0.37068   1.449
3       0.31078     0.30227 -0.01309 -0.00556  0.39480  0.38382   1.561
4       0.32549     0.29751 -0.01214 -0.00158  0.41139  0.37797   1.316
..          ...         ...      ...      ...      ...      ...     ...
225     4.78263     1.61105 -0.00918  0.00801  6.28481  2.58437  19.870
226     4.63704     1.26401 -0.04638 -0.00077  6.11701  2.07538  20.306
227     4.36090     1.23944  0.05411 -0.00833  5.76569  2.02487  18.135
228     3.90999     1.16633  0.05733  0.00468  4.90667  1.98418  16.283
229     4.15159     1.28780  0.02473 -0.00505  5.40245  2.00472  16.804

      min_h   max_v   min_v  time_deviation
0    -1.354   1.563  -1.316           99920
1    -1.852   1.244  -1.166           99920
2    -1.528   1.265  -1.426           99920
3    -2.283   1.293  -1.512           99920
4    -2.130   1.381  -1.344           99920
..      ...     ...     ...             ...
225 -18.254  38.889 -22.193           99920
226 -18.371  15.370 -14.625           99920
227 -17.548  16.997 -16.404           99920
228 -16.769  18.024 -23.281           99920
229 -16.751  17.547 -15.438           99920

[230 rows x 11 columns]
Bearing3_3_df
     abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v  max_h  min_h  \
0       0.22836     0.23635  0.00221 -0.00628  0.28805  0.29704  1.277 -1.131
1       0.24678     0.24859 -0.01742  0.00210  0.31110  0.31197  0.953 -1.261
2       0.23765     0.23651 -0.02088 -0.00637  0.29370  0.29739  0.986 -1.055
3       0.24305     0.23576  0.05725  0.00103  0.29863  0.29555  1.047 -0.879
4       0.25260     0.25107 -0.00430  0.00638  0.31708  0.31662  1.113 -1.039
..          ...         ...      ...      ...      ...      ...    ...    ...
429     0.90140     1.32143 -0.03920  0.00316  1.21123  1.79916  4.004 -6.815
430     0.88235     1.33355 -0.02996 -0.00206  1.17919  1.81695  3.762 -6.387
431     0.90315     1.40123 -0.05648  0.05088  1.20484  1.88076  4.365 -6.003
432     0.95303     1.50619  0.01310  0.02866  1.25497  2.05971  4.022 -6.062
433     0.99460     1.65159  0.04925  0.00473  1.29547  2.22718  4.578 -5.862

      max_v  min_v  time_deviation
0     1.160 -0.900           99920
1     1.571 -1.284           99920
2     1.131 -1.134           99920
3     1.120 -1.154           99920
4     1.098 -1.253           99920
..      ...    ...             ...
429  12.851 -6.985           99920
430  12.570 -8.043           99920
431  11.900 -7.761           99920
432  14.616 -8.082           99920
```

```
433  15.982 -9.992          99920

[434 rows x 11 columns]
```

Step10
(Aufgabe3) Combine all the Bearing df into one df: stack_bearing_df

In [15]:
```
stack_bearing_df = pd.concat([Bearing1_4_df, Bearing1_5_df, Bearing1_6_df,
                              Bearing1_7_df, Bearing2_4_df, Bearing2_5_df,
                              Bearing2_6_df, Bearing2_7_df, Bearing3_3_df], ignore_i

stack_bearing_df.reset_index(drop=True, inplace=True)
print(stack_bearing_df)
print(stack_bearing_df.shape)
```

```
       abs_mean_h  abs_mean_v   mean_h   mean_v  stand_h  stand_v  max_h  \
0         0.32318     0.35930  0.00636  0.00167  0.40337  0.45502  1.373
1         0.31214     0.36394 -0.00900  0.00669  0.39068  0.45886  1.299
2         0.31035     0.38840 -0.00622 -0.00830  0.39190  0.49150  1.313
3         0.33253     0.38023 -0.00582 -0.00175  0.41586  0.47481  1.508
4         0.31086     0.40921 -0.00202  0.00663  0.38677  0.51172  1.334
...           ...         ...      ...      ...      ...      ...    ...
13020     0.90140     1.32143 -0.03920  0.00316  1.21123  1.79916  4.004
13021     0.88235     1.33355 -0.02996 -0.00206  1.17919  1.81695  3.762
13022     0.90315     1.40123 -0.05648  0.05088  1.20484  1.88076  4.365
13023     0.95303     1.50619  0.01310  0.02866  1.25497  2.05971  4.022
13024     0.99460     1.65159  0.04925  0.00473  1.29547  2.22718  4.578

       min_h   max_v  min_v  time_deviation
0     -1.511   1.658 -2.045           99920
1     -1.446   1.537 -1.685           99920
2     -1.505   2.161 -1.872           99920
3     -1.476   1.637 -2.033           99920
4     -1.225   1.967 -1.690           99920
...      ...     ...    ...             ...
13020 -6.815  12.851 -6.985           99920
13021 -6.387  12.570 -8.043           99920
13022 -6.003  11.900 -7.761           99920
13023 -6.062  14.616 -8.082           99920
13024 -5.862  15.982 -9.992           99920

[13025 rows x 11 columns]
(13025, 11)
```

Step11
(Aufgabe 3) Merge 'stack_bearing_df' with 'state_df_new' horizontally into 'training_df'

In [16]:
```
training_df = pd.concat([state_df_new, stack_bearing_df], axis=1)
print(training_df)
print(training_df.shape)
print(training_df.columns.values)
training_df['state'].value_counts()
```

```
               file  state  abs_mean_h  abs_mean_v   mean_h   mean_v  \
0      acc_00001.csv     0     0.32318     0.35930  0.00636  0.00167
1      acc_00002.csv     0     0.31214     0.36394 -0.00900  0.00669
2      acc_00003.csv     0     0.31035     0.38840 -0.00622 -0.00830
3      acc_00004.csv     0     0.33253     0.38023 -0.00582 -0.00175
4      acc_00005.csv     0     0.31086     0.40921 -0.00202  0.00663
...             ...   ...         ...         ...      ...      ...
13020  acc_00430.csv     1     0.90140     1.32143 -0.03920  0.00316
13021  acc_00431.csv     1     0.88235     1.33355 -0.02996 -0.00206
```

```
13022  acc_00432.csv      1     0.90315     1.40123 -0.05648  0.05088
13023  acc_00433.csv      1     0.95303     1.50619  0.01310  0.02866
13024  acc_00434.csv      1     0.99460     1.65159  0.04925  0.00473

       stand_h  stand_v  max_h  min_h   max_v  min_v  time_deviation
0      0.40337  0.45502  1.373 -1.511   1.658 -2.045           99920
1      0.39068  0.45886  1.299 -1.446   1.537 -1.685           99920
2      0.39190  0.49150  1.313 -1.505   2.161 -1.872           99920
3      0.41586  0.47481  1.508 -1.476   1.637 -2.033           99920
4      0.38677  0.51172  1.334 -1.225   1.967 -1.690           99920
...        ...      ...    ...    ...     ...    ...             ...
13020  1.21123  1.79916  4.004 -6.815  12.851 -6.985           99920
13021  1.17919  1.81695  3.762 -6.387  12.570 -8.043           99920
13022  1.20484  1.88076  4.365 -6.003  11.900 -7.761           99920
13023  1.25497  2.05971  4.022 -6.062  14.616 -8.082           99920
13024  1.29547  2.22718  4.578 -5.862  15.982 -9.992           99920

[13025 rows x 13 columns]
(13025, 13)
['file' 'state' 'abs_mean_h' 'abs_mean_v' 'mean_h' 'mean_v' 'stand_h'
 'stand_v' 'max_h' 'min_h' 'max_v' 'min_v' 'time_deviation']
```

Out[16]:
```
0    11075
1     1950
Name: state, dtype: int64
```

Step12
(Aufgabe 3) Normalize dataframe

In [17]:
```
from sklearn import preprocessing
# all columns head
#'abs_mean_h', 'abs_mean_v', 'mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min


#drop column with string content 'file' & 'time_deviation'
df_features = training_df.drop(columns=['file','time_deviation'], axis=1)
df_label = training_df['state']


x = df_features.values #returns a numpy array
min_max_scaler = preprocessing.MinMaxScaler()
x_scaled = min_max_scaler.fit_transform(x)
df_features_n = pd.DataFrame(x_scaled)
df_features_n.columns = ['state', 'abs_mean_h', 'abs_mean_v', 'mean_h', 'mean_v', 's

#normalized df
df_features_n
```

Out[17]:

	state	abs_mean_h	abs_mean_v	mean_h	mean_v	stand_h	stand_v	max_h	min_h
0	0.0	0.020570	0.016372	0.651261	0.395370	0.019164	0.015944	0.017174	0.980737
1	0.0	0.019213	0.016796	0.634832	0.399351	0.018001	0.016211	0.015618	0.982104
2	0.0	0.018993	0.019027	0.637806	0.387464	0.018113	0.018483	0.015913	0.980863
3	0.0	0.021719	0.018282	0.638233	0.392658	0.020309	0.017321	0.020012	0.981473
4	0.0	0.019055	0.020926	0.642298	0.399304	0.017643	0.019890	0.016354	0.986752
...	...	...	...	...	...	...	...	...	...
13020	1.0	0.091641	0.104148	0.602531	0.396552	0.093209	0.109473	0.072480	0.869199
13021	1.0	0.089300	0.105254	0.612414	0.392412	0.090272	0.110711	0.067393	0.878199
13022	1.0	0.091856	0.111428	0.584048	0.434394	0.092623	0.115151	0.080068	0.886274

	state	abs_mean_h	abs_mean_v	mean_h	mean_v	stand_h	stand_v	max_h	min_h
13023	1.0	0.097987	0.121004	0.658470	0.416774	0.097218	0.127603	0.072858	0.885034
13024	1.0	0.103097	0.134269	0.697136	0.397797	0.100930	0.139256	0.084546	0.889239

13025 rows × 11 columns

In [ ]:

Step13
(Aufgabe 3) Prepare multiple datasets with different features

In [18]:

```
# all columns head
#'abs_mean_h', 'abs_mean_v', 'mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min


######
#based on the Correlation Matrix --> features['abs_mean_v', 'stand_v', 'max_h', 'min
df_features_0  = training_df.drop(columns=['file', 'state', 'abs_mean_h', 'abs_mean_
df_features_1  = training_df.drop(columns=['file', 'state', 'mean_h', 'mean_v', 'max
df_features_2  = training_df.drop(columns=['file', 'state', 'abs_mean_h', 'abs_mean_
df_label       = training_df['state']
######


print('df_features_0= ', df_features_0.columns)
print('df_features_1= ', df_features_1.columns)
print('df_features_2= ', df_features_2.columns)
print('df_features_shape = ', df_features_1.shape)
print('df_label_shape    = ', df_label.shape)
```

```
df_features_0=  Index(['mean_h', 'mean_v', 'stand_h', 'stand_v'], dtype='object')
df_features_1=  Index(['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'], dtype='obj
ect')
df_features_2=  Index(['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h',
'max_v',
       'min_v'],
      dtype='object')
df_features_shape =  (13025, 4)
df_label_shape    =  (13025,)
```

Definition:

- Precision: Positive Predictive Value --> of all Bearings classified as having worn heavily, how many of them actually had worn heavily (Interpretation)
    - Precision = (TP) / (TP+FP)
- Recall --> what percentage of actual bad health state predictions were correctly classified by classifier
    - Recall = (TP) / (FN+TP)

	Predicted 0	Predicted 1
Actual 0	TN	FP
Actual 1	FN	TP

Step14
(Aufgabe 5)Training with various Algorithms:

- 1_SVM_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 1_SVM_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])
- 1_SVM_2 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v'])

- 2_RandomForest_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 2_RandomForest_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])

- 3_GradientBoosting_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 3_GradientBoosting_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])

- 4_K-NearestNeighbors_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 4_K-NearestNeighbors_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])

- 5_CNN_0 (with features: [mean_h, mean_v, stand_h, stand_v]) (2 hidden layers, epochs=50)
- 5_CNN_1 (with features: [mean_h, mean_v, stand_h, stand_v]) (4 hidden layers, epochs=50)

- 5_CNN_2 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v]) (2 hidden layers, epochs=50)
- 5_CNN_3 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v]) (4 hidden layers, epochs=100)
- 5_CNN_4 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v]) (8 hidden layers, epochs=100)

- 5_CNN_5 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v']) (2 hidden layers, epochs=50)
- 5_CNN_6 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v']) (8 hidden layers, epochs=100)

- 5_CNN_7 (with features: ['abs_mean_v', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v']) (8 hidden layers, epochs=100)

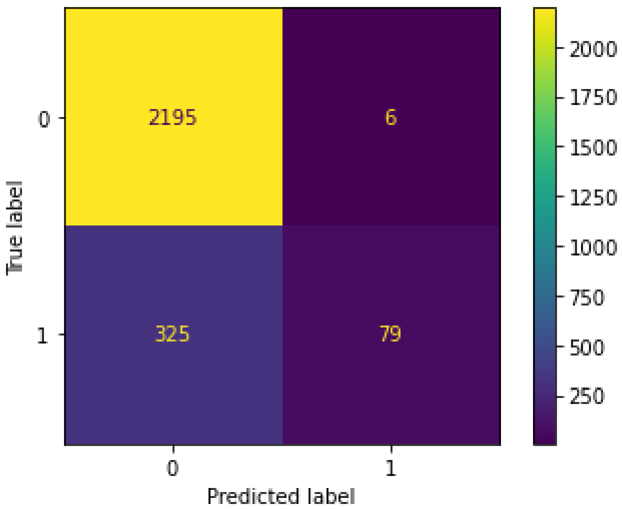
In [19]:
```
#create list for storing the result of each classifier
training_title_list                = []
train_accuracy_f1_result_list      = []
test_accuracy_f1_result_list       = []
train_test_difference_result_list = []
precision_result_list              = []
recall_result_list                 = []
```

1_SVM_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])

In [20]:
```
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix
from sklearn.metrics import plot_confusion_matrix
from sklearn.svm import SVC
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report



#1# split into 80:20
X=df_features_0
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat


clf = SVC(C=10)
clf.fit(X_train, y_train)


#train result
train_accuracy=clf.score(X_train, y_train).round(3)*100
#test result
acc_SVM    = clf.score(X_test, y_test).round(3)*100
prec_SVM   = precision_score(y_test, clf.predict(X_test)).round(3)*100
recall_SVM = recall_score(y_test, clf.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_SVM-train_accuracy).round(3)

print('Train_Accuracy_SVM_0  = ', train_accuracy)
print('Test_Accuracy_SVM_0   = ', acc_SVM)
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_SVM = ', prec_SVM)
print('Recall_SVM    = ', recall_SVM)
print()



#confusion matrix(y_true, y_pred)
tn, fp, fn, tp = confusion_matrix(y_test, clf.predict(X_test)).ravel()
print(('TN:{}'.format(tn), 'FP:{}'.format(fp), 'FN:{}'.format(fn), 'TP:{}'.format(tp

plot_confusion_matrix(clf, X_test, y_test)
plt.show()
```

```
#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('1_SVM_0')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_SVM)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_SVM)
recall_result_list.append(recall_SVM)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf.predict(X_test), target_names=target_names))



#f1_score
f1_score=f1_score(y_test, clf.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_SVM_0  =  87.8
Test_Accuracy_SVM_0   =  87.3
Train-Test Difference =  0.5

Precision_SVM =  92.9
Recall_SVM    =  19.6

('TN:2195', 'FP:6', 'FN:325', 'TP:79')
```




```
              precision    recall  f1-score   support

 state: good       0.87      1.00      0.93      2201
 state:  bad       0.93      0.20      0.32       404

    accuracy                           0.87      2605
   macro avg       0.90      0.60      0.63      2605
weighted avg       0.88      0.87      0.84      2605

f1_score= 0.872936660268714
```

In [21]:

```
print(training_title_list)
print(train_accuracy_f1_result_list)
print(test_accuracy_f1_result_list)
print(train_test_difference_result_list)
print(precision_result_list)
print(recall_result_list)
```

```
['1_SVM_0']
[87.8]
[87.3]
```

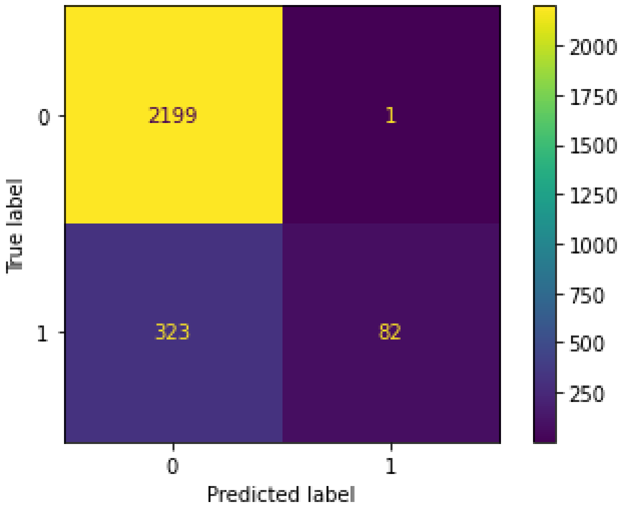
```
[0.5]
[92.9]
[19.6]
```

1_SVM_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])

In [22]:
```
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix
from sklearn.metrics import plot_confusion_matrix
from sklearn.svm import SVC
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

#1# split into 80:20
X=df_features_1
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat


clf_1 = SVC(C = 10)
clf_1.fit(X_train, y_train)


#train result
train_accuracy=clf_1.score(X_train, y_train).round(3)*100
#test result
acc_SVM_1    = clf_1.score(X_test, y_test).round(3)*100
prec_SVM_1   = precision_score(y_test, clf_1.predict(X_test)).round(3)*100
recall_SVM_1 = recall_score(y_test, clf_1.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_SVM_1-train_accuracy).round(3)

print('Train_Accuracy_SVM_1 =', train_accuracy.round(3))
print('Test_Accuracy_SVM_1  = ', acc_SVM_1.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_SVM = ', prec_SVM_1.round(3))
print('Recall_SVM    = ', recall_SVM_1.round(3))
print()


#confusion matrix(y_true, y_pred)
tn_1, fp_1, fn_1, tp_1 = confusion_matrix(y_test, clf_1.predict(X_test)).ravel()
print(('TN:{}'.format(tn_1), 'FP:{}'.format(fp_1), 'FN:{}'.format(fn_1), 'TP:{}'.for

plot_confusion_matrix(clf_1, X_test, y_test)
plt.show()



#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('1_SVM_1')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_SVM_1)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_SVM_1)
recall_result_list.append(recall_SVM_1)



#Classification report
print()
```

```
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf_1.predict(X_test), target_names=target_names



#f1_score
f1_score=f1_score(y_test, clf_1.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_SVM_1 = 87.8
Test_Accuracy_SVM_1  =  87.6
Train-Test Difference =  0.2

Precision_SVM =  98.8
Recall_SVM    =  20.2

('TN:2199', 'FP:1', 'FN:323', 'TP:82')
```



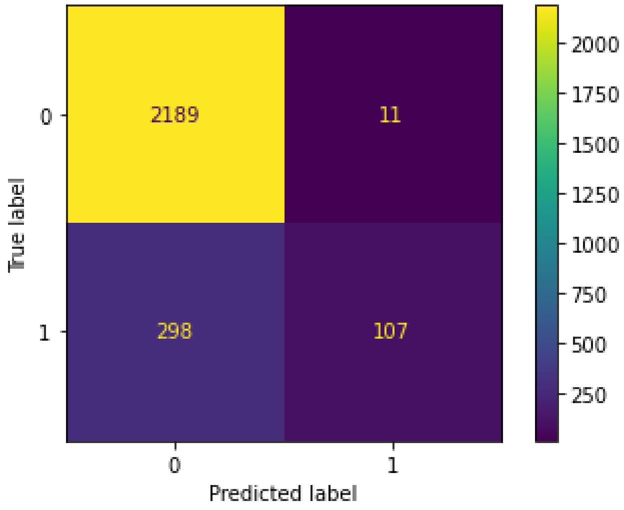

```
              precision    recall  f1-score   support

 state: good       0.87      1.00      0.93      2200
 state:  bad       0.99      0.20      0.34       405

    accuracy                           0.88      2605
   macro avg       0.93      0.60      0.63      2605
weighted avg       0.89      0.88      0.84      2605

f1_score= 0.8756238003838771
```

1_SVM_2 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v'])

In [23]:
```
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix
from sklearn.metrics import plot_confusion_matrix
from sklearn.svm import SVC
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report


#1# split into 80:20
X=df_features_2
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat


clf_2 = SVC(C = 10000)
```

```
clf_2.fit(X_train, y_train)


#train result
train_accuracy=clf_2.score(X_train, y_train).round(3)*100
#test result
acc_SVM_2    = clf_2.score(X_test, y_test).round(3)*100
prec_SVM_2   = precision_score(y_test, clf_2.predict(X_test)).round(3)*100
recall_SVM_2 = recall_score(y_test, clf_2.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_SVM_2-train_accuracy).round(3)

print('Train_Accuracy_SVM =', train_accuracy.round(3))
print('Test_Accuracy_SVM  = ', acc_SVM_2.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_SVM = ', prec_SVM_2.round(3))
print('Recall_SVM    = ', recall_SVM_2.round(3))
print()


#confusion matrix(y_true, y_pred)
tn_2, fp_2, fn_2, tp_2 = confusion_matrix(y_test, clf_2.predict(X_test)).ravel()
print(('TN:{}'.format(tn_2), 'FP:{}'.format(fp_2), 'FN:{}'.format(fn_2), 'TP:{}'.for

plot_confusion_matrix(clf_2, X_test, y_test)
plt.show()



#train result
train_accuracy=clf.fit(X_train, y_train)
#test result
accuracy = (tp+tn)/(tp+tn+fp+fn)
precision = tp/(tp+fp)
recall = tp/(tp+fn)


#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('1_SVM_2')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_SVM_2)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_SVM_2)
recall_result_list.append(recall_SVM_2)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf_2.predict(X_test), target_names=target_names


#f1_score
f1_score=f1_score(y_test, clf_2.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_SVM = 88.7
Test_Accuracy_SVM  =  88.1
Train-Test Difference =  0.6

Precision_SVM =  90.7
Recall_SVM    =  26.4

('TN:2189', 'FP:11', 'FN:298', 'TP:107')
```




```
              precision    recall  f1-score   support

 state: good       0.88      0.99      0.93      2200
 state:  bad       0.91      0.26      0.41       405

    accuracy                           0.88      2605
   macro avg       0.89      0.63      0.67      2605
weighted avg       0.88      0.88      0.85      2605

f1_score= 0.8813819577735125
```

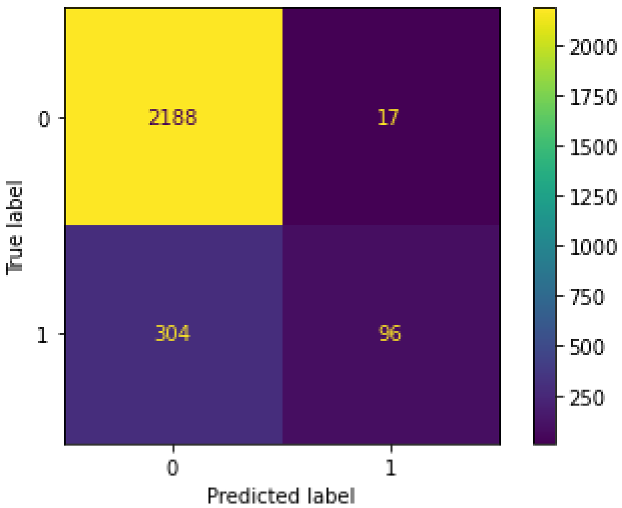
2_RandomForest_0

In [24]:

```
from sklearn.preprocessing import LabelBinarizer
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

#1# split into 80:20
X=df_features_0
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



clf = RandomForestClassifier(n_estimators=50, max_depth=5)
clf.fit(X_train, y_train)


#train result
train_accuracy=clf.score(X_train, y_train).round(3)*100
#test result
acc_RF    = clf.score(X_test, y_test).round(3)*100
prec_RF   = precision_score(y_test, clf.predict(X_test)).round(3)*100
recall_RF = recall_score(y_test, clf.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_RF-train_accuracy).round(3)


print('Train_Accuracy_RF =', train_accuracy.round(3))
print('Test_Accuracy_RF  = ', acc_RF.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_RF = ', prec_RF.round(3))
print('Recall_RF    = ', recall_RF.round(3))
print(clf.predict(X_test))
print()
```

```
#confusion matrix(y_true, y_pred)
tn, fp, fn, tp = confusion_matrix(y_test, clf.predict(X_test)).ravel()
print(('TN:{}'.format(tn), 'FP:{}'.format(fp), 'FN:{}'.format(fn), 'TP:{}'.format(tp

plot_confusion_matrix(clf, X_test, y_test)
plt.show()


#train result
train_accuracy=clf.fit(X_train, y_train)
#test result
accuracy = (tp+tn)/(tp+tn+fp+fn)
precision = tp/(tp+fp)
recall = tp/(tp+fn)


#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('2_RandomForest_0')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_RF)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_RF)
recall_result_list.append(recall_RF)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf.predict(X_test), target_names=target_names))



#f1_score
f1_score=f1_score(y_test, clf.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_RF = 88.2
Test_Accuracy_RF  =  87.7
Train-Test Difference =  0.5

Precision_RF =  85.0
Recall_RF    =  24.0
[0 1 0 ... 0 0 0]

('TN:2188', 'FP:17', 'FN:304', 'TP:96')
```



```
              precision    recall  f1-score   support

 state: good       0.88      0.99      0.93      2205
 state:  bad       0.86      0.24      0.38       400

    accuracy                           0.88      2605
   macro avg       0.87      0.62      0.66      2605
weighted avg       0.88      0.88      0.85      2605

f1_score= 0.8775431861804224
```

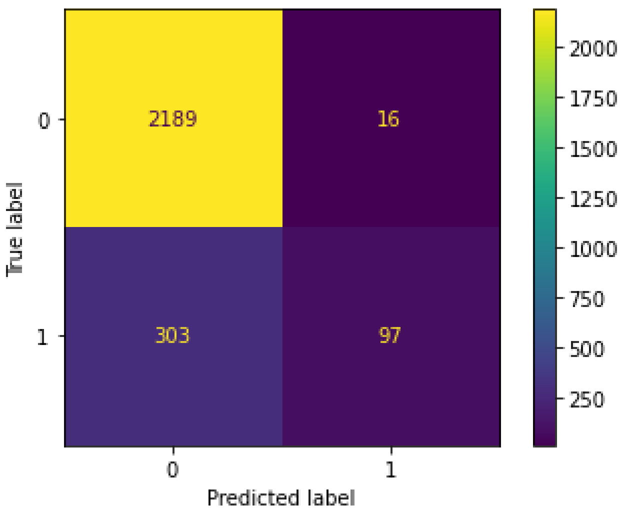
2_RandomForest_1

In [25]:

```python
from sklearn.preprocessing import LabelBinarizer
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

#1# split into 80:20
X=df_features_1
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



clf = RandomForestClassifier(n_estimators=50, max_depth=5)
clf.fit(X_train, y_train)

#train result
train_accuracy=clf.score(X_train, y_train).round(3)*100
#test result
acc_RF    = clf.score(X_test, y_test).round(3)*100
prec_RF   = precision_score(y_test, clf.predict(X_test)).round(3)*100
recall_RF = recall_score(y_test, clf.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_RF-train_accuracy).round(3)


print('Train_Accuracy_RF_1 =', train_accuracy.round(3))
print('Test_Accuracy_RF_1  = ', acc_RF.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_RF_1 = ', prec_RF.round(3))
print('Recall_RF_1    = ', recall_RF.round(3))
print(clf.predict(X_test))
print()


#confusion matrix(y_true, y_pred)
tn, fp, fn, tp = confusion_matrix(y_test, clf.predict(X_test)).ravel()
print(('TN:{}'.format(tn), 'FP:{}'.format(fp), 'FN:{}'.format(fn), 'TP:{}'.format(tp

plot_confusion_matrix(clf, X_test, y_test)
plt.show()


#train result
train_accuracy=clf.fit(X_train, y_train)
#test result
accuracy = (tp+tn)/(tp+tn+fp+fn)
precision = tp/(tp+fp)
recall = tp/(tp+fn)
```

```
#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('2_RandomForest_1')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_RF)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_RF)
recall_result_list.append(recall_RF)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf.predict(X_test), target_names=target_names))



#f1_score
f1_score=f1_score(y_test, clf.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_RF_1 = 88.5
Test_Accuracy_RF_1  =  87.8
Train-Test Difference =  0.7

Precision_RF_1 =  85.8
Recall_RF_1     =  24.2
[0 1 0 ... 0 0 0]

('TN:2189', 'FP:16', 'FN:303', 'TP:97')
```




```
              precision    recall  f1-score   support

 state: good       0.88      0.99      0.93      2205
 state:  bad       0.86      0.24      0.38       400

    accuracy                           0.88      2605
   macro avg       0.87      0.62      0.65      2605
weighted avg       0.87      0.88      0.85      2605

f1_score= 0.8771593090211133
```

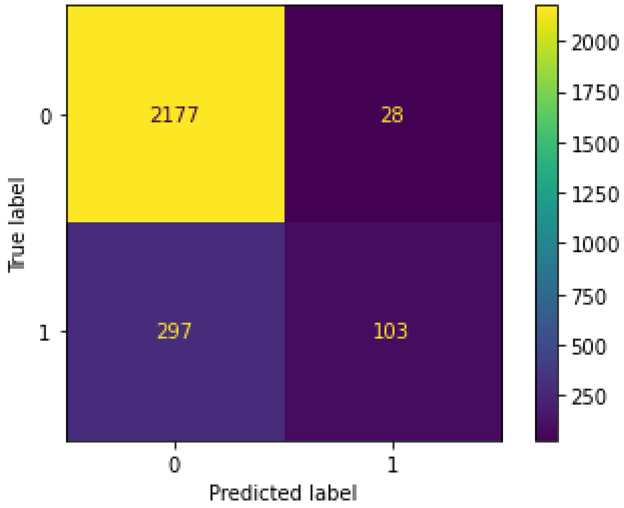
3_GradientBoosting_0

In [26]:

```
from sklearn.datasets import make_hastie_10_2
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report
```

```
#1# split into 80:20
X=df_features_0
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



clf_GB = GradientBoostingClassifier(n_estimators=1000, learning_rate=1, max_depth=1,

#train result
train_accuracy=clf_GB.score(X_train, y_train).round(3)*100
#test result
acc_GB    = clf_GB.score(X_test, y_test).round(3)*100
prec_GB   = precision_score(y_test, clf_GB.predict(X_test)).round(3)*100
recall_GB = recall_score(y_test, clf_GB.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_GB-train_accuracy).round(3)


print('Train_Accuracy_GB_0 =', train_accuracy.round(3))
print('Test_Accuracy_GB_0  = ', acc_GB.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_GB_0 = ', prec_GB.round(3))
print('Recall_GB_0    = ', recall_GB.round(3))
print()

#confusion matrix(y_true, y_pred)
tn_GB, fp_GB, fn_GB, tp_GB = confusion_matrix(y_test, clf_GB.predict(X_test)).ravel(
print(('TN:{}'.format(tn), 'FP:{}'.format(fp), 'FN:{}'.format(fn), 'TP:{}'.format(tp

plot_confusion_matrix(clf_GB, X_test, y_test)
plt.show()



#train result
train_accuracy=clf.fit(X_train, y_train)
#test result
accuracy = (tp_GB+tn_GB)/(tp_GB+tn_GB+fp_GB+fn_GB)
precision = tp_GB/(tp_GB+fp_GB)
recall = tp_GB/(tp_GB+fn_GB)



#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('3_GradientBoosting_0')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_GB)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_GB)
recall_result_list.append(recall_GB)


#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf_GB.predict(X_test), target_names=target_name


#f1_score
f1_score=f1_score(y_test, clf_GB.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_GB_0 = 88.8
Test_Accuracy_GB_0  =  87.5
Train-Test Difference =  1.3

Precision_GB_0 =  78.6
Recall_GB_0    =  25.8

('TN:2189', 'FP:16', 'FN:303', 'TP:97')
```




```
              precision    recall  f1-score   support

 state: good       0.88      0.99      0.93      2205
 state:  bad       0.79      0.26      0.39       400

    accuracy                           0.88      2605
   macro avg       0.83      0.62      0.66      2605
weighted avg       0.87      0.88      0.85      2605

f1_score= 0.8752399232245681
```

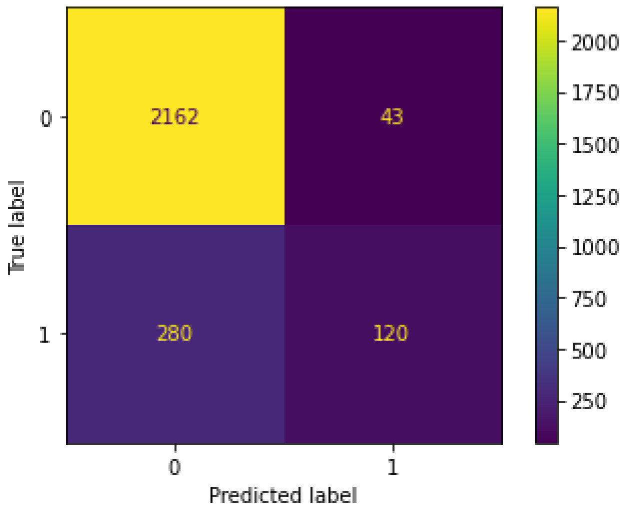
3_GradientBoosting_1

In [27]:

```
from sklearn.datasets import make_hastie_10_2
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

#1# split into 80:20
X=df_features_1
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



clf_GB = GradientBoostingClassifier(n_estimators=1000, learning_rate=1, max_depth=1,

#train result
train_accuracy=clf_GB.score(X_train, y_train).round(3)*100
#test result
acc_GB    = clf_GB.score(X_test, y_test).round(3)*100
prec_GB   = precision_score(y_test, clf_GB.predict(X_test)).round(3)*100
recall_GB = recall_score(y_test, clf_GB.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_GB-train_accuracy).round(3)


print('Train_Accuracy_GB_1 =', train_accuracy.round(3))
print('Test_Accuracy_GB_1  = ', acc_GB.round(3))
```

```
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_GB_1 = ', prec_GB.round(3))
print('Recall_GB_1    = ', recall_GB.round(3))
print()

#confusion matrix(y_true, y_pred)
tn_GB, fp_GB, fn_GB, tp_GB = confusion_matrix(y_test, clf_GB.predict(X_test)).ravel(
print(('TN:{}'.format(tn), 'FP:{}'.format(fp), 'FN:{}'.format(fn), 'TP:{}'.format(tp

plot_confusion_matrix(clf_GB, X_test, y_test)
plt.show()


#train result
train_accuracy=clf.fit(X_train, y_train)
#test result
accuracy = (tp_GB+tn_GB)/(tp_GB+tn_GB+fp_GB+fn_GB)
precision = tp_GB/(tp_GB+fp_GB)
recall = tp_GB/(tp_GB+fn_GB)



#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('3_GradientBoosting_1')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_GB)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_GB)
recall_result_list.append(recall_GB)


#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf_GB.predict(X_test), target_names=target_name


#f1_score
f1_score=f1_score(y_test, clf_GB.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_GB_1 = 89.3
Test_Accuracy_GB_1  =  87.6
Train-Test Difference =  1.7

Precision_GB_1 =  73.6
Recall_GB_1    =  30.0

('TN:2189', 'FP:16', 'FN:303', 'TP:97')
```




```
              precision    recall  f1-score   support

 state: good       0.89      0.98      0.93      2205
 state:  bad       0.74      0.30      0.43       400

    accuracy                           0.88      2605
   macro avg       0.81      0.64      0.68      2605
weighted avg       0.86      0.88      0.85      2605

f1_score= 0.8760076775431862
```

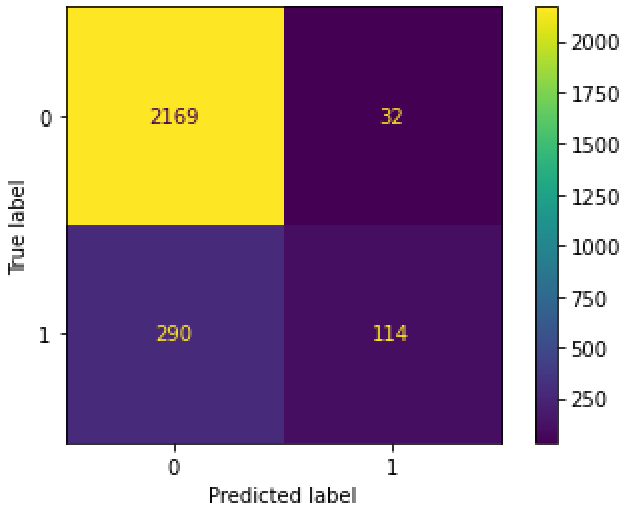
4_K-NearestNeighbors_0

In [28]:

```
from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix
from sklearn.metrics import plot_confusion_matrix
from sklearn.svm import SVC
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report


#1# split into 80:20
X=df_features_0
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat


clf_k = KNeighborsClassifier(n_neighbors=10)
clf_k.fit(X_train, y_train)

#train result
train_accuracy=clf_k.score(X_train, y_train).round(3)*100
#test result
acc_k    = clf_k.score(X_test, y_test).round(3)*100
prec_k   = precision_score(y_test, clf_k.predict(X_test)).round(3)*100
recall_k = recall_score(y_test, clf_k.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_k-train_accuracy).round(3)


print('Train_Accuracy_k_0 =', train_accuracy.round(3))
print('Test_Accuracy_k_0  = ', acc_k.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_k_0 = ', prec_k.round(3))
print('Recall_k_0    = ', recall_k.round(3))
```

```
print()


#confusion matrix(y_true, y_pred)
tn, fp, fn, tp = confusion_matrix(y_test, clf_k.predict(X_test)).ravel()
print(('TN:{}'.format(tn), 'FP:{}'.format(fp), 'FN:{}'.format(fn), 'TP:{}'.format(tp

plot_confusion_matrix(clf_k, X_test, y_test)
plt.show()




#train result
train_accuracy=clf.fit(X_train, y_train)
#test result
accuracy = (tp+tn)/(tp+tn+fp+fn)
precision = tp/(tp+fp)
recall = tp/(tp+fn)



#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('4_K-NearestNeighbors_0')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_k)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_k)
recall_result_list.append(recall_k)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf_k.predict(X_test), target_names=target_names


#f1_score
f1_score=f1_score(y_test, clf_k.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_k_0 = 89.2
Test_Accuracy_k_0  =  87.6
Train-Test Difference =  1.6

Precision_k_0 =  78.1
Recall_k_0    =  28.2

('TN:2169', 'FP:32', 'FN:290', 'TP:114')
```




```
              precision    recall  f1-score   support

 state: good       0.88      0.99      0.93      2201
 state:  bad       0.78      0.28      0.41       404

    accuracy                           0.88      2605
   macro avg       0.83      0.63      0.67      2605
weighted avg       0.87      0.88      0.85      2605

f1_score= 0.8763915547024952
```

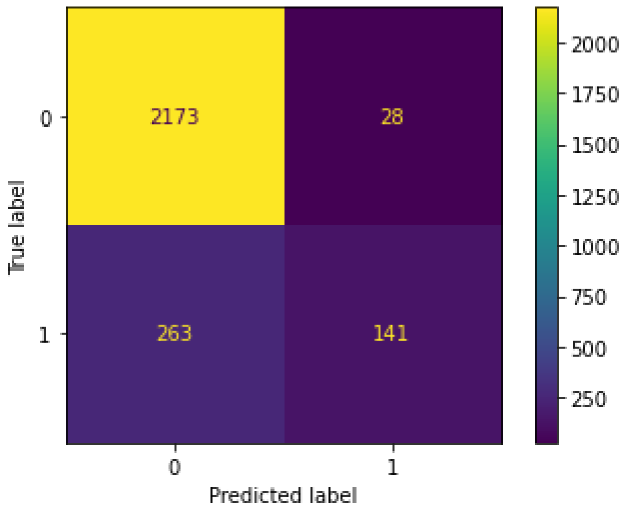
4_K-NearestNeighbors_1

In [29]:

```
from sklearn.neighbors import KNeighborsClassifier
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix
from sklearn.metrics import plot_confusion_matrix
from sklearn.svm import SVC
from sklearn.metrics import recall_score, precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report


#1# split into 80:20
X=df_features_1
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat


clf_k = KNeighborsClassifier(n_neighbors=10)
clf_k.fit(X_train, y_train)

#train result
train_accuracy=clf_k.score(X_train, y_train).round(3)*100
#test result
acc_k     = clf_k.score(X_test, y_test).round(3)*100
prec_k    = precision_score(y_test, clf_k.predict(X_test)).round(3)*100
recall_k = recall_score(y_test, clf_k.predict(X_test)).round(3)*100
Train_Test_Difference = abs(acc_k-train_accuracy).round(3)


print('Train_Accuracy_k_1 =', train_accuracy.round(3))
print('Test_Accuracy_k_1  = ', acc_k.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_k_1 = ', prec_k.round(3))
print('Recall_k_1     = ', recall_k.round(3))
```

```
print()


#confusion matrix(y_true, y_pred)
tn, fp, fn, tp = confusion_matrix(y_test, clf_k.predict(X_test)).ravel()
print(('TN:{}'.format(tn), 'FP:{}'.format(fp), 'FN:{}'.format(fn), 'TP:{}'.format(tp

plot_confusion_matrix(clf_k, X_test, y_test)
plt.show()




#train result
train_accuracy=clf.fit(X_train, y_train)
#test result
accuracy = (tp+tn)/(tp+tn+fp+fn)
precision = tp/(tp+fp)
recall = tp/(tp+fn)



#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('4_K-NearestNeighbors_1')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(acc_k)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(prec_k)
recall_result_list.append(recall_k)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, clf_k.predict(X_test), target_names=target_names


#f1_score
f1_score=f1_score(y_test, clf_k.predict(X_test), average='micro')
print('f1_score= {}'.format(f1_score))
```

```
Train_Accuracy_k_1 = 90.2
Test_Accuracy_k_1  =  88.8
Train-Test Difference =  1.4

Precision_k_1 =  83.4
Recall_k_1    =  34.9

('TN:2173', 'FP:28', 'FN:263', 'TP:141')
```




```
              precision    recall  f1-score   support

 state: good       0.89      0.99      0.94      2201
 state:  bad       0.83      0.35      0.49       404

    accuracy                           0.89      2605
   macro avg       0.86      0.67      0.71      2605
weighted avg       0.88      0.89      0.87      2605

f1_score= 0.8882917466410749
```

5_CNN_0 (with features: [mean_h, mean_v, stand_h, stand_v])

In [30]:
```python
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
from sklearn.metrics import confusion_matrix
```

In [31]:
```python
#1# split into 80:20
X=df_features_0
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



#2# build the model
clf_cnn = keras.Sequential([
    keras.layers.Flatten(input_shape=(4,)),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])
```

```
#4# training
clf_cnn.fit(X_train, y_train, epochs=50, batch_size=1)

test_loss, test_acc = clf_cnn.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

```
Train on 10420 samples
Epoch 1/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3992 - accur
acy: 0.8605
Epoch 2/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3848 - accur
acy: 0.8604
Epoch 3/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3821 - accur
acy: 0.8630
Epoch 4/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3800 - accur
acy: 0.8667
Epoch 5/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3777 - accur
acy: 0.8702
Epoch 6/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3752 - accur
acy: 0.8713
Epoch 7/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3734 - accur
acy: 0.8713
Epoch 8/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3703 - accur
acy: 0.8711
Epoch 9/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3700 - accur
acy: 0.8720
Epoch 10/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3675 - accur
acy: 0.8721
Epoch 11/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3664 - accur
acy: 0.8730
Epoch 12/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3646 - accur
acy: 0.8738
Epoch 13/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3642 - accur
acy: 0.8741
Epoch 14/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3619 - accur
acy: 0.8743
Epoch 15/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3613 - accur
acy: 0.8750
Epoch 16/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3601 - accur
acy: 0.8755
Epoch 17/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3599 - accur
acy: 0.8756
Epoch 18/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3586 - accur
acy: 0.8758
Epoch 19/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3576 - accur
acy: 0.8764
Epoch 20/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3584 - accur
acy: 0.8763
Epoch 21/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3567 - accur
```

```
acy: 0.8771
Epoch 22/50
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3557 - accur
acy: 0.8768
Epoch 23/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3556 - accur
acy: 0.8761
Epoch 24/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3545 - accur
acy: 0.8772
Epoch 25/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3548 - accur
acy: 0.8765
Epoch 26/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3533 - accur
acy: 0.8771
Epoch 27/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3531 - accur
acy: 0.8771
Epoch 28/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3522 - accur
acy: 0.8766
Epoch 29/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3539 - accur
acy: 0.8769
Epoch 30/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3520 - accur
acy: 0.8760
Epoch 31/50
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3513 - accur
acy: 0.8771
Epoch 32/50
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3512 - accur
acy: 0.8773
Epoch 33/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3511 - accur
acy: 0.8774
Epoch 34/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3515 - accur
acy: 0.8771
Epoch 35/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3508 - accur
acy: 0.8769
Epoch 36/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3514 - accur
acy: 0.8774
Epoch 37/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3512 - accur
acy: 0.8774
Epoch 38/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3503 - accur
acy: 0.8774
Epoch 39/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3510 - accur
acy: 0.8770
Epoch 40/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3500 - accur
acy: 0.8767
Epoch 41/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3495 - accur
acy: 0.8770
Epoch 42/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3490 - accur
acy: 0.8770
Epoch 43/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3499 - accur
acy: 0.8771
Epoch 44/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3489 - accur
```

```
acy: 0.8776
Epoch 45/50
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3491 - accur
acy: 0.8777
Epoch 46/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3495 - accur
acy: 0.8776
Epoch 47/50
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3481 - accur
acy: 0.8781
Epoch 48/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3471 - accur
acy: 0.8774
Epoch 49/50
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3482 - accur
acy: 0.8777
Epoch 50/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3470 - accur
acy: 0.8781
2605/2605 [==============================] - 0s 73us/sample - loss: 0.3482 - accurac
y: 0.8775
Test accuracy: 0.8775432
```

In [32]:

```
Y_pred = clf_cnn.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)


#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()


#train result
train_accuracy= clf_cnn.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)

print()
print('Train_Accuracy_cnn_0 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_0  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_0 = ', precision.round(3))
print('Recall_cnn_0    = ', recall.round(3))
print()


#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_0')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)



#Classification report
```

```
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

```
10420/10420 [==============================] - 0s 43us/sample - loss: 0.3435 - accur
acy: 0.8782

Train_Accuracy_cnn_0 =  87.8
Test_Accuracy_cnn_0  =  87.754
Train-Test Difference =  0.046

Precision_cnn_0 =  94.792
Recall_cnn_0    =  22.469


              precision    recall  f1-score   support

 state: good       0.87      1.00      0.93      2200
 state:  bad       0.95      0.22      0.36       405

    accuracy                           0.88      2605
   macro avg       0.91      0.61      0.65      2605
weighted avg       0.89      0.88      0.84      2605
```

5_CNN_1 (with features: [mean_h, mean_v, stand_h, stand_v])

In [33]:

```
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
```

In [34]:

```
#1# split into 80:20
X=df_features_0
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



#2# build the model
clf_cnn_1 = keras.Sequential([
    keras.layers.Flatten(input_shape=(4,)),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn_1.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

#4# training
clf_cnn_1.fit(X_train, y_train, epochs=50, batch_size=1)
```

```
test_loss, test_acc = clf_cnn_1.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

```
Train on 10420 samples
Epoch 1/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3964 - accur
acy: 0.8615
Epoch 2/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3819 - accur
acy: 0.8686
Epoch 3/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3773 - accur
acy: 0.8705
Epoch 4/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3723 - accur
acy: 0.8716
Epoch 5/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3687 - accur
acy: 0.8735
Epoch 6/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3643 - accur
acy: 0.8745
Epoch 7/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3617 - accur
acy: 0.8763
Epoch 8/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3592 - accur
acy: 0.8765
Epoch 9/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3557 - accur
acy: 0.8784
Epoch 10/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3540 - accur
acy: 0.8783
Epoch 11/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3522 - accur
acy: 0.8792
Epoch 12/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3502 - accur
acy: 0.8789
Epoch 13/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3483 - accur
acy: 0.8784
Epoch 14/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3485 - accur
acy: 0.8790
Epoch 15/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3490 - accur
acy: 0.8794
Epoch 16/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3460 - accur
acy: 0.8792
Epoch 17/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3470 - accur
acy: 0.8795
Epoch 18/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3457 - accur
acy: 0.8790
Epoch 19/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3442 - accur
acy: 0.8802
Epoch 20/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3439 - accur
acy: 0.8790
Epoch 21/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3458 - accur
acy: 0.8796
Epoch 22/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3443 - accur
```

```
acy: 0.8799
Epoch 23/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3451 - accur
acy: 0.8803
Epoch 24/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3456 - accur
acy: 0.8783
Epoch 25/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3429 - accur
acy: 0.8794
Epoch 26/50
10420/10420 [==============================] - 29s 3ms/sample - loss: 0.3434 - accur
acy: 0.8787
Epoch 27/50
10420/10420 [==============================] - 28s 3ms/sample - loss: 0.3426 - accur
acy: 0.8802
Epoch 28/50
10420/10420 [==============================] - 27s 3ms/sample - loss: 0.3414 - accur
acy: 0.8810
Epoch 29/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3418 - accur
acy: 0.8801
Epoch 30/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3413 - accur
acy: 0.8802
Epoch 31/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3404 - accur
acy: 0.8808
Epoch 32/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3417 - accur
acy: 0.8808
Epoch 33/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3405 - accur
acy: 0.8810
Epoch 34/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3394 - accur
acy: 0.8809
Epoch 35/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3395 - accur
acy: 0.8802
Epoch 36/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3385 - accur
acy: 0.8803
Epoch 37/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3375 - accur
acy: 0.8807
Epoch 38/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3380 - accur
acy: 0.8811
Epoch 39/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3379 - accur
acy: 0.8801
Epoch 40/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3394 - accur
acy: 0.8799
Epoch 41/50
10420/10420 [==============================] - 26s 3ms/sample - loss: 0.3371 - accur
acy: 0.8812
Epoch 42/50
10420/10420 [==============================] - 27s 3ms/sample - loss: 0.3380 - accur
acy: 0.8807
Epoch 43/50
10420/10420 [==============================] - 27s 3ms/sample - loss: 0.3383 - accur
acy: 0.8810
Epoch 44/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3365 - accur
acy: 0.8812
Epoch 45/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3366 - accur
```

```
acy: 0.8809
Epoch 46/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3361 - accur
acy: 0.8814
Epoch 47/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3345 - accur
acy: 0.8816
Epoch 48/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3373 - accur
acy: 0.8807
Epoch 49/50
10420/10420 [==============================] - 27s 3ms/sample - loss: 0.3364 - accur
acy: 0.8812
Epoch 50/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3367 - accur
acy: 0.8814
2605/2605 [==============================] - 0s 86us/sample - loss: 0.3321 - accurac
y: 0.8818
Test accuracy: 0.88176584
```

In [35]:

```
Y_pred = clf_cnn_1.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)

#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()


#train result
train_accuracy= clf_cnn_1.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)

print('Train_Accuracy_cnn_1 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_1  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_1 = ', precision.round(3))
print('Recall_cnn_1    = ', recall.round(3))
print()



#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_1')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

```
10420/10420 [==============================] - 0s 47us/sample - loss: 0.3265 - accur
acy: 0.8823
Train_Accuracy_cnn_1 =  88.2
Test_Accuracy_cnn_1  =  88.177
Train-Test Difference =  0.023

Precision_cnn_1 =  97.087
Recall_cnn_1    =  24.691


              precision    recall  f1-score   support

 state: good       0.88      1.00      0.93      2200
 state:  bad       0.97      0.25      0.39       405

    accuracy                           0.88      2605
   macro avg       0.92      0.62      0.66      2605
weighted avg       0.89      0.88      0.85      2605
```

5_CNN_2 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v])

In [36]:

```python
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
```

In [37]:

```python
#1# split into 80:20
X=df_features_1
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



#2# build the model
clf_cnn_1 = keras.Sequential([
    keras.layers.Flatten(input_shape=(4,)),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn_1.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

#4# training
clf_cnn_1.fit(X_train, y_train, epochs=50, batch_size=1)

test_loss, test_acc = clf_cnn_1.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

```
Train on 10420 samples
Epoch 1/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3998 - accur
acy: 0.8607
```

```
Epoch 2/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3870 - accur
acy: 0.8615
Epoch 3/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3816 - accur
acy: 0.8614
Epoch 4/50
10420/10420 [==============================] - 26s 2ms/sample - loss: 0.3769 - accur
acy: 0.8622
Epoch 5/50
10420/10420 [==============================] - 25s 2ms/sample - loss: 0.3723 - accur
acy: 0.8673
Epoch 6/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3695 - accur
acy: 0.8708
Epoch 7/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3653 - accur
acy: 0.8725
Epoch 8/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3623 - accur
acy: 0.8726
Epoch 9/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3595 - accur
acy: 0.8743
Epoch 10/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3588 - accur
acy: 0.8754
Epoch 11/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3574 - accur
acy: 0.8744
Epoch 12/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3556 - accur
acy: 0.8770
Epoch 13/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3547 - accur
acy: 0.8762
Epoch 14/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3529 - accur
acy: 0.8768
Epoch 15/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3532 - accur
acy: 0.8776
Epoch 16/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3514 - accur
acy: 0.8770
Epoch 17/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3507 - accur
acy: 0.8767
Epoch 18/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3514 - accur
acy: 0.8764
Epoch 19/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3487 - accur
acy: 0.8780
Epoch 20/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3482 - accur
acy: 0.8769
Epoch 21/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3462 - accur
acy: 0.8785
Epoch 22/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3462 - accur
acy: 0.8770
Epoch 23/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3455 - accur
acy: 0.8780
Epoch 24/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3432 - accur
acy: 0.8781
```

```
Epoch 25/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3419 - accur
acy: 0.8789
Epoch 26/50
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3411 - accur
acy: 0.8785
Epoch 27/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3401 - accur
acy: 0.8789
Epoch 28/50
10420/10420 [==============================] - 24s 2ms/sample - loss: 0.3402 - accur
acy: 0.8792
Epoch 29/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3371 - accur
acy: 0.8792
Epoch 30/50
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3389 - accur
acy: 0.8788
Epoch 31/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3363 - accur
acy: 0.8794
Epoch 32/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3336 - accur
acy: 0.8790
Epoch 33/50
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3353 - accur
acy: 0.8790
Epoch 34/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3330 - accur
acy: 0.8788
Epoch 35/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3308 - accur
acy: 0.8798
Epoch 36/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3297 - accur
acy: 0.8797
Epoch 37/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3293 - accur
acy: 0.8788
Epoch 38/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3295 - accur
acy: 0.8792
Epoch 39/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3288 - accur
acy: 0.8801
Epoch 40/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3272 - accur
acy: 0.8808
Epoch 41/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3251 - accur
acy: 0.8805
Epoch 42/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3272 - accur
acy: 0.8803
Epoch 43/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3284 - accur
acy: 0.8805
Epoch 44/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3252 - accur
acy: 0.8802
Epoch 45/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3244 - accur
acy: 0.8809
Epoch 46/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3244 - accur
acy: 0.8806
Epoch 47/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3231 - accur
acy: 0.8813
```

```
Epoch 48/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3210 - accur
acy: 0.8815
Epoch 49/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3234 - accur
acy: 0.8808
Epoch 50/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3210 - accur
acy: 0.8812
2605/2605 [==============================] - 0s 76us/sample - loss: 0.3362 - accurac
y: 0.8810
Test accuracy: 0.8809981
```

In [38]:

```
Y_pred = clf_cnn_1.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)

#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()


#train result
train_accuracy= clf_cnn_1.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)

print('Train_Accuracy_cnn_2 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_2  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_2 = ', precision.round(3))
print('Recall_cnn_2    = ', recall.round(3))
print()


#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_2')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

```
10420/10420 [==============================] - 0s 43us/sample - loss: 0.3363 - accur
acy: 0.8827
Train_Accuracy_cnn_2 =  88.3
Test_Accuracy_cnn_2  =  88.1
Train-Test Difference =  0.2

Precision_cnn_2 =  92.793
Recall_cnn_2    =  25.432
```

```
              precision    recall  f1-score   support

 state: good       0.88      1.00      0.93      2200
 state:  bad       0.93      0.25      0.40       405

    accuracy                           0.88      2605
   macro avg       0.90      0.63      0.67      2605
weighted avg       0.89      0.88      0.85      2605
```

5_CNN_3 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v])

In [39]:

```
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
```

In [40]:

```
#1# split into 80:20
X=df_features_1
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



#2# build the model
clf_cnn_1 = keras.Sequential([
    keras.layers.Flatten(input_shape=(4,)),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn_1.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

#4# training
clf_cnn_1.fit(X_train, y_train, epochs=100, batch_size=1)

test_loss, test_acc = clf_cnn_1.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

```
Train on 10420 samples
Epoch 1/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3960 - accur
acy: 0.8614
Epoch 2/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3822 - accur
acy: 0.8671
Epoch 3/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3791 - accur
acy: 0.8708
```

```
Epoch 4/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3743 - accur
acy: 0.8726
Epoch 5/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3686 - accur
acy: 0.8749
Epoch 6/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3648 - accur
acy: 0.8770
Epoch 7/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3607 - accur
acy: 0.8781
Epoch 8/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3576 - accur
acy: 0.8790
Epoch 9/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3533 - accur
acy: 0.8789
Epoch 10/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3527 - accur
acy: 0.8788
Epoch 11/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3508 - accur
acy: 0.8789
Epoch 12/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3476 - accur
acy: 0.8807
Epoch 13/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3459 - accur
acy: 0.8797
Epoch 14/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3448 - accur
acy: 0.8805
Epoch 15/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3434 - accur
acy: 0.8806
Epoch 16/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3401 - accur
acy: 0.8821
Epoch 17/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3395 - accur
acy: 0.8803
Epoch 18/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3419 - accur
acy: 0.8812
Epoch 19/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3378 - accur
acy: 0.8810
Epoch 20/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3366 - accur
acy: 0.8810
Epoch 21/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3356 - accur
acy: 0.8803
Epoch 22/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3335 - accur
acy: 0.8821
Epoch 23/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3335 - accur
acy: 0.8813
Epoch 24/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3326 - accur
acy: 0.8817
Epoch 25/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3293 - accur
acy: 0.8824
Epoch 26/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3323 - accur
acy: 0.8819
```

```
Epoch 27/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3309 - accur
acy: 0.8821
Epoch 28/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3280 - accur
acy: 0.8829
Epoch 29/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3301 - accur
acy: 0.8820
Epoch 30/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3269 - accur
acy: 0.8826
Epoch 31/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3282 - accur
acy: 0.8829
Epoch 32/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3304 - accur
acy: 0.8819
Epoch 33/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3261 - accur
acy: 0.8820
Epoch 34/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3280 - accur
acy: 0.8824
Epoch 35/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3268 - accur
acy: 0.8825
Epoch 36/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3275 - accur
acy: 0.8826
Epoch 37/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3256 - accur
acy: 0.8835
Epoch 38/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3217 - accur
acy: 0.8827
Epoch 39/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3262 - accur
acy: 0.8825
Epoch 40/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3235 - accur
acy: 0.8824
Epoch 41/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3246 - accur
acy: 0.8822
Epoch 42/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3243 - accur
acy: 0.8830
Epoch 43/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3243 - accur
acy: 0.8828
Epoch 44/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3231 - accur
acy: 0.8834
Epoch 45/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3212 - accur
acy: 0.8829
Epoch 46/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3227 - accur
acy: 0.8831
Epoch 47/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3224 - accur
acy: 0.8832
Epoch 48/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3219 - accur
acy: 0.8833
Epoch 49/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3207 - accur
acy: 0.8833
```

```
Epoch 50/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3212 - accur
acy: 0.8828
Epoch 51/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3222 - accur
acy: 0.8830
Epoch 52/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3187 - accur
acy: 0.8841
Epoch 53/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3212 - accur
acy: 0.8826
Epoch 54/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3202 - accur
acy: 0.8838
Epoch 55/100
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3175 - accur
acy: 0.8833
Epoch 56/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3196 - accur
acy: 0.8833
Epoch 57/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3161 - accur
acy: 0.8836
Epoch 58/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3197 - accur
acy: 0.8827
Epoch 59/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3215 - accur
acy: 0.8824
Epoch 60/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3172 - accur
acy: 0.8833
Epoch 61/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3184 - accur
acy: 0.8834
Epoch 62/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3157 - accur
acy: 0.8837
Epoch 63/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3184 - accur
acy: 0.8837
Epoch 64/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3191 - accur
acy: 0.8819
Epoch 65/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3194 - accur
acy: 0.8835
Epoch 66/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3197 - accur
acy: 0.8833
Epoch 67/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3170 - accur
acy: 0.8832
Epoch 68/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3144 - accur
acy: 0.8836
Epoch 69/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3175 - accur
acy: 0.8830
Epoch 70/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3171 - accur
acy: 0.8823
Epoch 71/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3164 - accur
acy: 0.8830
Epoch 72/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3165 - accur
acy: 0.8833
```

```
Epoch 73/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3181 - accur
acy: 0.8829
Epoch 74/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3153 - accur
acy: 0.8839
Epoch 75/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3165 - accur
acy: 0.8837
Epoch 76/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3154 - accur
acy: 0.8832
Epoch 77/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3160 - accur
acy: 0.8832
Epoch 78/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3124 - accur
acy: 0.8835
Epoch 79/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3133 - accur
acy: 0.8837
Epoch 80/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3133 - accur
acy: 0.8845
Epoch 81/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3142 - accur
acy: 0.8837
Epoch 82/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3140 - accur
acy: 0.8846
Epoch 83/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3132 - accur
acy: 0.8824
Epoch 84/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3123 - accur
acy: 0.8839
Epoch 85/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3142 - accur
acy: 0.8831
Epoch 86/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3132 - accur
acy: 0.8839
Epoch 87/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3148 - accur
acy: 0.8829
Epoch 88/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3126 - accur
acy: 0.8831
Epoch 89/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3126 - accur
acy: 0.8843
Epoch 90/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3153 - accur
acy: 0.8831
Epoch 91/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3125 - accur
acy: 0.8843
Epoch 92/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3125 - accur
acy: 0.8831
Epoch 93/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3120 - accur
acy: 0.8840
Epoch 94/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3158 - accur
acy: 0.8838
Epoch 95/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3124 - accur
acy: 0.8829
```

```
Epoch 96/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3107 - accur
acy: 0.8839
Epoch 97/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3134 - accur
acy: 0.8839
Epoch 98/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3095 - accur
acy: 0.8838
Epoch 99/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3125 - accur
acy: 0.8836
Epoch 100/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3124 - accur
acy: 0.8841
2605/2605 [==============================] - 0s 65us/sample - loss: 0.3213 - accurac
y: 0.8841
Test accuracy: 0.8840691
```

In [41]:

```
Y_pred = clf_cnn_1.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)


#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()


#train result
train_accuracy= clf_cnn_1.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)

print('Train_Accuracy_cnn_3 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_3  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_3 = ', precision.round(3))
print('Recall_cnn_3    = ', recall.round(3))
print()

#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_3')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

```
10420/10420 [==============================] - 0s 44us/sample - loss: 0.3305 - accur
acy: 0.8859
```

```
Train_Accuracy_cnn_3 =  88.6
Test_Accuracy_cnn_3  =  88.407
Train-Test Difference =  0.193

Precision_cnn_3 =  97.248
Recall_cnn_3    =  26.173


              precision    recall  f1-score   support

 state: good       0.88      1.00      0.94      2200
 state:  bad       0.97      0.26      0.41       405

    accuracy                           0.88      2605
   macro avg       0.93      0.63      0.67      2605
weighted avg       0.89      0.88      0.85      2605
```

5_CNN_4 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v])

In [42]:
```
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
```

In [43]:
```
#1# split into 80:20
X=df_features_1
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



#2# build the model
clf_cnn_1 = keras.Sequential([
    keras.layers.Flatten(input_shape=(4,)),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(16, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn_1.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

#4# training
clf_cnn_1.fit(X_train, y_train, epochs=100, batch_size=1)

test_loss, test_acc = clf_cnn_1.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

```
Train on 10420 samples
Epoch 1/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3911 - accur
acy: 0.8629
```

```
Epoch 2/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3803 - accur
acy: 0.8697
Epoch 3/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3767 - accur
acy: 0.8669
Epoch 4/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3732 - accur
acy: 0.8696
Epoch 5/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3707 - accur
acy: 0.8715
Epoch 6/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3692 - accur
acy: 0.8702
Epoch 7/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3650 - accur
acy: 0.8717
Epoch 8/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3618 - accur
acy: 0.8736
Epoch 9/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3605 - accur
acy: 0.8740
Epoch 10/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3564 - accur
acy: 0.8760
Epoch 11/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3535 - accur
acy: 0.8755
Epoch 12/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3499 - accur
acy: 0.8772
Epoch 13/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3469 - accur
acy: 0.8779
Epoch 14/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3426 - accur
acy: 0.8776
Epoch 15/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3380 - accur
acy: 0.8794
Epoch 16/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3405 - accur
acy: 0.8784
Epoch 17/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3373 - accur
acy: 0.8793
Epoch 18/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3356 - accur
acy: 0.8808
Epoch 19/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3346 - accur
acy: 0.8805
Epoch 20/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3332 - accur
acy: 0.8804
Epoch 21/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3320 - accur
acy: 0.8798
Epoch 22/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3302 - accur
acy: 0.8810
Epoch 23/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3297 - accur
acy: 0.8815
Epoch 24/100
10420/10420 [==============================] - 23s 2ms/sample - loss: 0.3307 - accur
acy: 0.8802
```

```
Epoch 25/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3303 - accur
acy: 0.8807
Epoch 26/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3290 - accur
acy: 0.8801
Epoch 27/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3300 - accur
acy: 0.8813
Epoch 28/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3318 - accur
acy: 0.8805
Epoch 29/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3304 - accur
acy: 0.8801
Epoch 30/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3292 - accur
acy: 0.8812
Epoch 31/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3262 - accur
acy: 0.8818
Epoch 32/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3257 - accur
acy: 0.8816
Epoch 33/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3246 - accur
acy: 0.8825
Epoch 34/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3260 - accur
acy: 0.8806
Epoch 35/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3251 - accur
acy: 0.8816
Epoch 36/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3241 - accur
acy: 0.8820
Epoch 37/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3247 - accur
acy: 0.8813
Epoch 38/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3238 - accur
acy: 0.8815
Epoch 39/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3223 - accur
acy: 0.8814
Epoch 40/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3247 - accur
acy: 0.8809
Epoch 41/100
10420/10420 [==============================] - 22s 2ms/sample - loss: 0.3244 - accur
acy: 0.8806
Epoch 42/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3227 - accur
acy: 0.8821
Epoch 43/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3217 - accur
acy: 0.8834
Epoch 44/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3228 - accur
acy: 0.8815
Epoch 45/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3204 - accur
acy: 0.8831
Epoch 46/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3200 - accur
acy: 0.8818
Epoch 47/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3228 - accur
acy: 0.8817
```

```
Epoch 48/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3201 - accur
acy: 0.8818
Epoch 49/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3196 - accur
acy: 0.8820
Epoch 50/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3189 - accur
acy: 0.8842
Epoch 51/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3200 - accur
acy: 0.8822
Epoch 52/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3190 - accur
acy: 0.8828
Epoch 53/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3206 - accur
acy: 0.8834
Epoch 54/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3203 - accur
acy: 0.8829
Epoch 55/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3205 - accur
acy: 0.8829
Epoch 56/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3203 - accur
acy: 0.8821
Epoch 57/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3185 - accur
acy: 0.8831
Epoch 58/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3215 - accur
acy: 0.8845
Epoch 59/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3170 - accur
acy: 0.8827
Epoch 60/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3175 - accur
acy: 0.8845
Epoch 61/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3183 - accur
acy: 0.8827
Epoch 62/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3173 - accur
acy: 0.8841
Epoch 63/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3203 - accur
acy: 0.8832
Epoch 64/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3177 - accur
acy: 0.8840
Epoch 65/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3206 - accur
acy: 0.8834
Epoch 66/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3173 - accur
acy: 0.8852
Epoch 67/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3158 - accur
acy: 0.8846
Epoch 68/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3186 - accur
acy: 0.8829
Epoch 69/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3145 - accur
acy: 0.8832
Epoch 70/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3192 - accur
acy: 0.8837
```

```
Epoch 71/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3227 - accur
acy: 0.8841
Epoch 72/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3167 - accur
acy: 0.8849
Epoch 73/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3168 - accur
acy: 0.8845
Epoch 74/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3143 - accur
acy: 0.8838
Epoch 75/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3171 - accur
acy: 0.8849
Epoch 76/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3177 - accur
acy: 0.8846
Epoch 77/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3169 - accur
acy: 0.8846
Epoch 78/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3148 - accur
acy: 0.8845
Epoch 79/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3151 - accur
acy: 0.8841
Epoch 80/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3145 - accur
acy: 0.8845
Epoch 81/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3145 - accur
acy: 0.8843
Epoch 82/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3143 - accur
acy: 0.8840
Epoch 83/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3206 - accur
acy: 0.8842
Epoch 84/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3124 - accur
acy: 0.8860
Epoch 85/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3159 - accur
acy: 0.8835
Epoch 86/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3134 - accur
acy: 0.8845
Epoch 87/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3158 - accur
acy: 0.8849
Epoch 88/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3146 - accur
acy: 0.8834
Epoch 89/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3121 - accur
acy: 0.8851
Epoch 90/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3157 - accur
acy: 0.8837
Epoch 91/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3142 - accur
acy: 0.8841
Epoch 92/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3143 - accur
acy: 0.8835
Epoch 93/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3139 - accur
acy: 0.8839
```

```
Epoch 94/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3123 - accur
acy: 0.8857
Epoch 95/100
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3135 - accur
acy: 0.8841
Epoch 96/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3133 - accur
acy: 0.8844
Epoch 97/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3115 - accur
acy: 0.8845
Epoch 98/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3126 - accur
acy: 0.8843
Epoch 99/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3114 - accur
acy: 0.8849
Epoch 100/100
10420/10420 [==============================] - 21s 2ms/sample - loss: 0.3127 - accur
acy: 0.8846
2605/2605 [==============================] - 0s 67us/sample - loss: 0.2949 - accurac
y: 0.8887
Test accuracy: 0.88867563
```

In [44]:

```
Y_pred = clf_cnn_1.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)


#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()


#train result
train_accuracy= clf_cnn_1.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)

print('Train_Accuracy_cnn_4 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_4  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_4 = ', precision.round(3))
print('Recall_cnn_4     = ', recall.round(3))
print()

#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_4')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)



#Classification report
```

```
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

```
10420/10420 [==============================] - 0s 42us/sample - loss: 0.3012 - accur
acy: 0.8877
Train_Accuracy_cnn_4 =  88.8
Test_Accuracy_cnn_4  =  88.868
Train-Test Difference =  0.068

Precision_cnn_4 =  91.971
Recall_cnn_4    =  31.111


              precision    recall  f1-score   support

 state: good       0.89      0.99      0.94      2200
 state:  bad       0.92      0.31      0.46       405

    accuracy                           0.89      2605
   macro avg       0.90      0.65      0.70      2605
weighted avg       0.89      0.89      0.86      2605
```

5_CNN_5 (with features: [mean_h, mean_v, stand_h, stand_v, max_h, min_h, max_v, min_v])

In [45]:

```
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
```

In [49]:

```
#1# split into 80:20
X=df_features_2
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



#2# build the model
clf_cnn_1 = keras.Sequential([
    keras.layers.Flatten(input_shape=(8,)),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn_1.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

#4# training
clf_cnn_1.fit(X_train, y_train, epochs=50, batch_size=1)

test_loss, test_acc = clf_cnn_1.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

```
Train on 10420 samples
Epoch 1/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3992 - accur
acy: 0.8607
Epoch 2/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3779 - accur
acy: 0.8635
Epoch 3/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3718 - accur
acy: 0.8661
Epoch 4/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3651 - accur
acy: 0.8676
Epoch 5/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3583 - accur
acy: 0.8669
Epoch 6/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3531 - accur
acy: 0.8670
Epoch 7/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3483 - accur
acy: 0.8699
Epoch 8/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3459 - accur
acy: 0.8697
Epoch 9/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3422 - accur
acy: 0.8707
Epoch 10/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3424 - accur
acy: 0.8710
Epoch 11/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3373 - accur
acy: 0.8713
Epoch 12/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3377 - accur
acy: 0.8726
Epoch 13/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3369 - accur
acy: 0.8727
Epoch 14/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3348 - accur
acy: 0.8731
Epoch 15/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3365 - accur
acy: 0.8751
Epoch 16/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3342 - accur
acy: 0.8753
Epoch 17/50
10420/10420 [==============================] - 20s 2ms/sample - loss: 0.3321 - accur
acy: 0.8775
Epoch 18/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3348 - accur
acy: 0.8764
Epoch 19/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3328 - accur
acy: 0.8755
Epoch 20/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3327 - accur
acy: 0.8771
Epoch 21/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3314 - accur
acy: 0.8767
Epoch 22/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3339 - accur
acy: 0.8750
Epoch 23/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3297 - accur
```

```
acy: 0.8773
Epoch 24/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3310 - accur
acy: 0.8778
Epoch 25/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3315 - accur
acy: 0.8772
Epoch 26/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3337 - accur
acy: 0.8766
Epoch 27/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3315 - accur
acy: 0.8760
Epoch 28/50
10420/10420 [==============================] - 16s 2ms/sample - loss: 0.3308 - accur
acy: 0.8778
Epoch 29/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3296 - accur
acy: 0.8775
Epoch 30/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3308 - accur
acy: 0.8771
Epoch 31/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3277 - accur
acy: 0.8789
Epoch 32/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3274 - accur
acy: 0.8782
Epoch 33/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3267 - accur
acy: 0.8770
Epoch 34/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3258 - accur
acy: 0.8774
Epoch 35/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3289 - accur
acy: 0.8781
Epoch 36/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3263 - accur
acy: 0.8783
Epoch 37/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3276 - accur
acy: 0.8774
Epoch 38/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3253 - accur
acy: 0.8778
Epoch 39/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3258 - accur
acy: 0.8779
Epoch 40/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3283 - accur
acy: 0.8772
Epoch 41/50
10420/10420 [==============================] - 16s 2ms/sample - loss: 0.3240 - accur
acy: 0.8781
Epoch 42/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3266 - accur
acy: 0.8784
Epoch 43/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3273 - accur
acy: 0.8774
Epoch 44/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3267 - accur
acy: 0.8779
Epoch 45/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3248 - accur
acy: 0.8786
Epoch 46/50
10420/10420 [==============================] - 19s 2ms/sample - loss: 0.3219 - accur
```

```
acy: 0.8781
Epoch 47/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3254 - accur
acy: 0.8793
Epoch 48/50
10420/10420 [==============================] - 18s 2ms/sample - loss: 0.3245 - accur
acy: 0.8771
Epoch 49/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3232 - accur
acy: 0.8794
Epoch 50/50
10420/10420 [==============================] - 17s 2ms/sample - loss: 0.3268 - accur
acy: 0.8788
2605/2605 [==============================] - 0s 60us/sample - loss: 0.3257 - accurac
y: 0.8752
Test accuracy: 0.8752399
```

In [50]:

```
Y_pred = clf_cnn_1.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)


#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()


#train result
train_accuracy= clf_cnn_1.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)

print('Train_Accuracy_cnn_5 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_5  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_5 = ', precision.round(3))
print('Recall_cnn_5    = ', recall.round(3))
print()

#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_5')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

```
10420/10420 [==============================] - 0s 35us/sample - loss: 0.3169 - accur
acy: 0.8793
Train_Accuracy_cnn_5 =  87.9
Test_Accuracy_cnn_5  =  87.524
```

```
Train-Test Difference =  0.376

Precision_cnn_5 =  78.571
Recall_cnn_5    =  27.16


              precision    recall  f1-score   support

 state: good       0.88      0.99      0.93      2200
 state:  bad       0.79      0.27      0.40       405

    accuracy                           0.88      2605
   macro avg       0.83      0.63      0.67      2605
weighted avg       0.87      0.88      0.85      2605
```

5_CNN_6 (with features: [mean_h, mean_v, stand_h, stand_v, max_h, min_h, max_v, min_v])

In [ ]:

```
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
```

In [ ]:

```
#1# split into 80:20
X=df_features_2
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat



#2# build the model
clf_cnn_1 = keras.Sequential([
    keras.layers.Flatten(input_shape=(8,)),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn_1.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

#4# training
clf_cnn_1.fit(X_train, y_train, epochs=100, batch_size=1)

test_loss, test_acc = clf_cnn_1.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

In [ ]:
```
Y_pred = clf_cnn_1.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)


#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()


#train result
train_accuracy= clf_cnn_1.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)

print('Train_Accuracy_cnn_7 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_7  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_7 = ', precision.round(3))
print('Recall_cnn_7    = ', recall.round(3))
print()

#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_7')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)



#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

Step15_0
Run Correlation Matrix --> evaluate the relationships btw features & state

In [ ]:
```
corrmat = training_df.corr()
sns.heatmap(corrmat, annot=True, annot_kws=  {'size':7}, square=True)
```

In [ ]:
```
# index in matrix
corrdat = df_features_n.corr()
corrdat
corrdat.index
```

Step15_1
Create a func --> to find which features have most related relationship with 'state'

In [ ]:
```
def getCorrelatedFeature(Corrdata, threshold):
    feature = []
    value = []

    for i , index in enumerate(Corrdata.index):
        if abs(Corrdata[index])>threshold:
            feature.append(index)
            print(index)
            value.append(Corrdata[index])
    df = pd.DataFrame(data = value, index = feature, columns = ['corr value'])
    return df
```

In [ ]:
```
threshold = 0.29
corr_value = getCorrelatedFeature(corrdat['state'],threshold)
```

- According to the Correlation Matrix Map, above are the features most correlated with 'state'
- Will keep above features in the dataset, and filter out the rest features in the following step

In [ ]:
```
# check correlation value of each feature
corr_value
```

Step15_2 Generate a new dataset(df_features_3) with most important features based on the Correlation Matrix Result

In [ ]:
```
#Generate new dataset based on CorrelationMatrix
df_features_3  = training_df.drop(columns=['file', 'state', 'abs_mean_h', 'mean_h',
df_label       = training_df['state']
######


print('df_features_3= ', df_features_3.columns)
```

Step16 5_CNN_7 (with features: ['abs_mean_v', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v'])

- here with use new dataset: df_features_3

In [ ]:
```
from sklearn.metrics import classification_report
from pandas import read_csv
from keras.models import Sequential
from keras.layers import Dense
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import cross_val_score
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.metrics import f1_score
```

In [ ]:
```
#1# split into 80:20
X=df_features_3
y=df_label

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_stat
```

```
#2# build the model
clf_cnn_1 = keras.Sequential([
    keras.layers.Flatten(input_shape=(6,)),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(32, activation=tf.nn.relu),
    keras.layers.Dense(1, activation=tf.nn.sigmoid),
])

#3# compile model
clf_cnn_1.compile(optimizer='adam',
              loss='binary_crossentropy',
              metrics=['accuracy'])

#4# training
clf_cnn_1.fit(X_train, y_train, epochs=100, batch_size=1)

test_loss, test_acc = clf_cnn_1.evaluate(X_test, y_test)
print('Test accuracy:', test_acc)
```

In [ ]:

```
Y_pred = clf_cnn_1.predict(X_test)
#print(Y_pred)
y_pred = np.where(Y_pred>0.5, 1, 0)


unique_y_pred, counts_y_pred = np.unique(y_pred, return_counts=True)
y_pred_static = dict(zip(unique_y_pred, counts_y_pred))
#print(y_pred_static)

#confusion matrix(y_true, y_pred)
tn_cnn, fp_cnn, fn_cnn, tp_cnn = confusion_matrix(y_test, y_pred).ravel()

#train result
train_accuracy= clf_cnn_1.evaluate(X_train, y_train)[1].round(3)*100
#test result
accuracy = (tp_cnn+tn_cnn)/(tp_cnn+tn_cnn+fp_cnn+fn_cnn).round(3)*100
precision = tp_cnn/(tp_cnn+fp_cnn).round(3)*100
recall = tp_cnn/(tp_cnn+fn_cnn).round(3)*100
Train_Test_Difference = abs(accuracy-train_accuracy).round(3)


print('Train_Accuracy_cnn_8 = ', train_accuracy.round(3))
print('Test_Accuracy_cnn_8  = ', accuracy.round(3))
print('Train-Test Difference = ', Train_Test_Difference)
print()
print('Precision_cnn_8 = ', precision.round(3))
print('Recall_cnn_8    = ', recall.round(3))
print()

#append result to 'precision_result_list' & 'recall_result_list'
training_title_list.append('5_CNN_8')
train_accuracy_f1_result_list.append(train_accuracy)
test_accuracy_f1_result_list.append(accuracy)
train_test_difference_result_list.append(Train_Test_Difference)
precision_result_list.append(precision)
recall_result_list.append(recall)
```

```
#Classification report
print()
target_names = ['state: good', 'state:  bad']
print(classification_report(y_test, y_pred, target_names=target_names))
```

In [ ]:

Step17
Display Results

In [ ]:

```
#result list
print(training_title_list)
print(train_accuracy_f1_result_list)
print(test_accuracy_f1_result_list)
print(train_test_difference_result_list)
print(precision_result_list)
print(recall_result_list)
```

Result Dataframe

Comparisions

- 1_SVM_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 1_SVM_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])
- 1_SVM_2 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v'])

- 2_RandomForest_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 2_RandomForest_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])

- 3_GradientBoosting_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 3_GradientBoosting_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])

- 4_K-NearestNeighbors_0 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v'])
- 4_K-NearestNeighbors_1 (with features: ['abs_mean_h', 'abs_mean_v', 'stand_h', 'stand_v'])

- 5_CNN_0 (with features: [mean_h, mean_v, stand_h, stand_v]) (2 hidden layers, epochs=50)
- 5_CNN_1 (with features: [mean_h, mean_v, stand_h, stand_v]) (4 hidden layers, epochs=50)

- 5_CNN_2 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v]) (2 hidden layers, epochs=50)
- 5_CNN_3 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v]) (4 hidden layers, epochs=100)
- 5_CNN_4 (with features: [abs_mean_h, abs_mean_v, stand_h, stand_v]) (8 hidden layers, epochs=100)

- 5_CNN_5 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v']) (2 hidden layers, epochs=50)

- 5_CNN_6 (with features: ['mean_h', 'mean_v', 'stand_h', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v']) (8 hidden layers, epochs=100)
- 5_CNN_7 (with features: ['abs_mean_v', 'stand_v', 'max_h', 'min_h', 'max_v', 'min_v']) (8 hidden layers, epochs=100)

Step18 Summary

The following results are gathered from each result of each algorithm.

In [5]:
```
result =[(87.8, 87.3, 0.5, 92.9, 19.6),
         (87.8, 87.6, 0.2, 98.8, 20.2),
         (88.7, 88.1, 0.6, 90.7, 26.4),
         (88.2, 87.7, 0.5, 85.0, 24.0),
         (88.5, 87.8, 0.7, 85.8, 24.2),
         (88.8, 87.5, 1.3, 78.6, 25.8),
         (89.3, 87.6, 1.7, 73.6, 30.0),
         (89.2, 87.6, 1.6, 78.1, 28.2),
         (90.2, 88.8, 1.4, 83.4, 34.9),
         (87.8, 87.754, 0.046, 94.79, 22.46),
         (88.2, 88.177, 0.023, 97.08, 24.69),
         (88.3, 88.100, 0.2, 92.79, 25.43),
         (88.6, 88.407, 0.193, 97.25, 26.17),
         (88.8, 88.868, 0.068, 91.97, 31.11),
         (87.9, 87.524, 0.376, 78.57, 27.16)]

columns = ['train_acc(%)', 'test_acc(%)', 'train-test diff(%)', 'precision(%)', 'rec

indexs = ['1_SMM_0',
         '1_SVM_1',
         '1_SVM_2',
         '2_RF_0',
         '2_RF_1',
         '3_GB_0',
         '3_GB_1',
         '4_k_0',
         '4_k_1',
         '5_CNN_0',
         '5_CNN_1',
         '5_CNN_2',
         '5_CNN_3',
         '5_CNN_4',
         '5_CNN_5']
```

In [10]:
```
result_df = pd.DataFrame(result,
                         columns=['train_acc(%)',
                                  'test_acc(%)',
                                  'train-test diff(%)',
                                  'precision(%)',
                                  'recall(%)'],
                         index  =['1_SMM_0',
                                  '1_SVM_1',
                                  '1_SVM_2',
                                  '2_RF_0',
                                  '2_RF_1',
                                  '3_GB_0',
                                  '3_GB_1',
                                  '4_k_0',
```

```
                                      '4_k_1',
                                      '5_CNN_0',
                                      '5_CNN_1',
                                      '5_CNN_2',
                                      '5_CNN_3',
                                      '5_CNN_4',
                                      '5_CNN_5'])
```

In [11]:
```
print(result_df)
```

```
         train_acc(%)  test_acc(%)  train-test diff(%)  precision(%)  \
1_SMM_0          87.8       87.300               0.500         92.90
1_SVM_1          87.8       87.600               0.200         98.80
1_SVM_2          88.7       88.100               0.600         90.70
2_RF_0           88.2       87.700               0.500         85.00
2_RF_1           88.5       87.800               0.700         85.80
3_GB_0           88.8       87.500               1.300         78.60
3_GB_1           89.3       87.600               1.700         73.60
4_k_0            89.2       87.600               1.600         78.10
4_k_1            90.2       88.800               1.400         83.40
5_CNN_0          87.8       87.754               0.046         94.79
5_CNN_1          88.2       88.177               0.023         97.08
5_CNN_2          88.3       88.100               0.200         92.79
5_CNN_3          88.6       88.407               0.193         97.25
5_CNN_4          88.8       88.868               0.068         91.97
5_CNN_5          87.9       87.524               0.376         78.57

         recall(%)
1_SMM_0      19.60
1_SVM_1      20.20
1_SVM_2      26.40
2_RF_0       24.00
2_RF_1       24.20
3_GB_0       25.80
3_GB_1       30.00
4_k_0        28.20
4_k_1        34.90
5_CNN_0      22.46
5_CNN_1      24.69
5_CNN_2      25.43
5_CNN_3      26.17
5_CNN_4      31.11
5_CNN_5      27.16
```

Summary

- From the results, most of the trained classifier have no overfitting issue. And most of the difference of 'Train-Test Accuracy' are less than 1%. Only the 'Train-Test Accuracy' from Gradient Boosting and K-nearest Neighbors are more than 1%.
- CNN_5 is trained with 8 features. Compared to previous Model, the features are increased from 4 to 8. With only 2 hidden layers and 50 training epoch. We can see the test accuracy is decreasing a bit. To improve the accuracy of the model, maybe can try to increase the hidden layers and the node in each layer and also increase the training epoch.
- To this case, CNN are slightly better than the other algorithm. I believe, by increase the hidden layer and training epoch, CNN can achieve better result.
- Because the training time is too long, so i have not run through CNN_6 and CNN_7.

In [ ]: