ansi_regression-final

April 22, 2018

1 ANSI Application analysis

```
In [1]: import numpy
        import pandas
        import matplotlib
        import matplotlib.pyplot as plotter
        from scipy.stats import pearsonr, probplot
        from sklearn.metrics import mean_squared_error, mean_absolute_error, f1_score
        matplotlib.rcParams['agg.path.chunksize'] = 10000
```

```
In [2]: def view_boxplot(df):
            %matplotlib
            df.boxplot()
            plotter.show()
```

1.1 CPU data

```
In [3]: cpu_df = pandas.read_csv('data/ansi_final/ansi_final_cpu.csv', index_col='Time').drop(
```

```
In [4]: #cpu_df.columns
```

```
In [5]: cpu_df = cpu_df.clip(lower=0, upper=1000)
        #view_boxplot(cpu_df)
```

1.2 Network TX

```
In [6]: txnet_df = pandas.read_csv('data/ansi_final/ansi_final_network_tx.csv', index_col='Time
```

```
In [7]: #txnet_df.columns
```

```
In [8]: txnet_df = txnet_df.clip(lower=0, upper=50000)
        #view_boxplot(txnet_df)
```

1.3 Network RX

```
In [9]: rxnet_df = pandas.read_csv('data/ansi_final/ansi_final_network_rx.csv', index_col='Time
```

```
In [10]: #rxnet_df.columns
```

```
In [11]: rxnet_df = rxnet_df.clip(lower=0, upper=15000)
         #view_boxplot(rxnet_df)
```

1.4 Disk IO data

```
In [12]: disk_df = pandas.read_csv('data/ansi_final/ansi_final_disk_io.csv', index_col='Time')
```

```
In [13]: #disk_df.columns
```

```
In [14]: disk_df = disk_df.clip(lower=0, upper=4000)
         #view_boxplot(disk_df)
```

1.5 Context switching

```
In [15]: context_df = pandas.read_csv('data/ansi_final/ansi_final_context.csv', index_col='Tim
```

```
In [16]: #context_df.columns
```

```
In [17]: context_df = context_df.clip(lower=0, upper=5000)
         #view_boxplot(context_df)
```

1.6 Seperate into proper dataframes for each node

```
In [18]: dframes = [cpu_df, txnet_df, rxnet_df, context_df, disk_df]
         node = {}

         for i in range(1,13):
             frames = []

             for dframe in dframes:
                 columns = list(filter(lambda x: f'bb{i}l' in x, dframe.columns))
                 frames.append(dframe[columns])

             node[i] = pandas.concat(frames, join='inner', axis=1).fillna(0)[:68300]
```

```
In [19]: for i in range(1,13):
             print(node[i].shape)

         for i in range(len(node[1].columns)):
             print(f"{i}: {node[1].columns[i]}")
```

```
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
(68300, 29)
```

```
(68300, 29)
0: cpu_value host bb1localdomain type_instance idle
1: cpu_value host bb1localdomain type_instance interrupt
2: cpu_value host bb1localdomain type_instance nice
3: cpu_value host bb1localdomain type_instance softirq
4: cpu_value host bb1localdomain type_instance steal
5: cpu_value host bb1localdomain type_instance system
6: cpu_value host bb1localdomain type_instance user
7: cpu_value host bb1localdomain type_instance wait
8: interface_tx host bb1localdomain instance lo type if_dropped
9: interface_tx host bb1localdomain instance lo type if_errors
10: interface_tx host bb1localdomain instance lo type if_octets
11: interface_tx host bb1localdomain instance lo type if_packets
12: interface_tx host bb1localdomain instance wlan0 type if_dropped
13: interface_tx host bb1localdomain instance wlan0 type if_errors
14: interface_tx host bb1localdomain instance wlan0 type if_octets
15: interface_tx host bb1localdomain instance wlan0 type if_packets
16: interface_rx host bb1localdomain instance lo type if_dropped
17: interface_rx host bb1localdomain instance lo type if_errors
18: interface_rx host bb1localdomain instance lo type if_octets
19: interface_rx host bb1localdomain instance lo type if_packets
20: interface_rx host bb1localdomain instance wlan0 type if_dropped
21: interface_rx host bb1localdomain instance wlan0 type if_errors
22: interface_rx host bb1localdomain instance wlan0 type if_octets
23: interface_rx host bb1localdomain instance wlan0 type if_packets
24: contextswitch_value host bb1localdomain type contextswitch
25: disk_io_time host bb1localdomain instance mmcblk1 type disk_io_time
26: disk_io_time host bb1localdomain instance mmcblk1boot0 type disk_io_time
27: disk_io_time host bb1localdomain instance mmcblk1boot1 type disk_io_time
28: disk_io_time host bb1localdomain instance mmcblk1p1 type disk_io_time
```

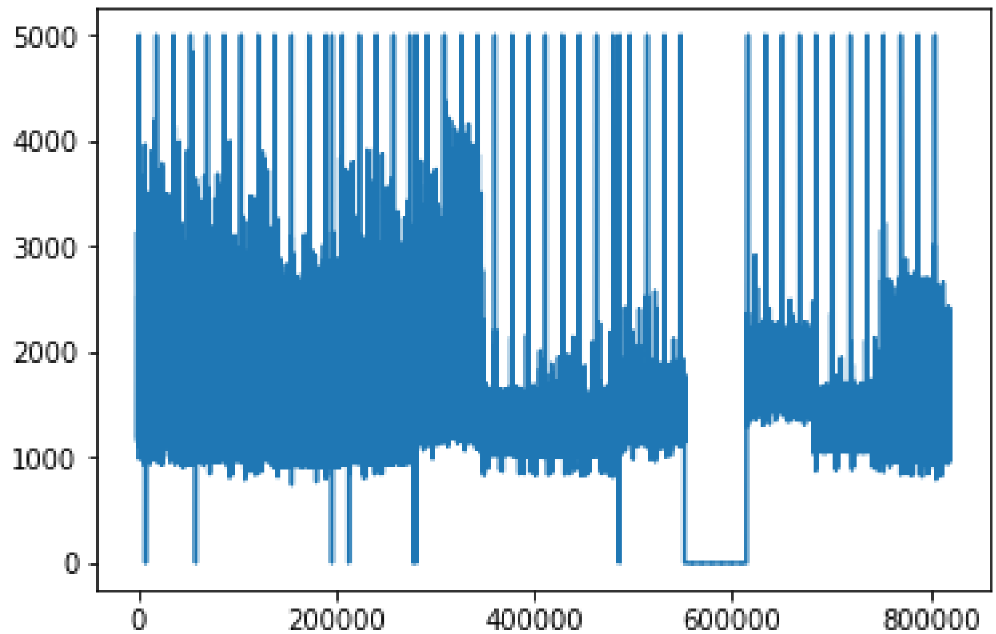
1.7 Get data

```
In [20]: data_matrices = []

         for i in range(1,13):
             data_matrices.append(node[i].as_matrix())

         data = numpy.vstack(data_matrices)
```

```
In [21]: data.shape
```

```
Out[21]: (819600, 29)
```

```
In [22]: tdata = data[:,24]
         plotter.plot(tdata.T)
         plotter.show()
         print(data.shape)
```




```
(819600, 29)
```

```
In [23]: #data = data[:,24]
```

1.8 Prepare scaler

```
In [24]: from sklearn.preprocessing import MinMaxScaler
         from sklearn.preprocessing import StandardScaler
         from sklearn.preprocessing import RobustScaler
         scaler = MinMaxScaler()

In [25]: scaler.fit(data)
         del data
```

1.9 Correrlation measurement

```
In [26]: for i in range(len(data_matrices)):

             transformed = scaler.transform(data_matrices[i])
             data_matrices[i] = transformed

         X = numpy.stack(data_matrices[:4], axis=1)
         test = numpy.stack(data_matrices[4:], axis=1)
         print(X.shape)
         print(test.shape)

(68300, 4, 29)
(68300, 8, 29)
```

```
In [27]: print(X.shape)
         LEN = X.shape[0]
         SPLIT = int(0.8*LEN)

         train_X = X[:SPLIT,:,:]
         val_X = X[SPLIT:,:,:]

         print(train_X.shape)
         print(val_X.shape)

(68300, 4, 29)
(54640, 4, 29)
(13660, 4, 29)
```

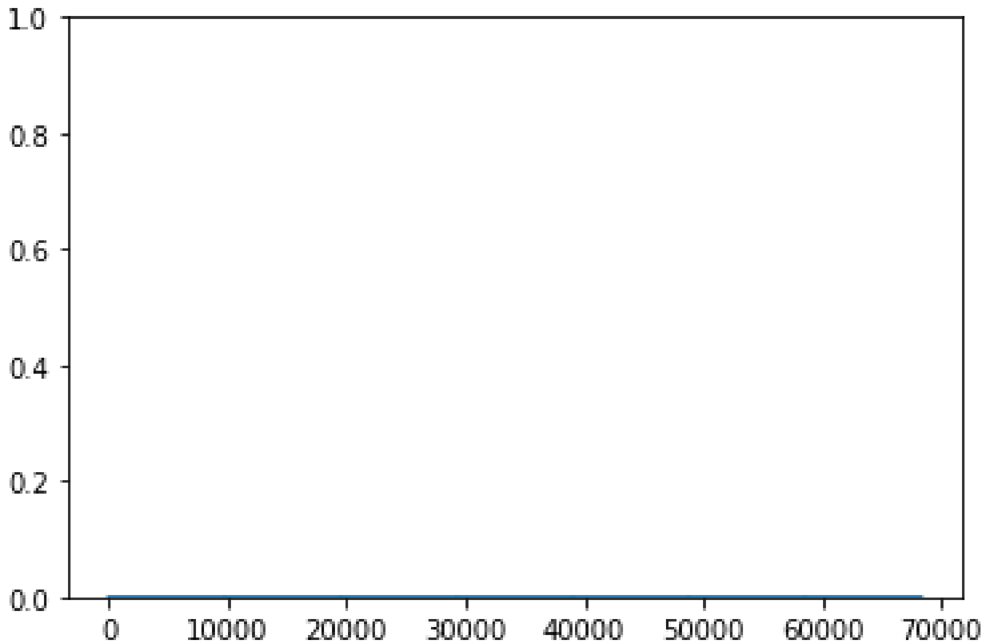
```
In [28]: test_X = numpy.transpose(test, (1,0,2))
         train_X = numpy.transpose(train_X, (1,0,2))
         val_X = numpy.transpose(val_X, (1,0,2))
         print(test_X.shape)
         print(train_X.shape)
         print(val_X.shape)

(8, 68300, 29)
(4, 54640, 29)
(4, 13660, 29)
```

```
In [29]: def flat_generator(X, tsteps = 5, ravel=1):
             i = 0

             while True:
                 batch_X = X[:,i:i+tsteps,:]
                 batch_y = X[:,i+tsteps,:]

                 if ravel:
```

```
            batch_X = batch_X.reshape((batch_X.shape[0], -1))
        #print(batch_X.shape)
        #print(batch_y.shape)

        yield batch_X, batch_y

        i += 1
        if i > (X.shape[1] - tsteps - 1):
            i = 0
            continue
```

In [30]:
```
series = test_X[7,:,21]
print(series.shape)
plotter.ylim(0,1)
plotter.plot(series)
plotter.show()
print(numpy.random.randint(29))
```

```
(68300,)
```



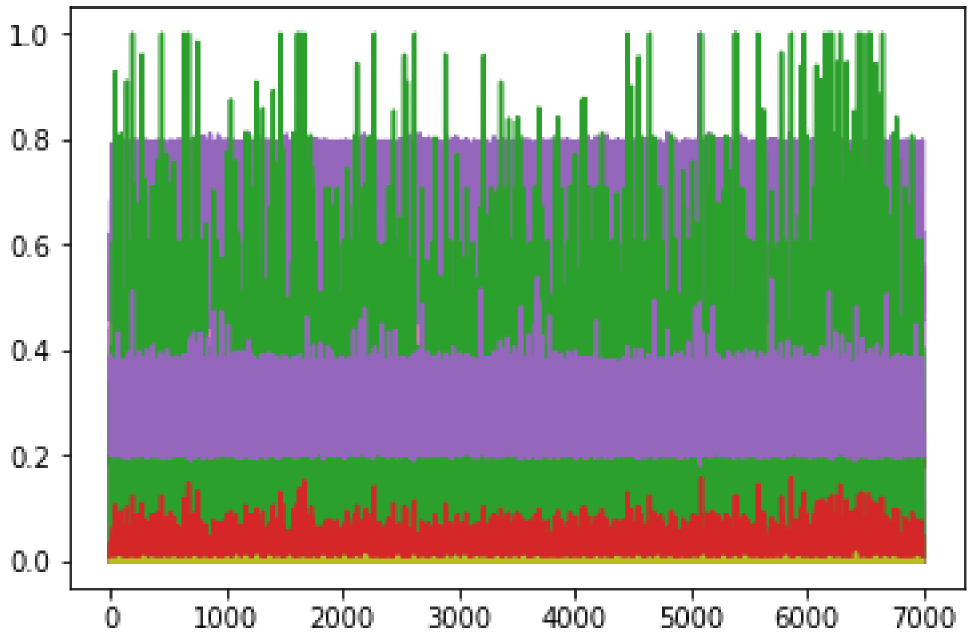

```
22
```

In [31]:
```
#avg_load = test_X[3,:,:]
#disk_io_start_late = test_X[0,:,:]
```

```
#app_change_early = test_X[1,:,:]
#idle_early = test_X[4,:,:]
normal_test = test_X[7,:,:]
synth_test = test_X[7,3000:10000,:]
```

In [32]:
```
print(synth_test.shape)
plotter.plot(synth_test[:,:])
plotter.show()
```

```
(7000, 29)
```



In [33]:
```
def get_anomaly_labels(error, window_size, technique):

    if technique == "rolling":
        arr = pandas.Series(error)
        means = arr.rolling(window=window_size).mean()
        std = arr.rolling(window=window_size).std()

    if technique == "exp":
        arr = pandas.Series(error)
        means = arr.ewm(halflife=window_size).mean()
        std = arr.ewm(halflife=window_size).std()

    outlier = (arr > (means + (5.0 * std))) * 1.0
    mark = numpy.zeros(arr.shape[0])
```

```python
    window = 100

    for i in range(window,outlier.shape[0]):
        num = window
        outliers = numpy.sum(outlier[i-window:i])
        per = outliers/num
        if per > 0.04:
            mark[i-window:i] = outlier[i-window:i]
        else:
            mark[i] = 0.0

    #plotter.plot(0.09 * true,'r-', alpha=0.5, label="True")
    #plotter.plot(0.09 * mark,'b-', alpha=0.3, label="Prediction", linewidth=1)
    #plotter.plot(means,'b--', alpha=0.9, linewidth=0.5)
    #plotter.plot(means + (5.0 * std), 'r-', alpha=0.5, linewidth=0.5)
    #plotter.plot(error,'g-', alpha=0.5, label="Error", linewidth=0.5)
    #plotter.ylim(0,0.1)
    #plotter.legend()
    #plotter.show()

    return mark

def get_score(error, true, moving_window, name="none", dataset_name="none"):

    # For rolling window
    labels = get_anomaly_labels(error, moving_window, "rolling")
    true = true[true.shape[0]-labels.shape[0]:]
    #print(true)
    #print(labels)

    #plotter.plot(0.09 * true,'r-', alpha=0.5, label="True")
    #plotter.plot(0.09 * labels,'b-', alpha=0.5, label="Prediction")
    #plotter.plot(error,'g-', alpha=0.3, label="Error")
    #plotter.ylim(0,0.1)
    #plotter.legend()
    #plotter.show()

    print(f"For {name} and rolling window size {moving_window} and dataset name {datas
    print(f"True: {numpy.sum(true)} Labels: {numpy.sum(labels)} Overlap: {numpy.sum(nu

    # For exp window
    labels = get_anomaly_labels(error, moving_window, "exp")
    true = true[true.shape[0]-labels.shape[0]:]

    #plotter.plot(0.09 * true,'r-', alpha=0.5, label="True")
    #plotter.plot(0.09 * labels,'b-', alpha=0.5, label="Prediction")
    #plotter.plot(error,'g-', alpha=0.3, label="Error")
```

```
    #plotter.ylim(0,0.5)
    #plotter.legend()
    #plotter.show()

    print(f"For {name} and exp window size {moving_window} and dataset name {dataset_n
    print(f"True: {numpy.sum(true)} Labels: {numpy.sum(labels)} Overlap: {numpy.sum(nu

def get_error(model ,dataset, ravel=1, name="none", window=10):

    test_gen = flat_generator(numpy.array([dataset]), window,0)
    error = []
    targets = []
    preds = []
    for i in range(dataset.shape[0]-(window+1)):
        _input,target = next(test_gen)
        targets.append(target.squeeze())
        #print(_input.shape)
        if ravel:
            _input = _input.ravel()[:,numpy.newaxis].T

        pred = model.predict(_input)
        #print(target.shape)
        #print(pred.shape)
        preds.append(pred.squeeze())
        error.append(mean_absolute_error(y_pred=pred, y_true=target))

    targets = numpy.vstack(targets)
    preds = numpy.vstack(preds)

    #plotter.plot(numpy.array(error), alpha=0.5, linewidth=0.5, label="error")
    #plotter.ylim(0,0.1)
    #plotter.legend()
    #plotter.plot()
    #plotter.show()

    return error


def test_anomalies(model, dataset, ravel=1, windows_list=[100], name="none", window=10


    for window_size in windows_list:

        ## For network flood:

        for i in range(1,10):

            test_set = numpy.copy(dataset)
```

```
            anomaly_range = numpy.random.randint(3000,5000)
            test_set[anomaly_range:anomaly_range+i,21:23] = 1.0
            true = numpy.zeros(test_set.shape[0])
            true[anomaly_range:anomaly_range+i] = 1.0

            error = numpy.array(get_error(model, test_set, ravel, window=window))
            fname = f"results/{name}_{window_size}_duration_{i}.npy"
            print(f"Writing {fname}")
            numpy.save(fname,error)
            numpy.save(f"results/{name}_{window_size}_duration_{i}_true.npy",true)
            #get_score(error, true, window_size, name, "network_flood")


        #noise = numpy.random.normal(size=test_set.shape, loc=0, scale=0.1)

        #test_set = numpy.clip(test_set + noise, a_min=0.0, a_max=1.0)


        #(test_set.shape)
```

1.10 Training functions

```
In [34]: from keras.models import Model
         from keras.layers import Dense, Input, Dropout, GRU
         from keras.callbacks import EarlyStopping
```

```
/home/adityas/miniconda3/lib/python3.6/site-packages/h5py/__init__.py:36: FutureWarning: Conve
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

```
In [35]: def train(model, tgen, vgen, name="none"):
             estopper = EarlyStopping(patience=15, min_delta=0.0001)
             history = model.fit_generator(tgen, steps_per_epoch=1000, epochs=10000, callbacks=
             plotter.plot(history.history['loss'],label='train')
             plotter.plot(history.history['val_loss'],label='validation')
             plotter.legend()
             plotter.xlim(0,150)
             plotter.xlabel("Epochs")
             plotter.ylabel("Error")
             plotter.savefig(f"{name}_train.png", dpi=500)
             plotter.show()
             print(f"Training loss for final epoch is {history.history['loss'][-1]}")
             print(f"Validation loss for final epoch is {history.history['val_loss'][-1]}")
```

In [36]:
```python
def plot_running_stats(error, name="none", window_size=5, bounds=None, qq=0):
    error = numpy.array(error)
    numpy.save(f"results/{name}_error.npy", error)
    window = numpy.ones(window_size)/window_size
    running_mean = numpy.convolve(error, window, mode="same")
    running_sigma = pandas.Series(error).rolling(window=window_size, center=True).std
    difference = 3.0 * running_sigma

    upper = running_mean + difference
    lower = running_mean - difference

    if bounds == None:
        global_mean = numpy.mean(error) * numpy.ones(error.shape[0])
        global_sigma = numpy.std(error) * numpy.ones(error.shape[0])
        bound = (5.0 * global_sigma) + global_mean

    else:

        global_mean = bounds[0]
        bound = bounds[1]

    anomaly = ((error > bound) * error)
    anomaly = numpy.array([float('nan') if x == 0.0 else x for x in anomaly])

    if qq:

        #a, b, l, s = beta.fit(error)
        probplot(error,dist="norm", plot=plotter)
        plotter.legend()
        plotter.savefig(f"{name}_qq.png",dpi=500)
        plotter.show()

        plotter.hist(error, bins=100)
        plotter.legend()
        plotter.savefig(f"{name}_hist.png")
        plotter.show()

    arr = pandas.Series(error)
    means = arr.rolling(window=720).mean()
    std = arr.rolling(window=720).std()
    outlier = (arr > (means + 5.0 * std)) * 1.0

    mark = numpy.ones(arr.shape[0]) * numpy.nan

    window = 100

    #for i in range(window,outlier.shape[0]):
    #    num = window
```

```
#    outliers = numpy.sum(outlier[i-window:i])
#    per = outliers/num
#    if per > 0.04:
#        mark[i-window:i] = 1.0
#    else:
#        mark[i] = 0.0

#plotter.plot(error, 'g-', label="Error", alpha=0.4, linewidth=0.5)
#plotter.ylim(0,0.2)
#plotter.xlabel("time")
#plotter.ylabel("Error")
#plotter.legend()
#plotter.savefig(f"{name}_error_plain.png", dpi=500)
#plotter.show()

#fig = plotter.figure()
#plotter.plot(error, 'g-', alpha=0.4, label="Error", linewidth=0.5)
#plotter.plot(means, 'r-.', alpha=0.9, label="Mean", linewidth=0.5)
##plotter.plot(upper,'b-', alpha=0.2, label="Upper Bound", linewidth=0.5)
#plotter.plot(means + 5.0 * std,'b--', alpha=0.9, label="Bound", linewidth=0.5)
#plotter.plot(0.1 * mark,'r-', alpha=0.5, label="Anomaly")
#plotter.legend()
#plotter.ylim(0,0.2)
#plotter.xlabel("time")
#plotter.ylabel("Error")
#plotter.draw()
#fig.savefig(f"{name}_truetestloss.png", dpi=500)
#plotter.show()



arr = pandas.Series(error)
means = arr.ewm(halflife=720).mean()
std = arr.ewm(halflife=720).std()
outlier = (arr > (means + 5.0 * std)) * 1.0

mark = numpy.ones(arr.shape[0]) * numpy.nan

window = 100

#for i in range(window, outlier.shape[0]):
#    num = window
#    outliers = numpy.sum(outlier[i-window: i])
#    per = outliers/num
#    if per > 0.04:
#        mark[i] = 1.0
#    else:
#        mark[i] = 0.0
```

```
        #fig = plotter.figure()
        #plotter.plot(error, 'g-', alpha=0.4, label="Error", linewidth=0.5)
        #plotter.plot(means, 'r-.', alpha=0.9, label="Mean", linewidth=0.5)
        #plotter.plot(upper,'b-', alpha=0.2, label="Upper Bound", linewidth=0.5)
        #plotter.plot(means + 5.0 * std,'b--', alpha=0.9, label="Bound", linewidth=0.5)
        #plotter.plot(0.1 * mark,'r-', alpha=0.5, label="Anomaly")
        #plotter.legend()
        #plotter.ylim(0,0.2)
        #plotter.xlabel("time")
        #plotter.ylabel("Error")
        #plotter.draw()
        #fig.savefig(f"{name}_truetestloss_exp.png", dpi=500)
        #plotter.show()


        #fig.clf()
        #plotter.clf()
        #plotter.close()
        error = numpy.array(error)
        print(f"The mean error for {name} is {numpy.mean(error)} for length {error.shape[(

        return (global_mean, bound)
```

```
In [37]: def data_test(model, dataset=test_X[0], ravel=1, write=0, name="none", window=5, bound
             test_gen = flat_generator(numpy.array([dataset]), window,0)
             error = []
             targets = []
             preds = []
             for i in range(dataset.shape[0]-(window+1)):
                 _input,target = next(test_gen)
                 targets.append(target.squeeze())
                 if ravel:
                     _input = _input.ravel()[:,numpy.newaxis].T

                 pred = model.predict(_input)
                 #print(target.shape)
                 #print(pred.shape)
                 preds.append(pred.squeeze())
                 error.append(mean_absolute_error(y_pred=pred, y_true=target))

             targets = numpy.vstack(targets)
             preds = numpy.vstack(preds)
             return plot_running_stats(error, name=name, window_size=window, bounds=bounds, qq=
             #return None
             #print(error)
```

```
In [38]: def gen_test(model, dataset=test_X[0], ravel=1, write=0, name="none"):
             test_gen = flat_generator(numpy.array([dataset]), TIMESTEPS,0)
```

```
        error = []
        targets = []
        preds = []
        for i in range(2000):
            _input,target = next(test_gen)

            if i != 0:
                #print(_input.shape)
                _input = _input.squeeze()[1:,:]
                #print(_input.shape)
                _input = numpy.append(pred,_input, axis=0)[numpy.newaxis,:,:]
                #print(_input.shape)

            targets.append(target.squeeze())
            if ravel:
                _input = _input.ravel()[:,numpy.newaxis].T

            pred = model.predict(_input)
            #print(target.shape)
            #print(pred.shape)
            preds.append(pred.squeeze())
            error.append(mean_absolute_error(y_pred=pred, y_true=target))

        targets = numpy.vstack(targets)
        preds = numpy.vstack(preds)

        plotter.plot(error, 'g-', alpha=0.5)
        plotter.ylim(0,0.2)
        plotter.xlabel("time")
        plotter.ylabel("Error")
        plotter.savefig(f"{name}_testloss.png")
        plotter.show()
        error = numpy.array(error)
        print(numpy.mean(error))
        plotter.boxplot(error)
        plotter.ylim(0,0.2)
        plotter.xlabel("time")
        plotter.ylabel("Error")
        plotter.savefig(f"{name}_boxplot.png")
        plotter.show()
        if write:
            numpy.savetxt('loss.txt', numpy.array(error))
        true_test(model,dataset,ravel=ravel,name=name)
        #print(error)
```

```
In [39]: def test(model, ravel=1, name="none", window=20):
        print(f"---------- Beginning tests for {name} ----------")
        #print(f"Testing on Disk IO begin data.")
```

```
#bounds = data_test(model, dataset=disk_io_start_late , ravel=ravel, name=(name+"_
#print(f"Testing on Avg. load data.")
#data_test(model, dataset=avg_load, ravel=ravel, name=(name+"_avg_load_"), window
#print(f"Testing on app change early data.")
#data_test(model, dataset=app_change_early, ravel=ravel, name=(name+"_app_change_
print(f"Testing on Normal data.")
data_test(model, dataset=normal_test, ravel=ravel, name=(name+"_normal_"), window=
#print(f"Testing on Idle early data.")
#data_test(model, dataset=idle_early, ravel=ravel, name=(name+"_idle_early_"), wi
#test_anomalies(model, synth_test, ravel=ravel, name=name, window=window)
print("="*20)
print("\r\n\r\n")
```

1.11 Train Models

```
In [40]: X = train_X
```

1.11.1 Linear Regression

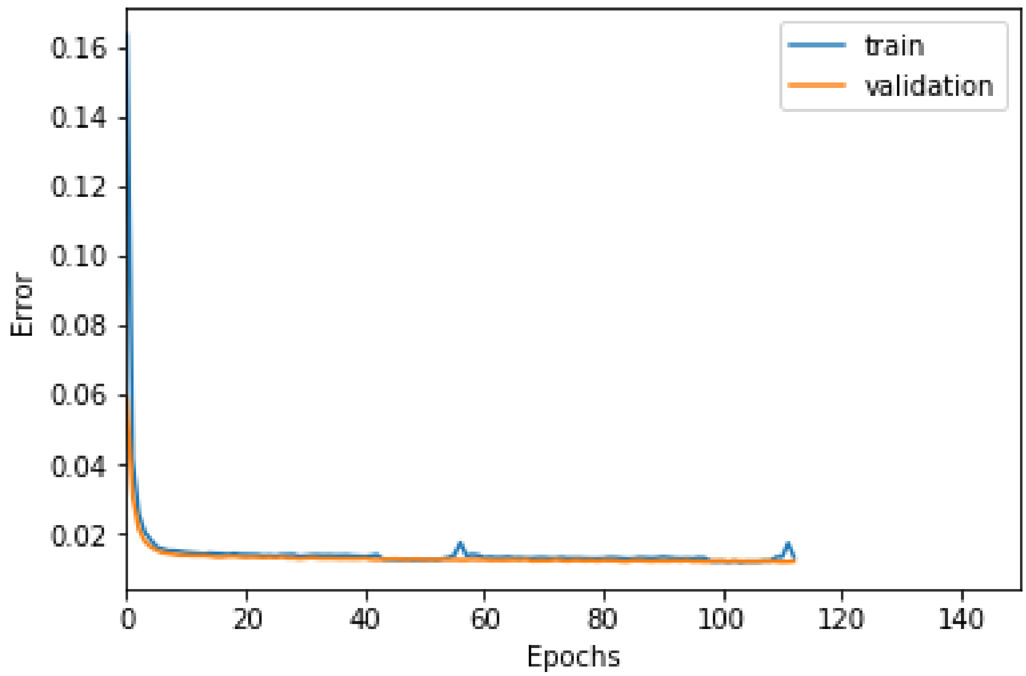
2 steps

```
In [41]: TIMESTEPS = 2
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "lin2"
```

```
In [42]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         output = Dense(DIM, activation='sigmoid')(input_layer)
```

```
In [43]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [44]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.013416780584026127
Validation loss for final epoch is 0.012254659853642807
---------- Beginning tests for lin2 ----------
Testing on Normal data.
The mean error for lin2_normal_ is 0.012387422840360412 for length 68297
====================
```

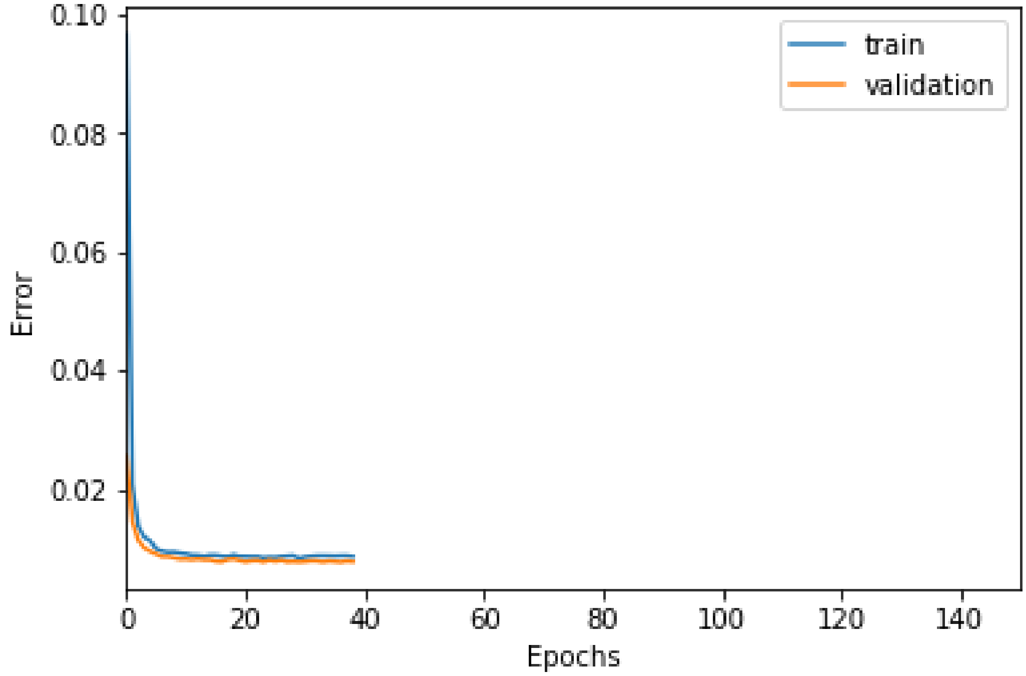
5 steps

```
In [45]: TIMESTEPS = 5
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "lin5"
```

```
In [46]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         output = Dense(DIM, activation='sigmoid')(input_layer)
```

```
In [47]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [48]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```



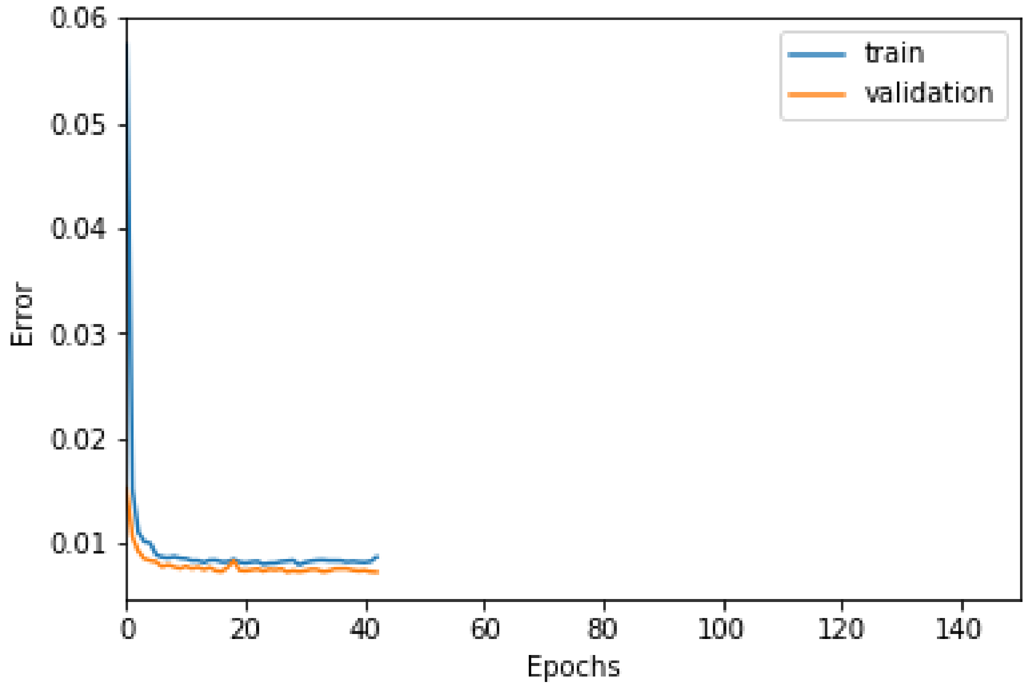

```
Training loss for final epoch is 0.008614786661812104
Validation loss for final epoch is 0.007737001340603456
---------- Beginning tests for lin5 ----------
Testing on Normal data.
The mean error for lin5_normal_ is 0.007877883068638 58 for length 68294
====================
```

10 steps

```
In [49]: TIMESTEPS = 10
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "lin10"
```

```
In [50]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         output = Dense(DIM, activation='sigmoid')(input_layer)
```

```
In [51]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [52]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.00875015032000374
Validation loss for final epoch is 0.007311971699469723
---------- Beginning tests for lin10 ----------
Testing on Normal data.
The mean error for lin10_normal_ is 0.00761069556404195 for length 68289
====================
```

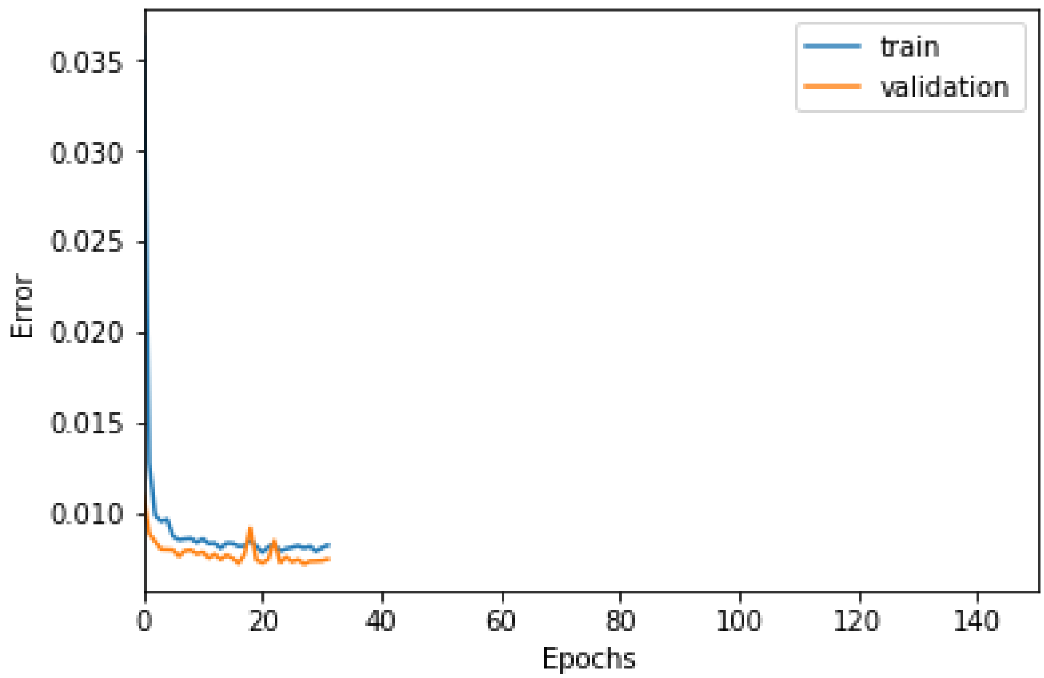
20 steps

```
In [53]: TIMESTEPS = 20
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "lin20"
```

```
In [54]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         output = Dense(DIM, activation='sigmoid')(input_layer)
```

```
In [55]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [56]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008191164544317871
Validation loss for final epoch is 0.0074185703984694555
---------- Beginning tests for lin20 ----------
Testing on Normal data.
The mean error for lin20_normal_ is 0.0073792219066618715 for length 68279
====================
```

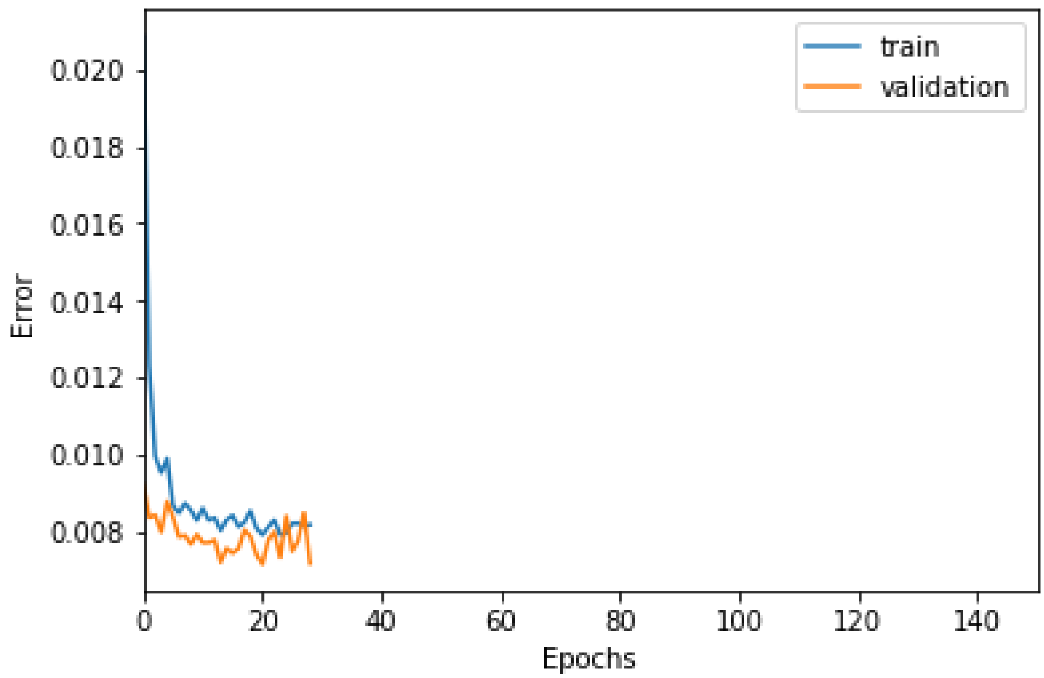
50 steps

```
In [57]: TIMESTEPS = 50
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "lin50"
```

In [58]:
```
input_layer = Input(shape=(TIMESTEPS*DIM,))
output = Dense(DIM, activation='sigmoid')(input_layer)
```

In [59]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [60]:
```
train(model, tgen, vgen, name=name)
test(model, name=name, window=TIMESTEPS)
```

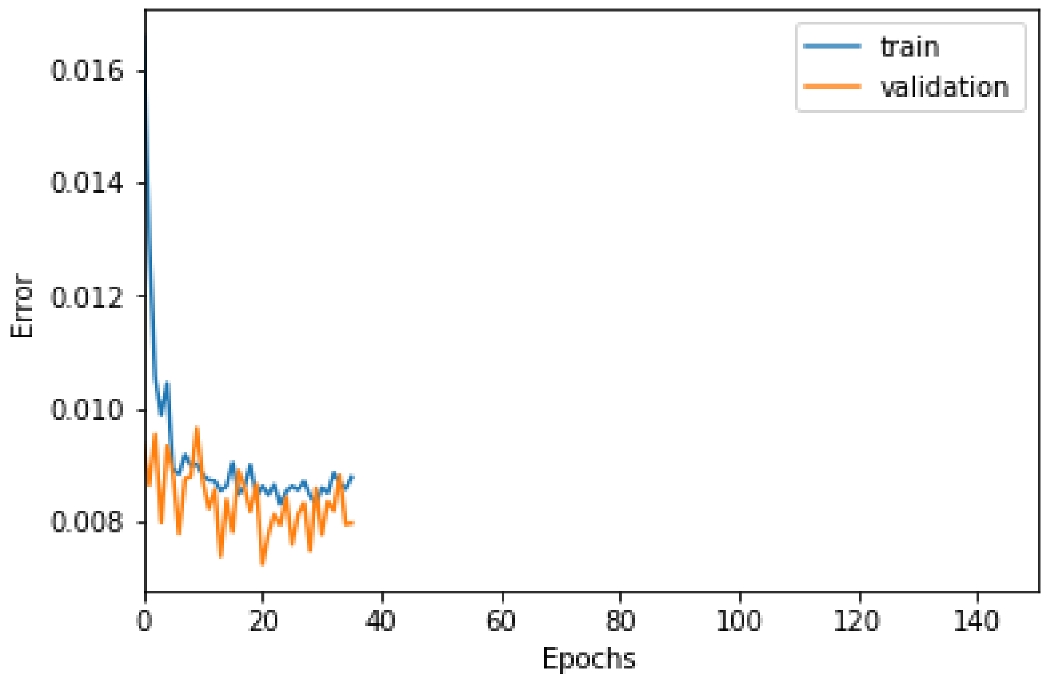



```
Training loss for final epoch is 0.00817395983391907
Validation loss for final epoch is 0.0071694665958639235
---------- Beginning tests for lin50 ----------
Testing on Normal data.
The mean error for lin50_normal_ is 0.007249869072372127 for length 68249
====================
```

100 steps

In [61]:
```
TIMESTEPS = 100
DIM = 29
tgen = flat_generator(X, TIMESTEPS)
vgen = flat_generator(val_X, TIMESTEPS)
name = "lin100"
```

```
In [62]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         output = Dense(DIM, activation='sigmoid')(input_layer)

In [63]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [64]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```

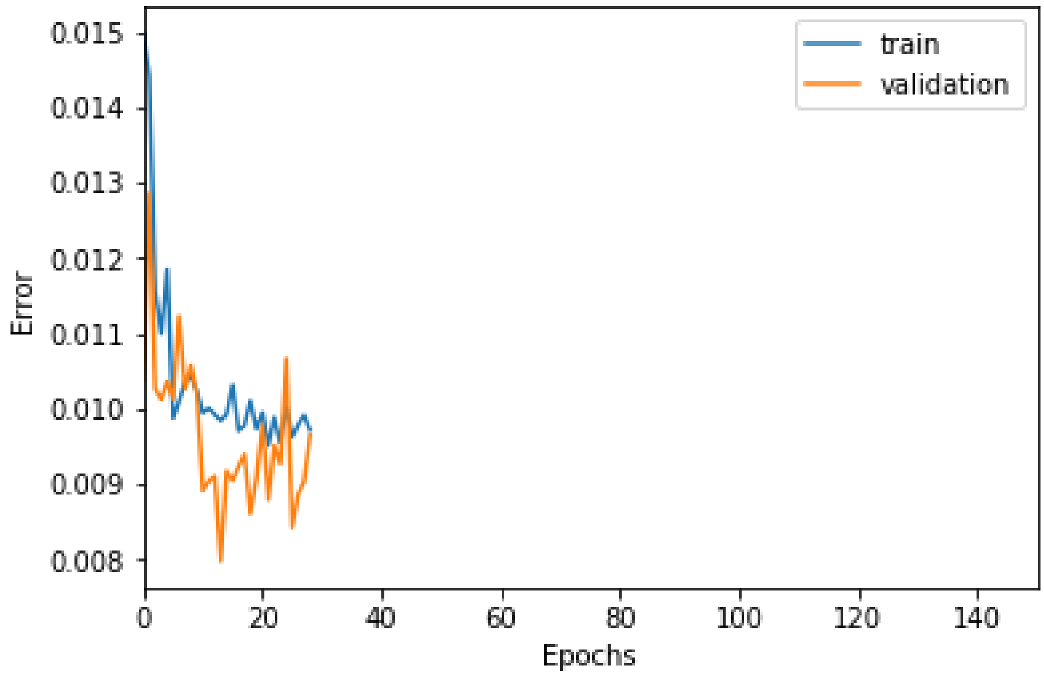



```
Training loss for final epoch is 0.008786280363216065
Validation loss for final epoch is 0.007973676408873871
---------- Beginning tests for lin100 ----------
Testing on Normal data.
The mean error for lin100_normal_ is 0.008220285709627795 for length 68199
====================
```

200 steps

```
In [65]: TIMESTEPS = 200
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "lin200"
```

```
In [66]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         output = Dense(DIM, activation='sigmoid')(input_layer)

In [67]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [68]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.009722595837665722
Validation loss for final epoch is 0.009655365781858563
---------- Beginning tests for lin200 ----------
Testing on Normal data.
The mean error for lin200_normal_ is 0.009828603685320828 for length 68099
====================
```

1.11.2 NN with 1 hidden layer

2 steps

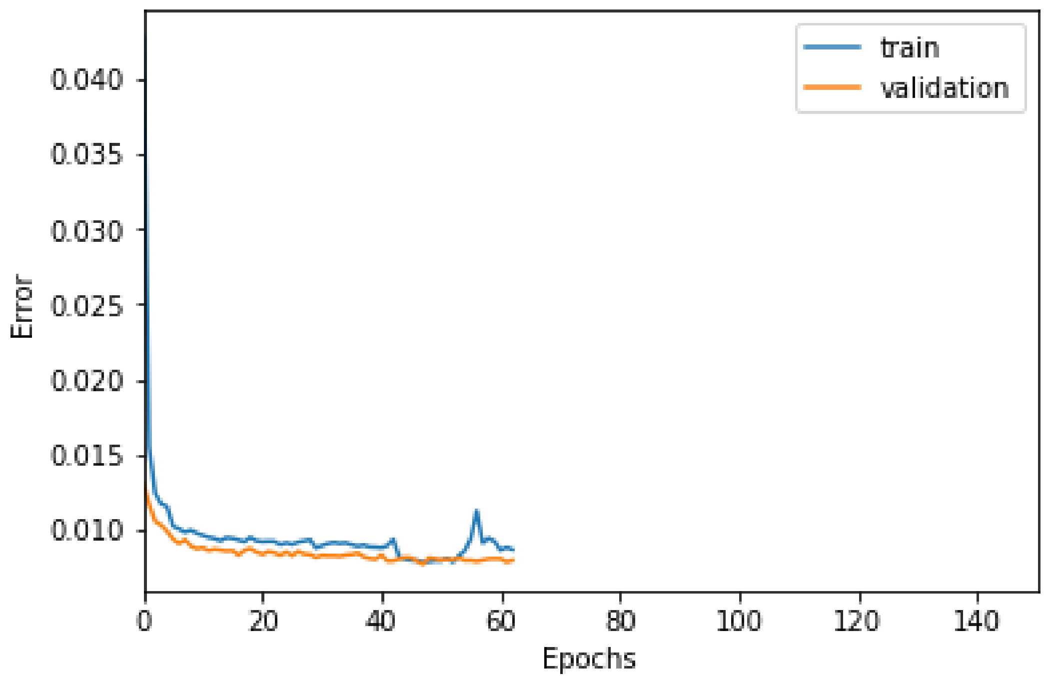
```
In [69]: TIMESTEPS = 2
         DIM = 29
```

```
tgen = flat_generator(X, TIMESTEPS)
vgen = flat_generator(val_X, TIMESTEPS)
name = "nn1_2"
```

In [70]:
```
input_layer = Input(shape=(TIMESTEPS*DIM,))
hidden = Dense(100, activation='relu')(input_layer)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [71]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

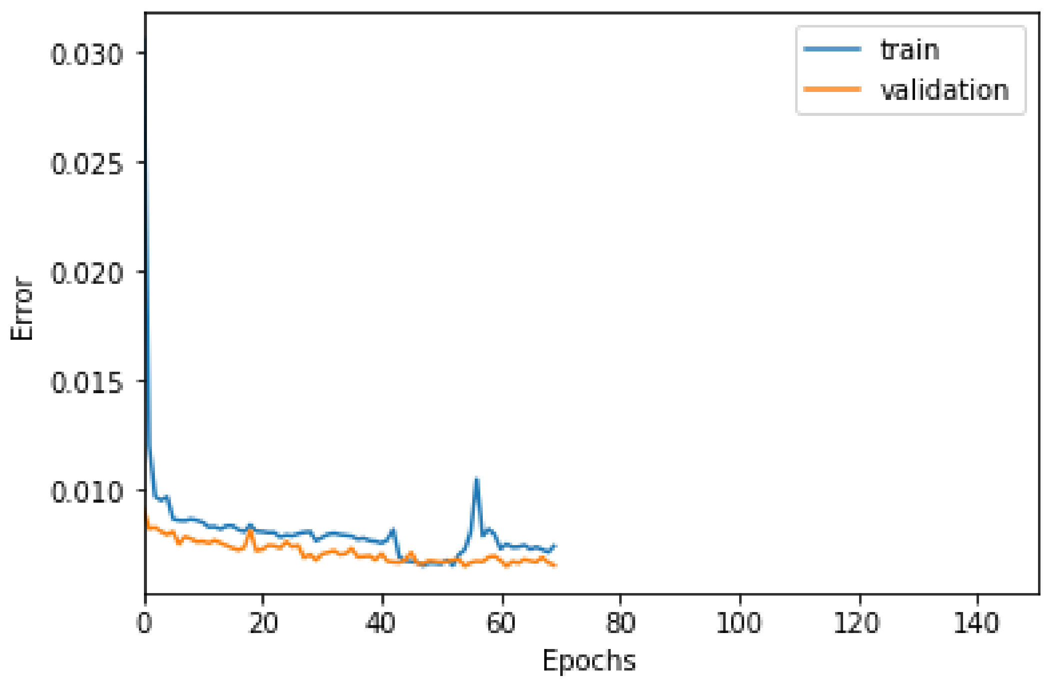
In [72]:
```
train(model, tgen, vgen, name=name)
test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008659293601755052
Validation loss for final epoch is 0.007953081339132041
---------- Beginning tests for nn1_2 ----------
Testing on Normal data.
The mean error for nn1_2_normal_ is 0.007994621592811366 for length 68297
====================
```

5 steps

```
In [73]: TIMESTEPS = 5
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "nn1_5"

In [74]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         hidden = Dense(100, activation='relu')(input_layer)
         output = Dense(DIM, activation='sigmoid')(hidden)

In [75]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [76]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.007452224144013598
Validation loss for final epoch is 0.006576215894776396
---------- Beginning tests for nn1_5 ----------
Testing on Normal data.
The mean error for nn1_5_normal_ is 0.0068011005026057565 for length 68294
====================
```

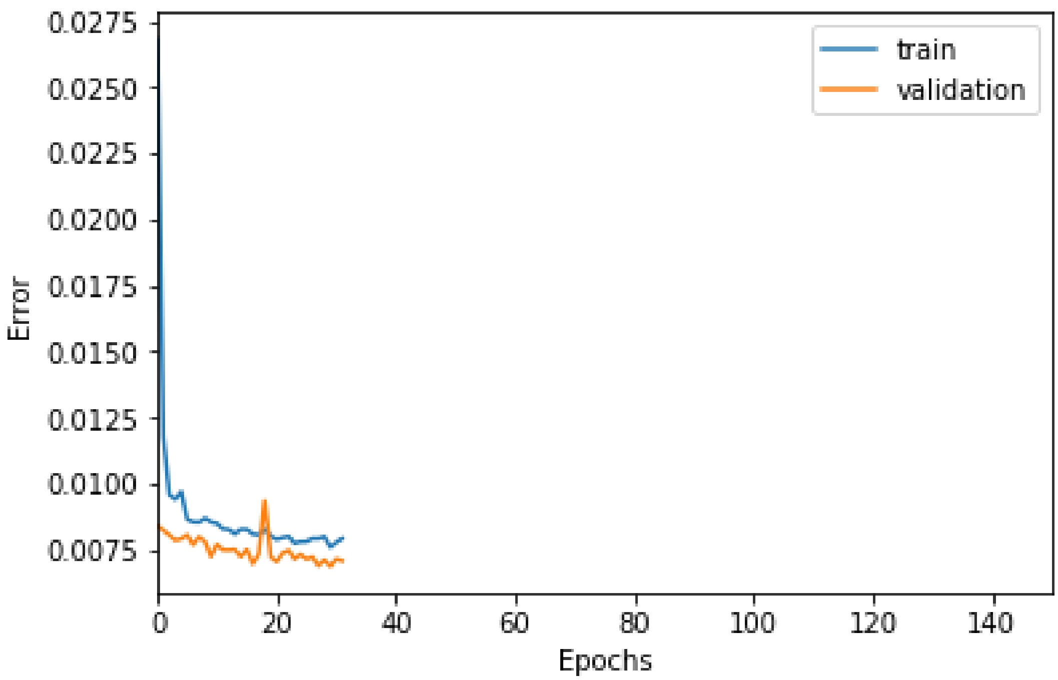
10 steps

```
In [77]: TIMESTEPS = 10
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "nn1_10"
```

```
In [78]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         hidden = Dense(100, activation='relu')(input_layer)
         output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [79]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [80]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.00793381834810134
Validation loss for final epoch is 0.007084297833265737
---------- Beginning tests for nn1_10 ----------
Testing on Normal data.
The mean error for nn1_10_normal_ is 0.0071015961934418085 for length 68289
====================
```

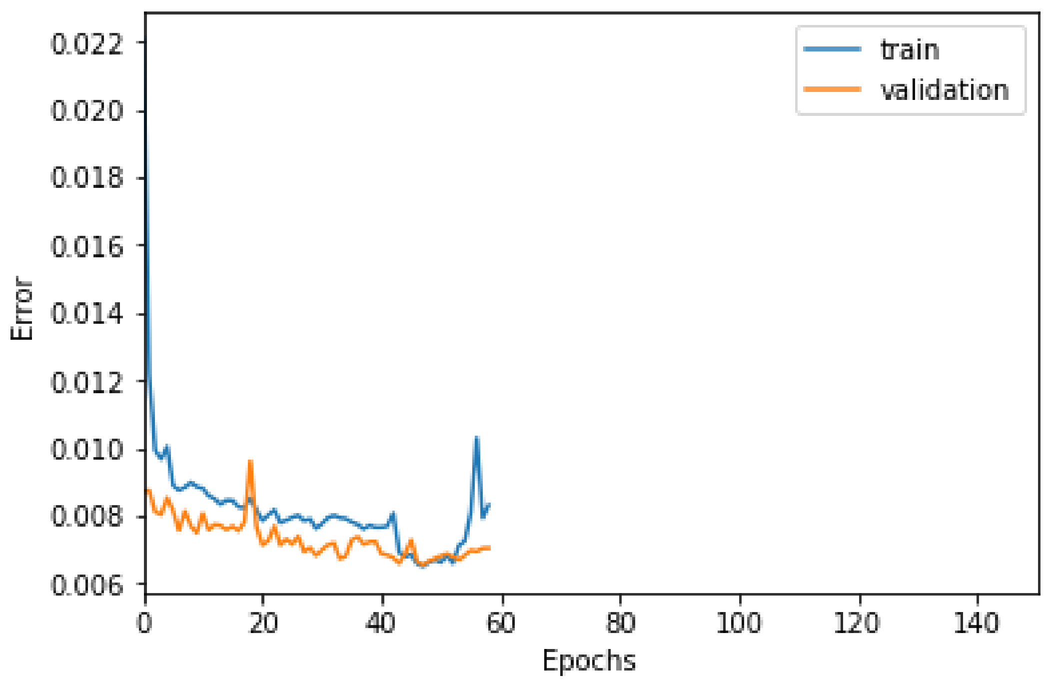
20 steps

```
In [81]: TIMESTEPS = 20
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "nn1_20"
```

```
In [82]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         hidden = Dense(100,activation='relu')(input_layer)
         output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [83]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [84]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008313262965297327
Validation loss for final epoch is 0.0070471914840163664
---------- Beginning tests for nn1_20 ----------
Testing on Normal data.
The mean error for nn1_20_normal_ is 0.007033562767864598 for length 68279
====================
```

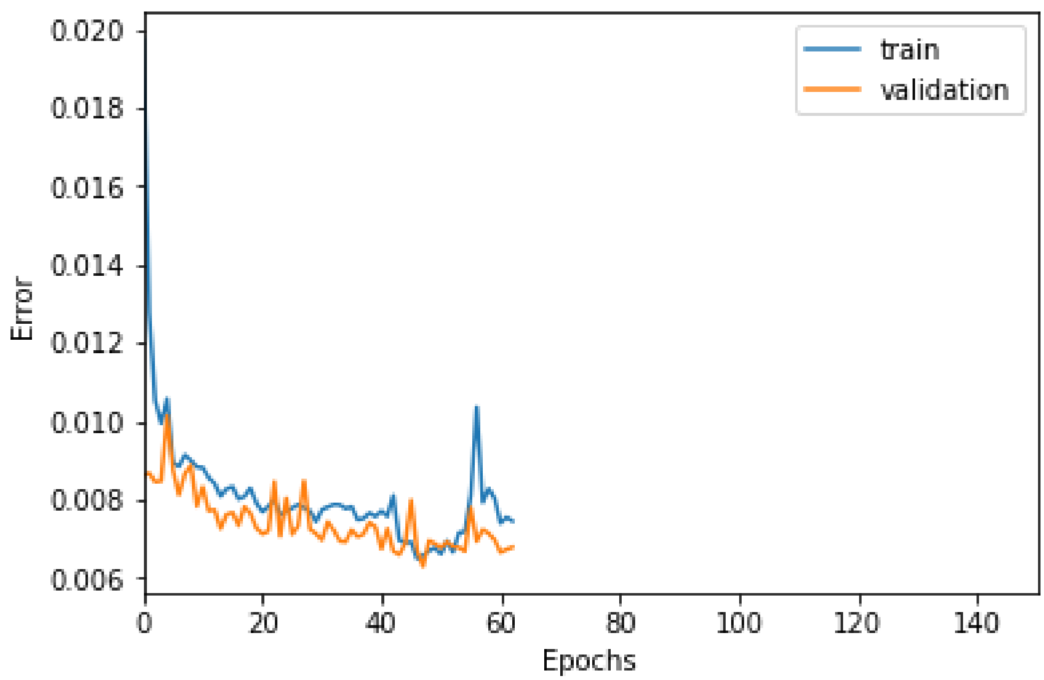
50 steps

```
In [85]: TIMESTEPS = 50
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "nn1_50"
```

```
In [86]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         hidden = Dense(100,activation='relu')(input_layer)
         output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [87]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [88]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.007449903451837599
Validation loss for final epoch is 0.006786971573252230 6
---------- Beginning tests for nn1_50 ----------
Testing on Normal data.
The mean error for nn1_50_normal_ is 0.006877856114368052 for length 68249
====================
```

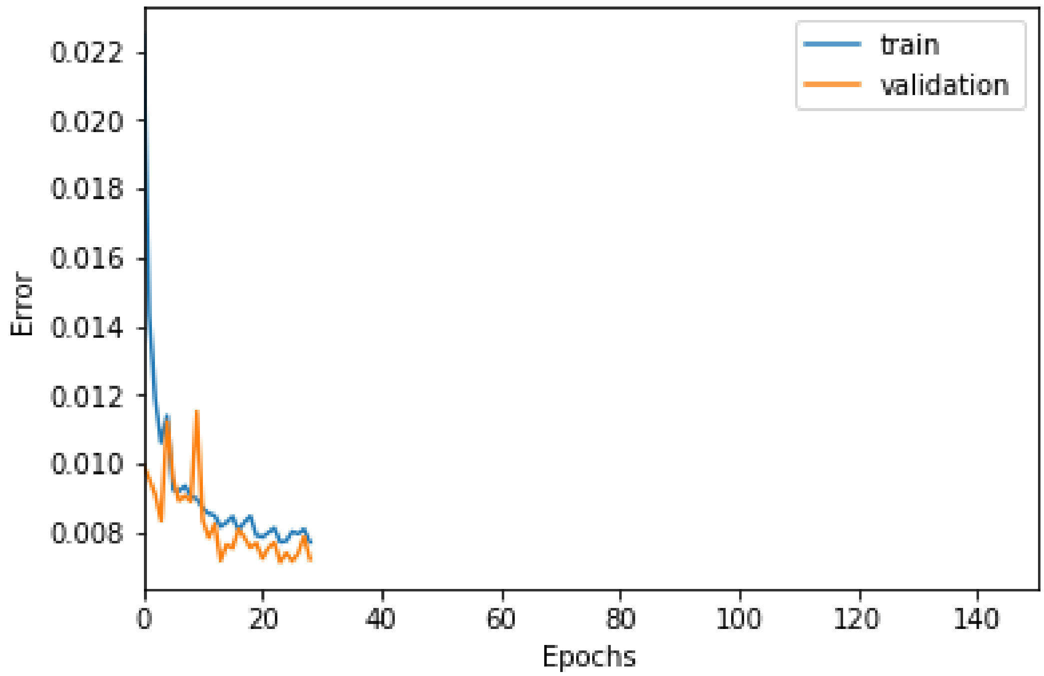
100 steps

```
In [89]: TIMESTEPS = 100
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "nn1_100"
```

```
In [90]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         hidden = Dense(100,activation='relu')(input_layer)
         output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [91]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [92]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.007719434232800268
Validation loss for final epoch is 0.007220762135460973
---------- Beginning tests for nn1_100 ----------
Testing on Normal data.
The mean error for nn1_100_normal_ is 0.00760213146233752 for length 68199
====================
```

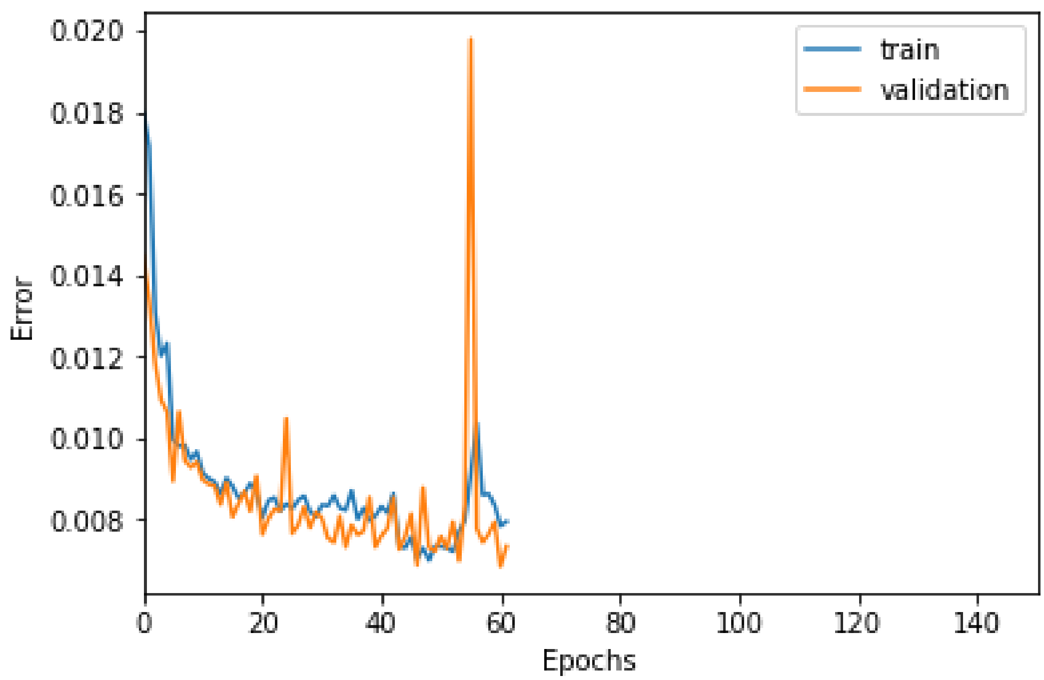
200 steps

```
In [93]: TIMESTEPS = 200
         DIM = 29
         tgen = flat_generator(X, TIMESTEPS)
         vgen = flat_generator(val_X, TIMESTEPS)
         name = "nn1_200"
```

```
In [94]: input_layer = Input(shape=(TIMESTEPS*DIM,))
         hidden = Dense(100,activation='relu')(input_layer)
         output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [95]: model = Model(input_layer, output)
         model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [96]: train(model, tgen, vgen, name=name)
         test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.007950572421657852
Validation loss for final epoch is 0.007343811719561927
---------- Beginning tests for nn1_200 ----------
Testing on Normal data.
The mean error for nn1_200_normal_ is 0.0072501510127501835 for length 68099
====================
```

1.11.3 NN with 2 hidden layers

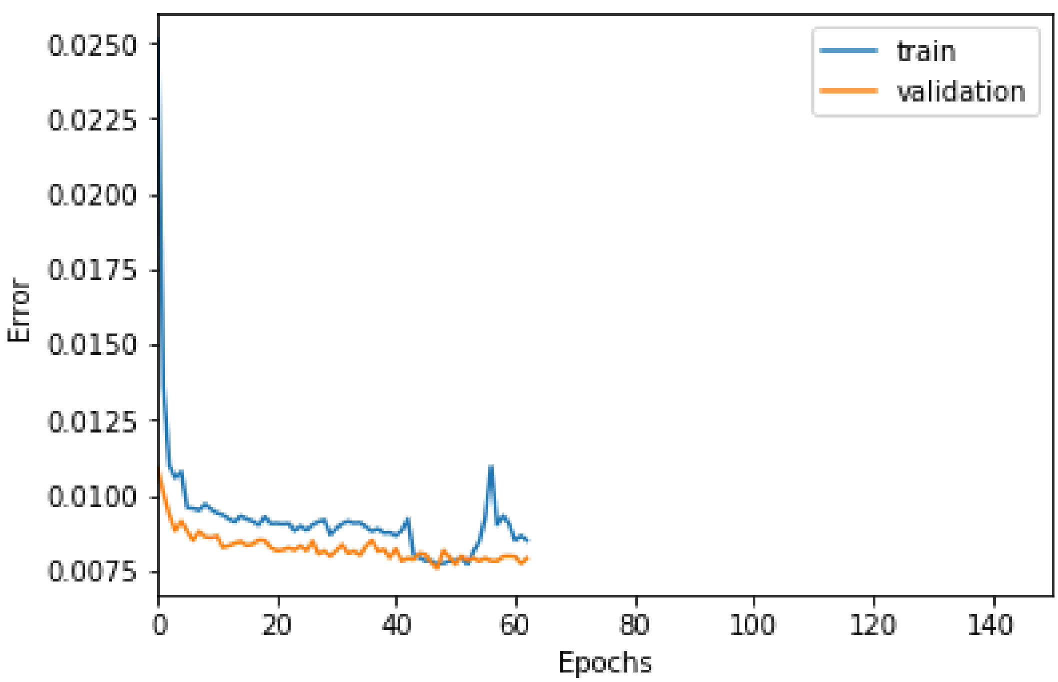
2 steps

In [97]:
```
TIMESTEPS = 2
DIM = 29
tgen = flat_generator(X, TIMESTEPS)
vgen = flat_generator(val_X, TIMESTEPS)
name = "nn2_2"
```

In [98]:
```
input_layer = Input(shape=(TIMESTEPS*DIM,))
hidden = Dense(500, activation='relu')(input_layer)
hidden = Dense(100, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [99]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [100]:
```
train(model, tgen, vgen, name=name)
test(model, name=name, window=TIMESTEPS)
```

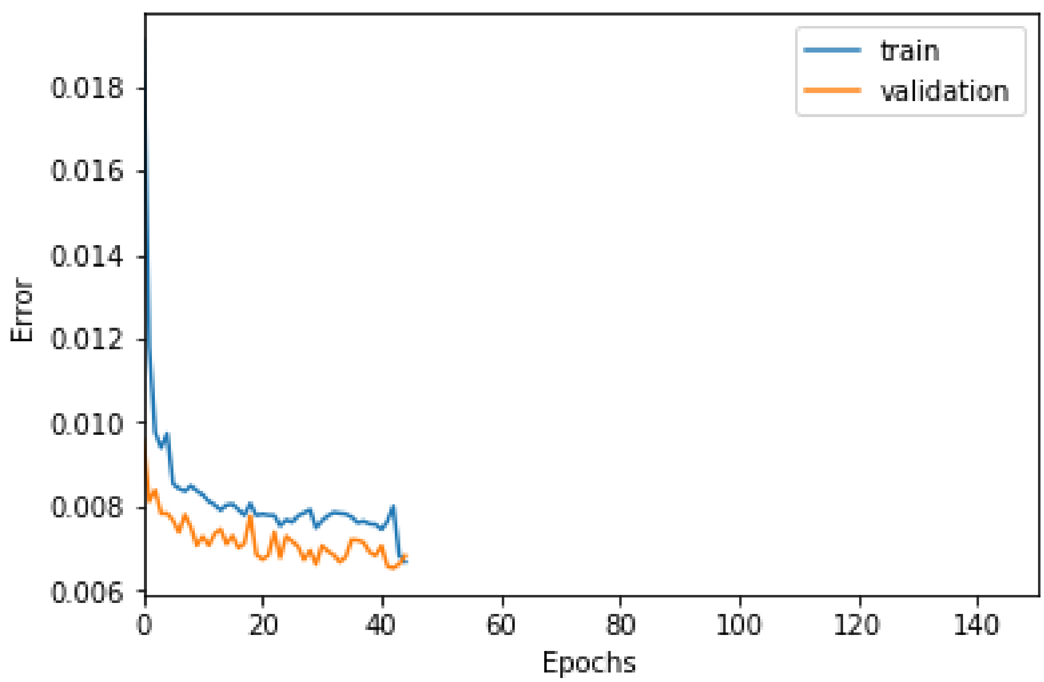



```
Training loss for final epoch is 0.008498040453880093
Validation loss for final epoch is 0.007903993673389778
---------- Beginning tests for nn2_2 ----------
Testing on Normal data.
The mean error for nn2_2_normal_ is 0.007917596801797305 for length 68297
```

```
====================
```

5 steps

```
In [101]: TIMESTEPS = 5
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn2_5"

In [102]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(500, activation='relu')(input_layer)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [103]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [104]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.0066789969558594744
Validation loss for final epoch is 0.006827179183368571
---------- Beginning tests for nn2_5 ----------
Testing on Normal data.
The mean error for nn2_5_normal_ is 0.006986421763700156 for length 68294
====================
```

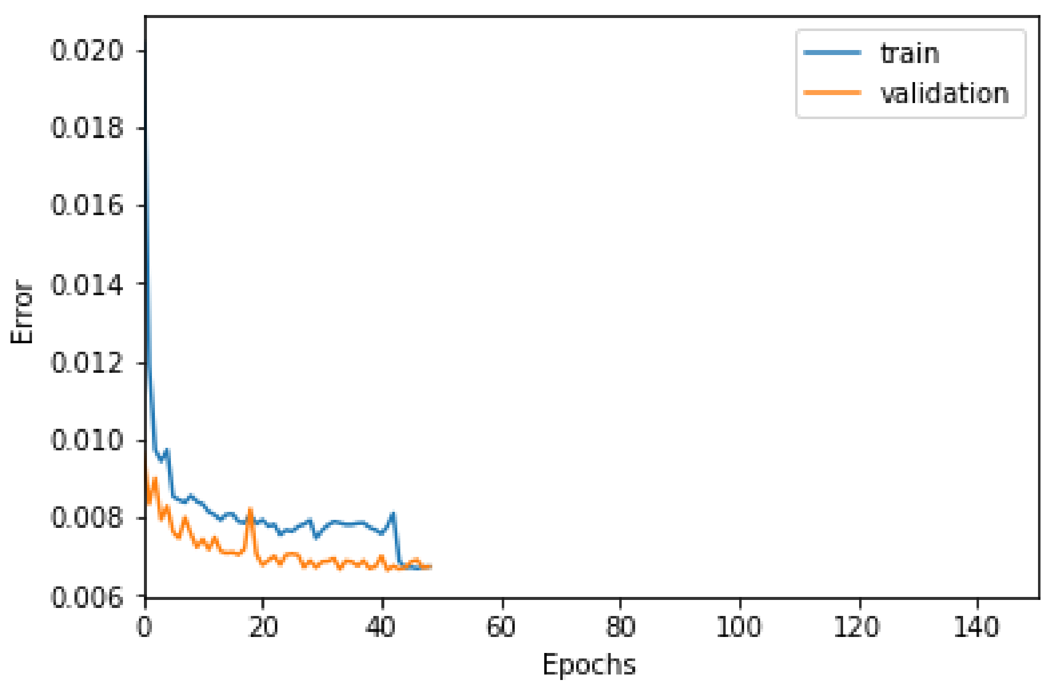
10 steps

In [105]:
```
TIMESTEPS = 10
DIM = 29
tgen = flat_generator(X, TIMESTEPS)
vgen = flat_generator(val_X, TIMESTEPS)
name = "nn2_10"
```

In [106]:
```
input_layer = Input(shape=(TIMESTEPS*DIM,))
hidden = Dense(500, activation='relu')(input_layer)
hidden = Dense(100, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [107]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [108]:
```
train(model, tgen, vgen, name=name)
test(model, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.0067363902067299935
Validation loss for final epoch is 0.006736550310859456
---------- Beginning tests for nn2_10 ----------
Testing on Normal data.
The mean error for nn2_10_normal_ is 0.006884008741104461 for length 68289
====================
```

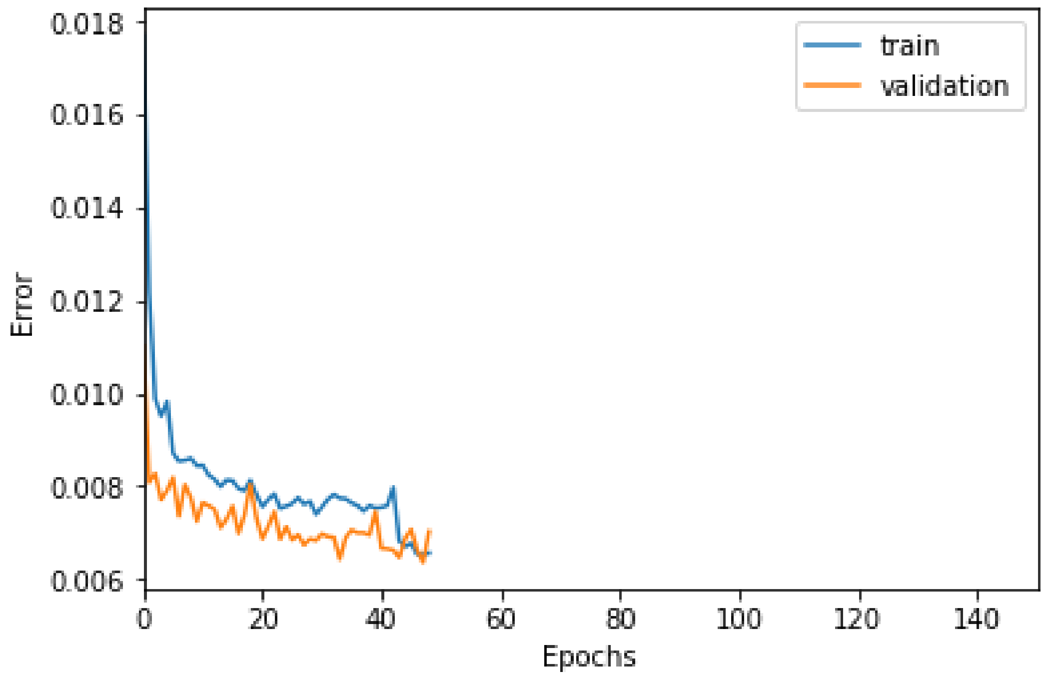
20 steps

```
In [109]: TIMESTEPS = 20
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn2_20"
```

```
In [110]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(500, activation='relu')(input_layer)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [111]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [112]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.006559579807100818
Validation loss for final epoch is 0.007027862660354003
---------- Beginning tests for nn2_20 ----------
Testing on Normal data.
The mean error for nn2_20_normal_ is 0.007108491733623256 for length 68279
====================
```

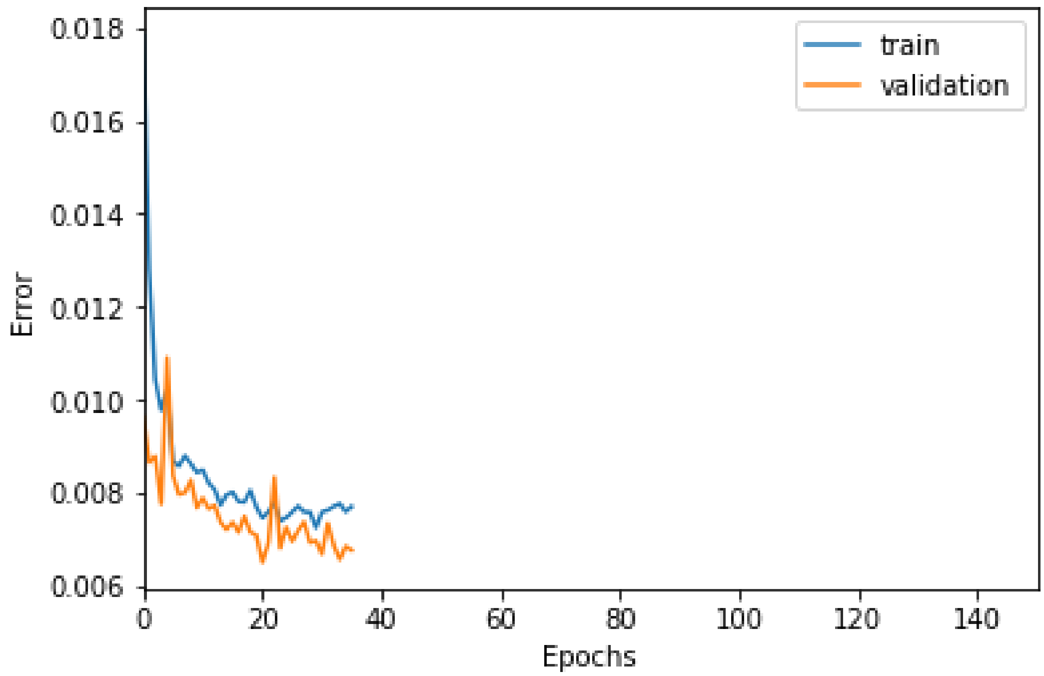
50 steps

In [113]:
```
TIMESTEPS = 50
DIM = 29
tgen = flat_generator(X, TIMESTEPS)
vgen = flat_generator(val_X, TIMESTEPS)
name = "nn2_50"
```

In [114]:
```
input_layer = Input(shape=(TIMESTEPS*DIM,))
hidden = Dense(500, activation='relu')(input_layer)
hidden = Dense(100, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [115]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [116]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.007712966272374615
Validation loss for final epoch is 0.006775653469841927
---------- Beginning tests for nn2_50 ----------
Testing on Normal data.
The mean error for nn2_50_normal_ is 0.006815644721617581 for length 68249
====================
```

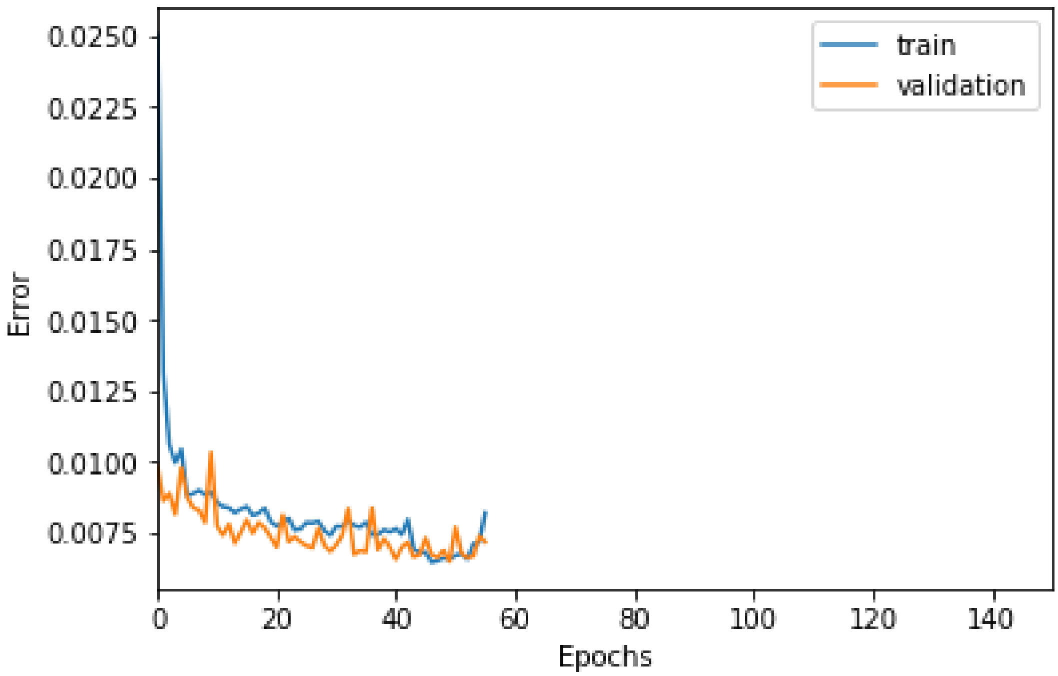
100 steps

```
In [117]: TIMESTEPS = 100
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn2_100"
```

```
In [118]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(500, activation='relu')(input_layer)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [119]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [120]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008214631992275827
Validation loss for final epoch is 0.007188862114795484
---------- Beginning tests for nn2_100 ----------
Testing on Normal data.
The mean error for nn2_100_normal_ is 0.007177533335801814 for length 68199
====================
```

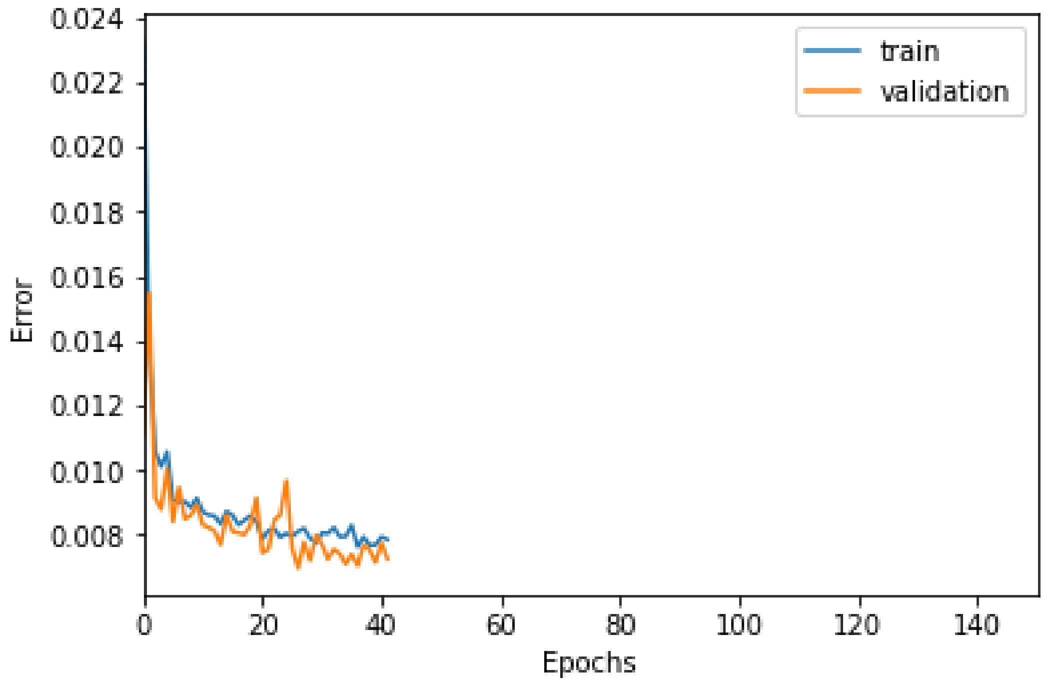
200 steps

```
In [121]: TIMESTEPS = 200
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn2_200"
```

```
In [122]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(500, activation='relu')(input_layer)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [123]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [124]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.00785774312983267
Validation loss for final epoch is 0.007260691675008275
---------- Beginning tests for nn2_200 ----------
Testing on Normal data.
The mean error for nn2_200_normal_ is 0.007535979158200196 for length 68099
====================
```

1.11.4 NN with 3 hidden layers

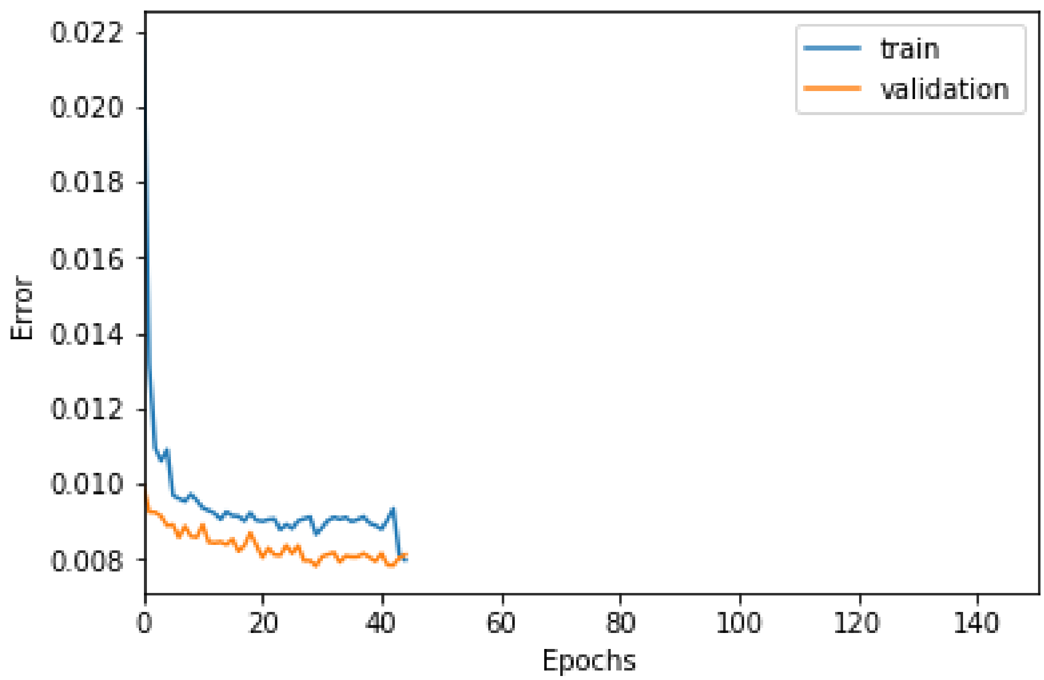
2 steps

In [125]:
```
TIMESTEPS = 2
DIM = 29
tgen = flat_generator(X, TIMESTEPS)
vgen = flat_generator(val_X, TIMESTEPS)
name = "nn3_2"
```

In [126]:
```
input_layer = Input(shape=(TIMESTEPS*DIM,))
hidden = Dense(1000, activation='relu')(input_layer)
hidden = Dense(500, activation='relu')(hidden)
hidden = Dense(100, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [127]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

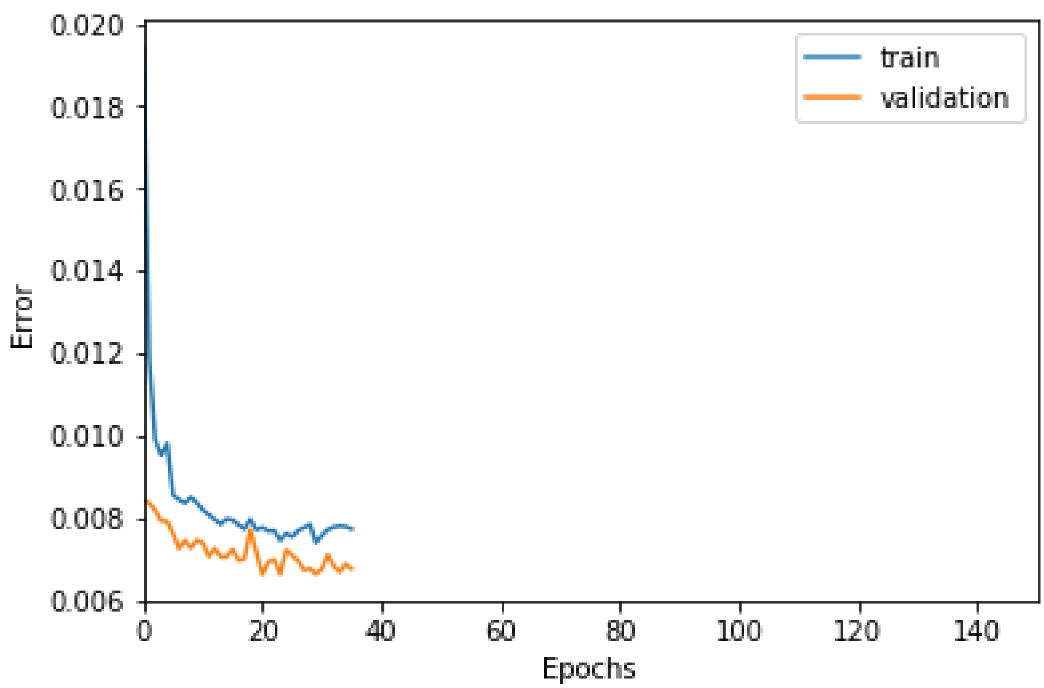
In [128]:
```
train(model, tgen, vgen, name=name)
test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.007967605119105428
Validation loss for final epoch is 0.008109678512904794
---------- Beginning tests for nn3_2 ----------
Testing on Normal data.
The mean error for nn3_2_normal_ is 0.00834088251664893 for length 68297
====================
```

5 steps

```
In [129]: TIMESTEPS = 5
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn3_5"

In [130]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(1000, activation='relu')(input_layer)
          hidden = Dense(500, activation='relu')(hidden)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [131]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [132]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.0077323188508162275
Validation loss for final epoch is 0.006765582909691147
---------- Beginning tests for nn3_5 ----------
Testing on Normal data.
The mean error for nn3_5_normal_ is 0.006954202823170684 for length 68294
====================
```

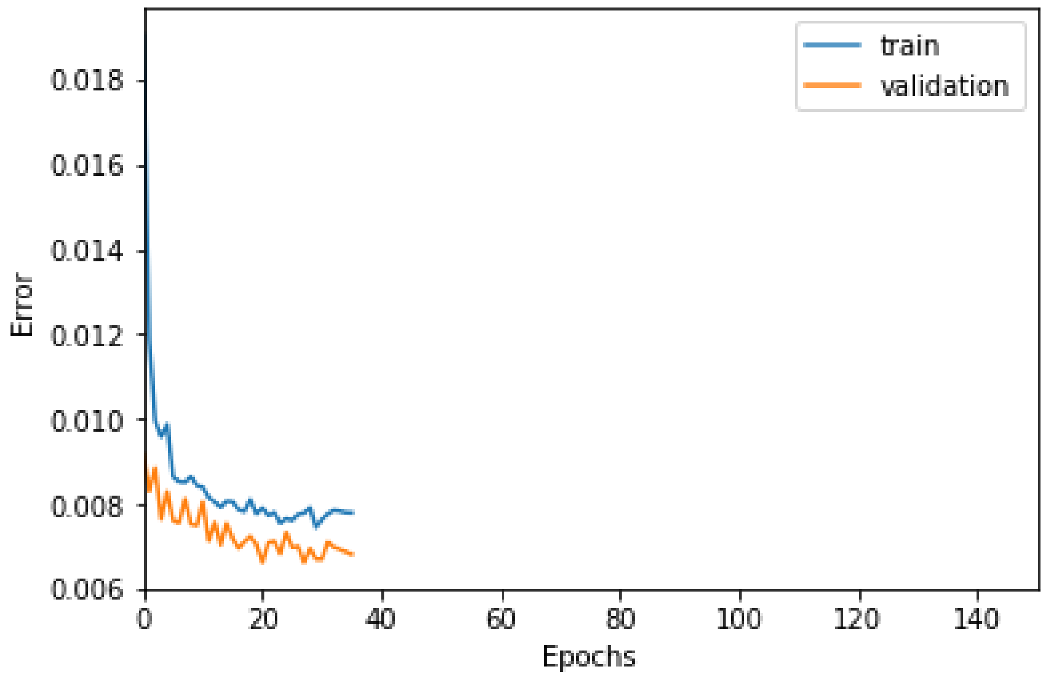
10 steps

In [133]:
```
TIMESTEPS = 10
DIM = 29
tgen = flat_generator(X, TIMESTEPS)
vgen = flat_generator(val_X, TIMESTEPS)
name = "nn3_10"
```

In [134]:
```
input_layer = Input(shape=(TIMESTEPS*DIM,))
hidden = Dense(1000, activation='relu')(input_layer)
hidden = Dense(500, activation='relu')(hidden)
hidden = Dense(100, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [135]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [136]:
```
train(model, tgen, vgen, name=name)
test(model, name=name, window=TIMESTEPS)
```



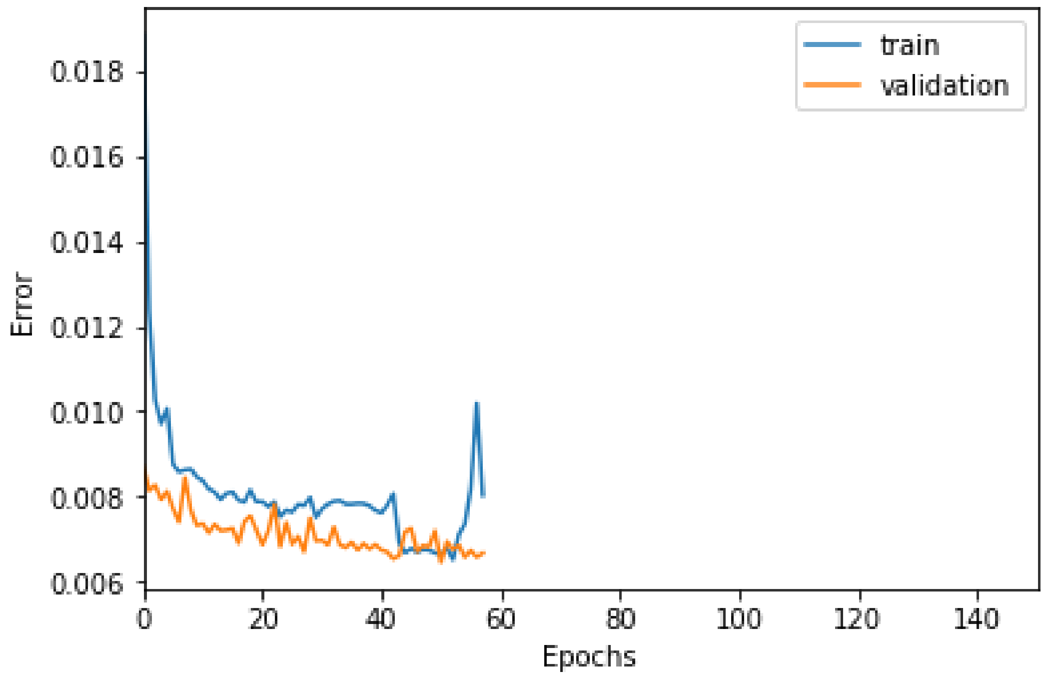

```
Training loss for final epoch is 0.007804850130574778
Validation loss for final epoch is 0.006826548885670491
---------- Beginning tests for nn3_10 ----------
Testing on Normal data.
The mean error for nn3_10_normal_ is 0.007050310612876376 for length 68289
====================
```

20 steps

```
In [137]: TIMESTEPS = 20
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn3_20"

In [138]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(1000, activation='relu')(input_layer)
          hidden = Dense(500, activation='relu')(hidden)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [139]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [140]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```

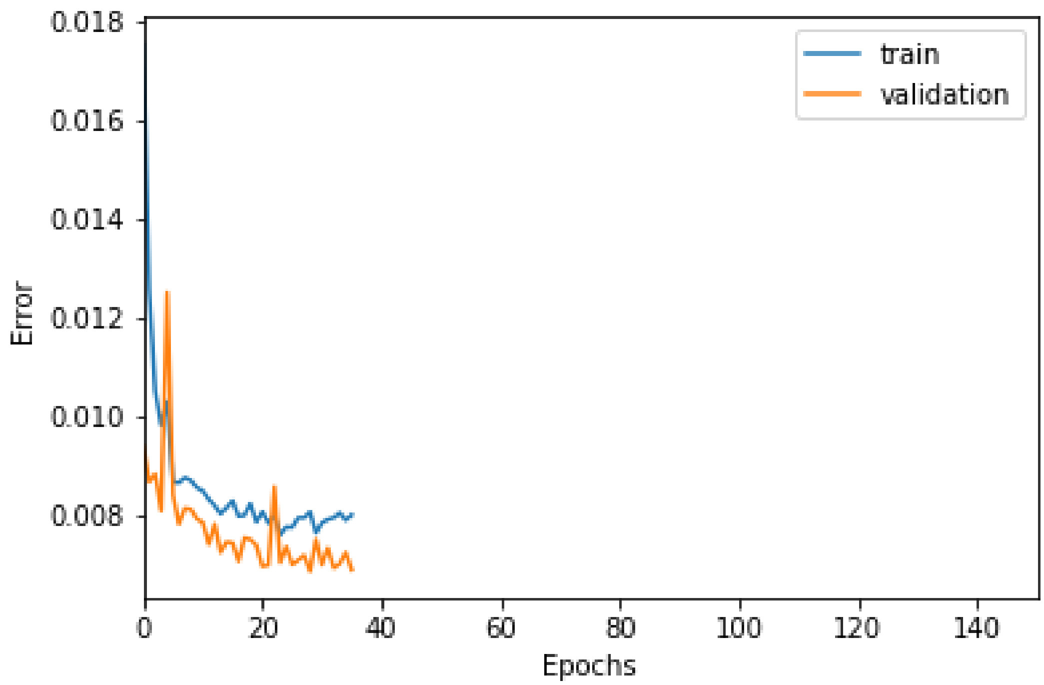



```
Training loss for final epoch is 0.008033045396790844
Validation loss for final epoch is 0.006671784618869424
---------- Beginning tests for nn3_20 ----------
Testing on Normal data.
The mean error for nn3_20_normal_ is 0.007110295118845597 for length 68279
====================
```

50 steps

```
In [141]: TIMESTEPS = 50
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn3_50"
```

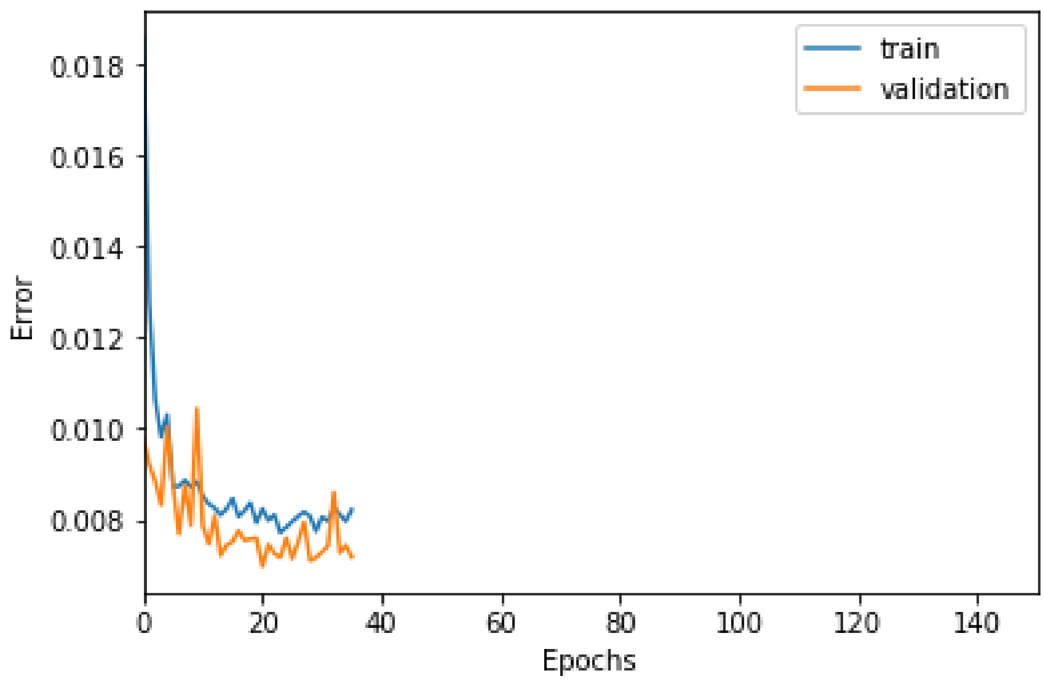
```
In [142]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(1000, activation='relu')(input_layer)
          hidden = Dense(500, activation='relu')(hidden)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [143]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [144]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008002389085246 25
Validation loss for final epoch is 0.0068953298605047165
---------- Beginning tests for nn3_50 ----------
Testing on Normal data.
The mean error for nn3_50_normal_ is 0.007024872893617079 for length 68249
====================
```

100 steps

```
In [145]: TIMESTEPS = 100
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn3_100"

In [146]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(1000, activation='relu')(input_layer)
          hidden = Dense(500, activation='relu')(hidden)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [147]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [148]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008213097173720598
Validation loss for final epoch is 0.007180382827762515
---------- Beginning tests for nn3_100 ----------
Testing on Normal data.
The mean error for nn3_100_normal_ is 0.007391991955082882 for length 68199
====================
```

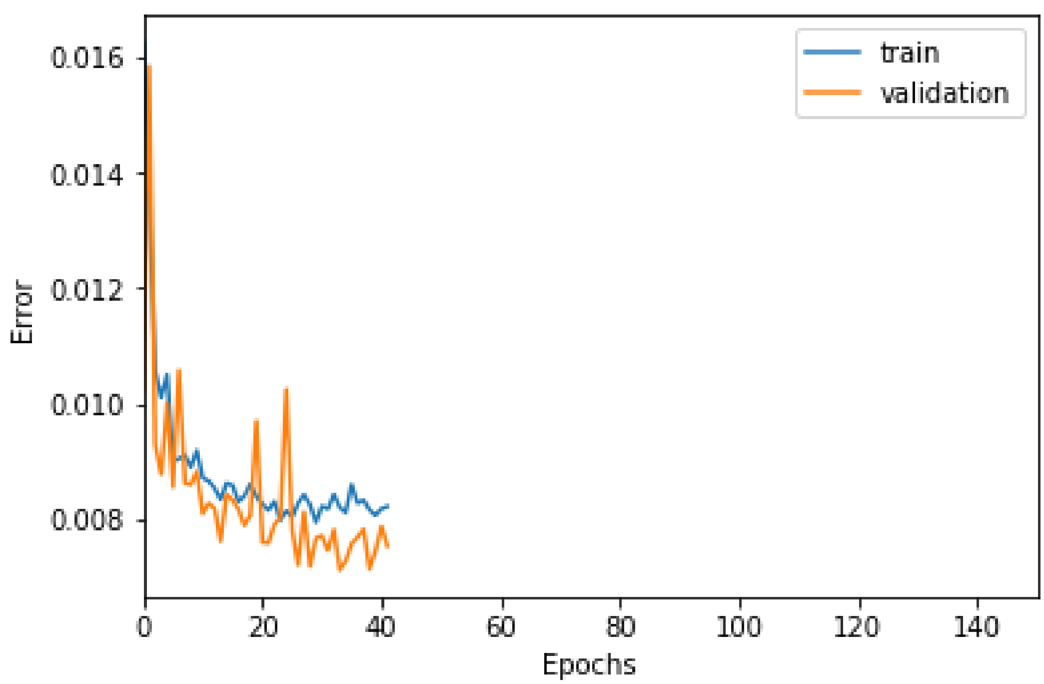
200 steps

```
In [149]: TIMESTEPS = 200
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS)
          vgen = flat_generator(val_X, TIMESTEPS)
          name = "nn3_200"
```

```
In [150]: input_layer = Input(shape=(TIMESTEPS*DIM,))
          hidden = Dense(1000, activation='relu')(input_layer)
          hidden = Dense(500, activation='relu')(hidden)
          hidden = Dense(100, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [151]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [152]: train(model, tgen, vgen, name=name)
          test(model, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.008216266793315299
Validation loss for final epoch is 0.007529144670930691
---------- Beginning tests for nn3_200 ----------
Testing on Normal data.
The mean error for nn3_200_normal_ is 0.007869367744395585 for length 68099
====================
```

1.11.5 RNN with 1 GRU layers

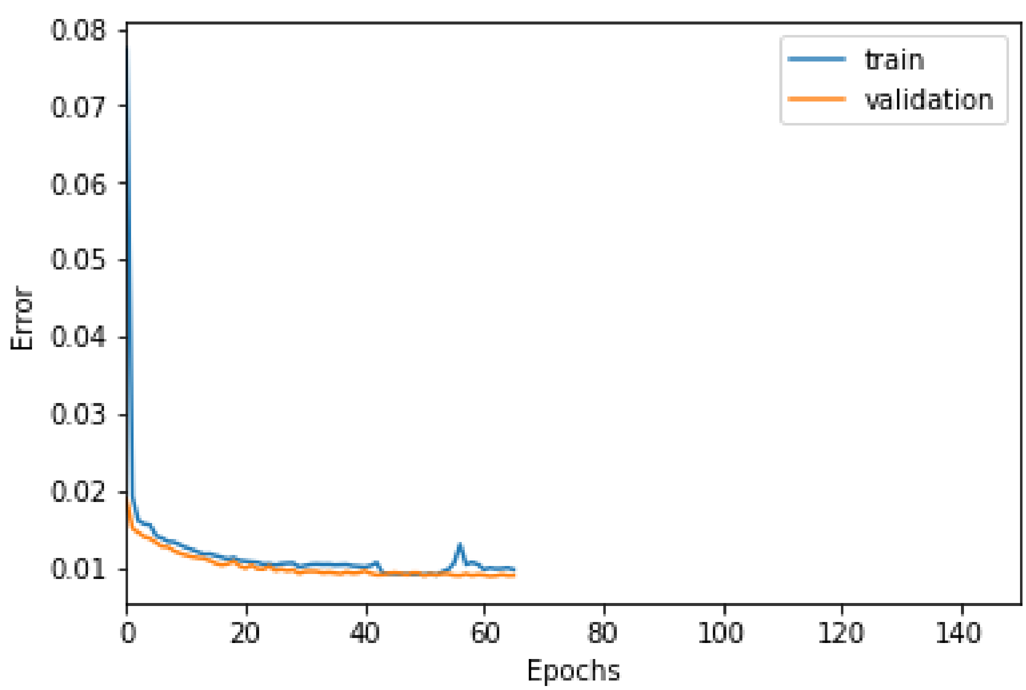
2 steps

In [153]:
```
TIMESTEPS = 2
DIM = 29
tgen = flat_generator(X, TIMESTEPS,0)
vgen = flat_generator(val_X, TIMESTEPS,0)
name = "gru1_2"
```

In [154]:
```
input_layer = Input(shape=(TIMESTEPS,DIM))
hidden = GRU(10, activation='relu')(input_layer)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [155]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [156]:
```
train(model, tgen, vgen, name=name)
test(model, ravel=0, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.009706683627562598
Validation loss for final epoch is 0.008947467094752937
---------- Beginning tests for gru1_2 ----------
Testing on Normal data.
The mean error for gru1_2_normal_ is 0.008993862685591608 for length 68297
====================
```

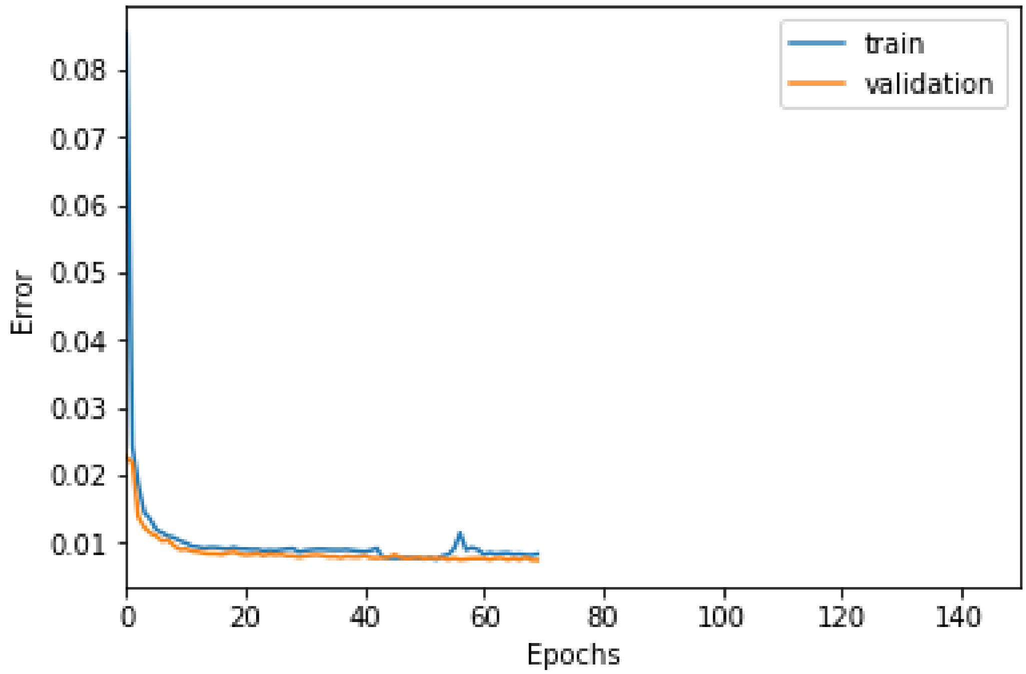
5 steps

In [157]:
```
TIMESTEPS = 5
DIM = 29
tgen = flat_generator(X, TIMESTEPS,0)
vgen = flat_generator(val_X, TIMESTEPS, 0)
name = "gru1_5"
```

In [158]:
```
input_layer = Input(shape=(TIMESTEPS,DIM))
hidden = GRU(10, activation='relu')(input_layer)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [159]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [160]:
```
train(model, tgen, vgen, name=name)
test(model, ravel=0, name=name, window=TIMESTEPS)
```

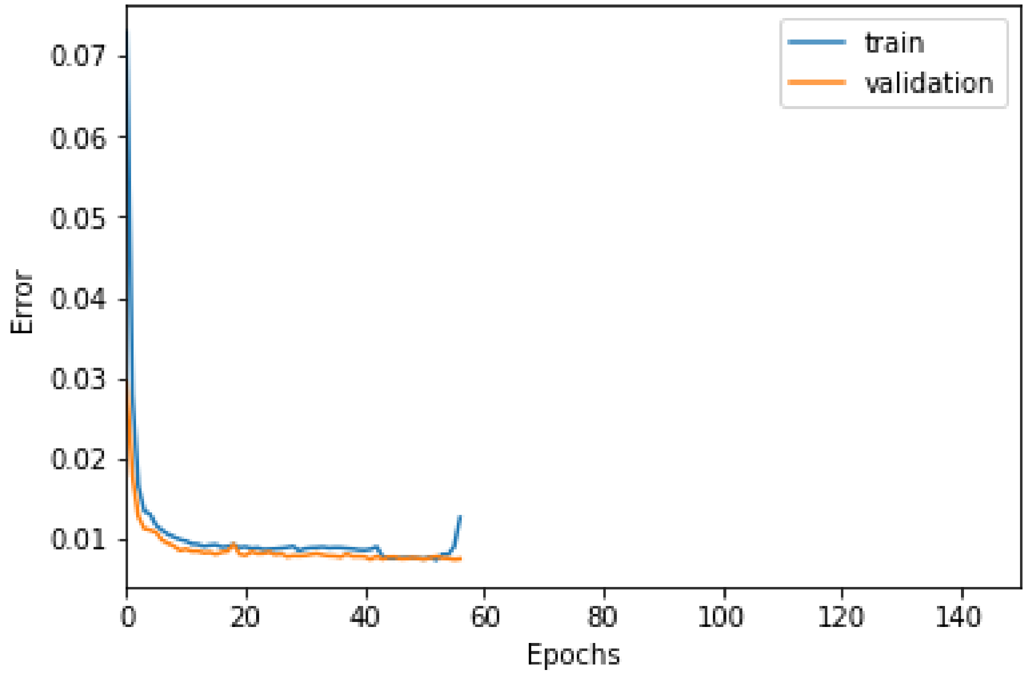



```
Training loss for final epoch is 0.008296772385830991
Validation loss for final epoch is 0.0073729068447137254
---------- Beginning tests for gru1_5 ----------
Testing on Normal data.
The mean error for gru1_5_normal_ is 0.007549772136475193 for length 68294
====================
```

10 steps

```
In [161]: TIMESTEPS = 10
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS, 0)
          vgen = flat_generator(val_X, TIMESTEPS, 0)
          name = "gru1_10"

In [162]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu')(input_layer)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [163]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [164]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```



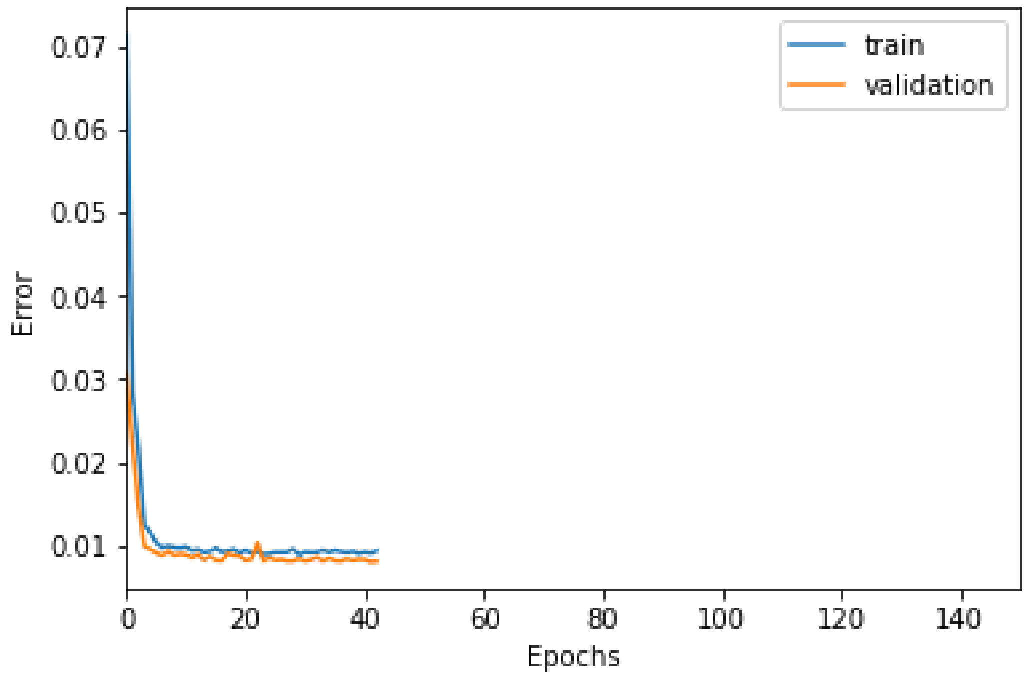

```
Training loss for final epoch is 0.012652858572313562
Validation loss for final epoch is 0.007511475227773189
---------- Beginning tests for gru1_10 ----------
Testing on Normal data.
The mean error for gru1_10_normal_ is 0.007927752853726001 for length 68289
====================
```

20 steps

```
In [165]: TIMESTEPS = 20
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru1_20"

In [166]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu')(input_layer)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [167]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [168]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```

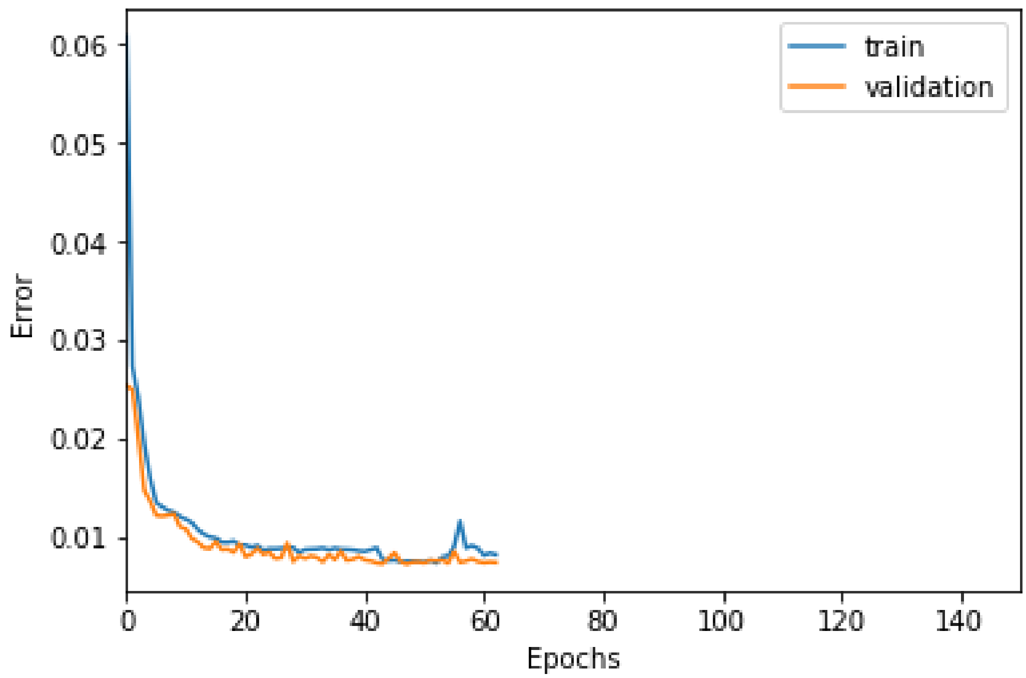



```
Training loss for final epoch is 0.009339298318489455
Validation loss for final epoch is 0.008080611640121789
---------- Beginning tests for gru1_20 ----------
Testing on Normal data.
The mean error for gru1_20_normal_ is 0.008391362892298393 for length 68279
====================
```

50 steps

```
In [169]: TIMESTEPS = 50
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru1_50"
```

```
In [170]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu')(input_layer)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [171]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [172]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008299405021243728
Validation loss for final epoch is 0.007497074310318567
---------- Beginning tests for gru1_50 ----------
Testing on Normal data.
The mean error for gru1_50_normal_ is 0.007770220456521439 for length 68249
====================
```

100 steps

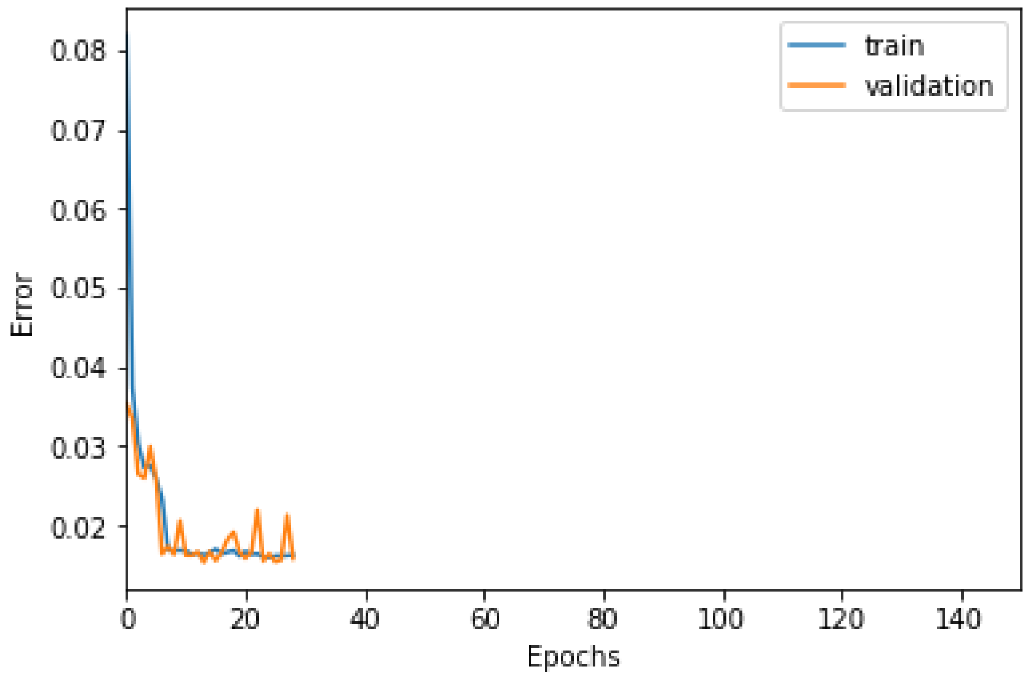
```
In [173]: TIMESTEPS = 100
          DIM = 29
```

```
tgen = flat_generator(X, TIMESTEPS,0)
vgen = flat_generator(val_X, TIMESTEPS,0)
name = "gru1_100"
```

```
In [174]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu')(input_layer)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [175]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [176]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.01631342939264141
Validation loss for final epoch is 0.01585128901596181
---------- Beginning tests for gru1_100 ----------
Testing on Normal data.
The mean error for gru1_100_normal_ is 0.016431981388441395 for length 68199
====================
```

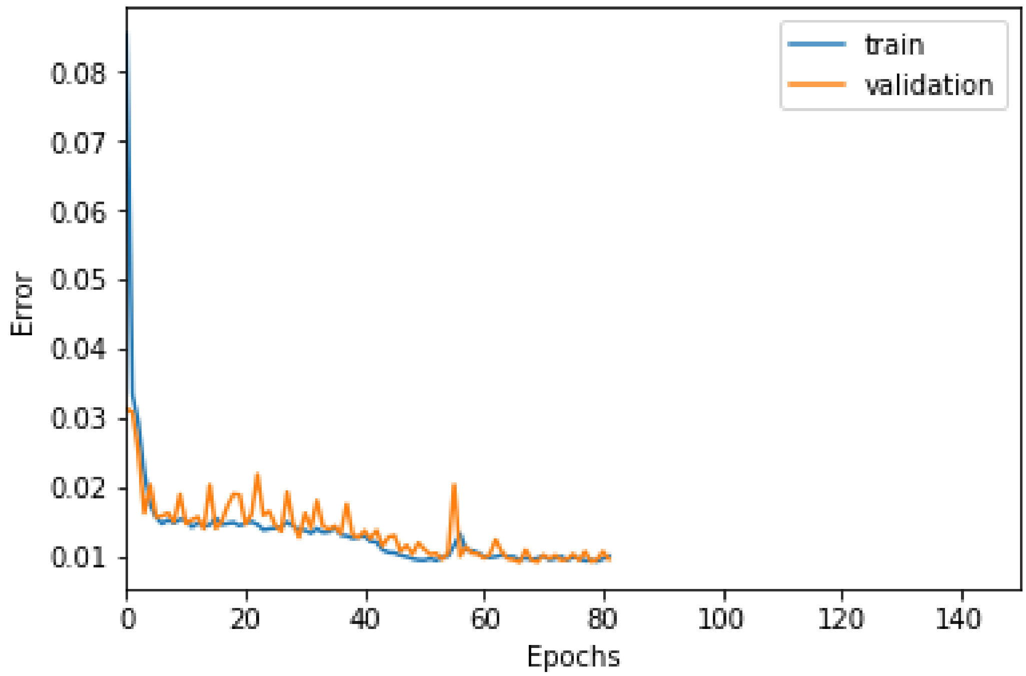
200 steps

```
In [177]: TIMESTEPS = 200
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru1_200"
```

```
In [178]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu')(input_layer)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [179]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [180]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.010022789542097598
Validation loss for final epoch is 0.009562388401012869
---------- Beginning tests for gru1_200 ----------
Testing on Normal data.
The mean error for gru1_200_normal_ is 0.010689449162389751 for length 68099
====================
```

1.11.6 RNN with 2 GRU layers

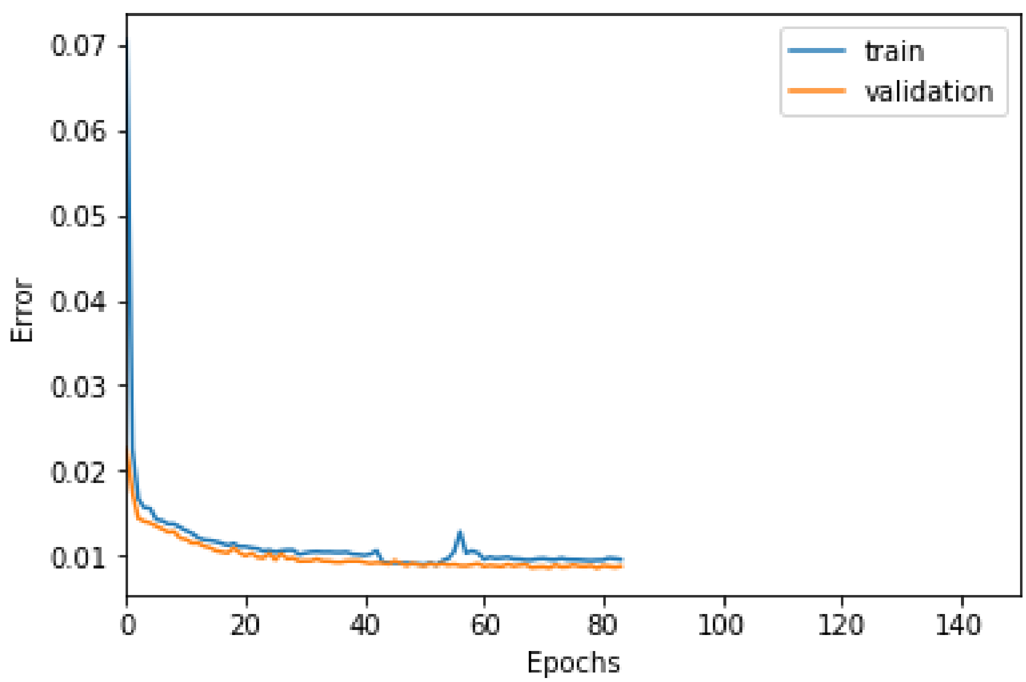
2 steps

```
In [181]: TIMESTEPS = 2
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru2_2"
```

```
In [182]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [183]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [184]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```

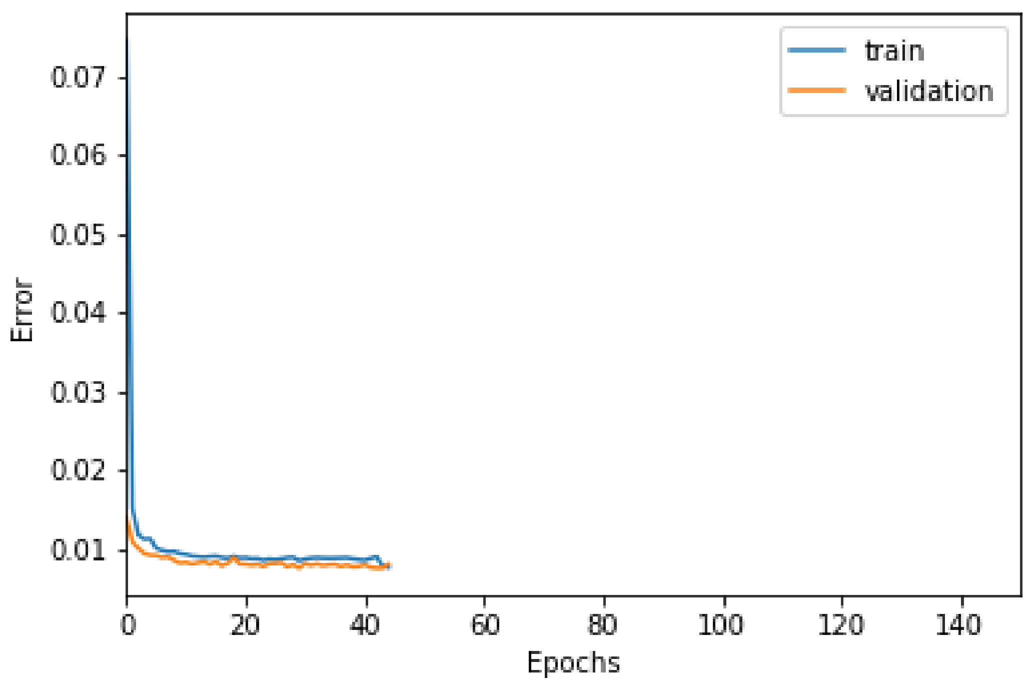



```
Training loss for final epoch is 0.009525582371163181
Validation loss for final epoch is 0.008728021897375584
---------- Beginning tests for gru2_2 ----------
Testing on Normal data.
The mean error for gru2_2_normal_ is 0.009121337264530432 for length 68297
```

```
====================
```

5 steps

```
In [185]: TIMESTEPS = 5
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS, 0)
          name = "gru2_5"

In [186]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [187]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [188]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.007584470974630676
Validation loss for final epoch is 0.007987136821029708
---------- Beginning tests for gru2_5 ----------
Testing on Normal data.
The mean error for gru2_5_normal_ is 0.008080197580486092 for length 68294
====================
```

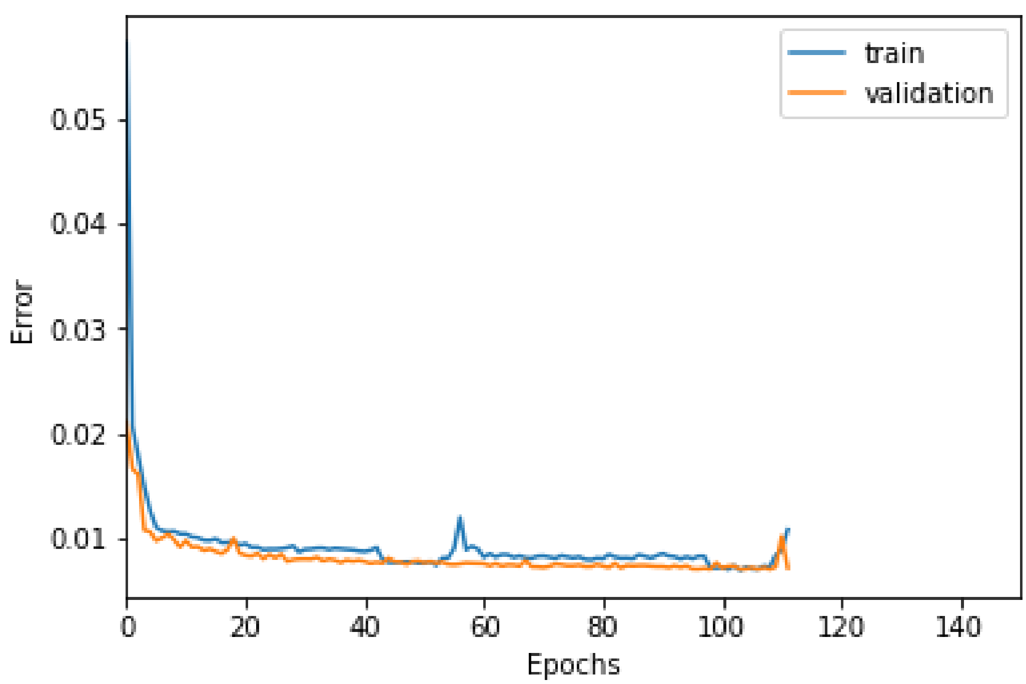
10 steps

In [189]:
```
TIMESTEPS = 10
DIM = 29
tgen = flat_generator(X, TIMESTEPS, 0)
vgen = flat_generator(val_X, TIMESTEPS, 0)
name = "gru2_10"
```

In [190]:
```
input_layer = Input(shape=(TIMESTEPS,DIM))
hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
hidden = GRU(10, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [191]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [192]:
```
train(model, tgen, vgen, name=name)
test(model, ravel=0, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.010848661084892228
Validation loss for final epoch is 0.007174341501900926
---------- Beginning tests for gru2_10 ----------
Testing on Normal data.
The mean error for gru2_10_normal_ is 0.0076239894978364035 for length 68289
====================
```

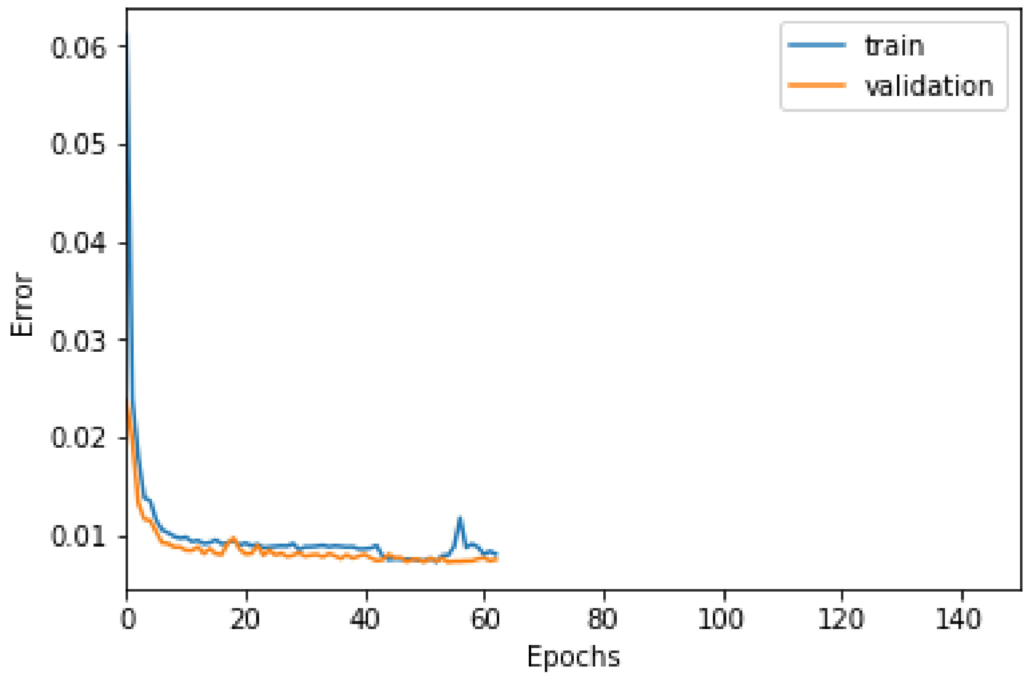
20 steps

In [193]:
```
TIMESTEPS = 20
DIM = 29
tgen = flat_generator(X, TIMESTEPS,0)
vgen = flat_generator(val_X, TIMESTEPS,0)
name = "gru2_20"
```

In [194]:
```
input_layer = Input(shape=(TIMESTEPS,DIM))
hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
hidden = GRU(10, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [195]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [196]:
```
train(model, tgen, vgen, name=name)
test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008011758126784115
Validation loss for final epoch is 0.007475883128354326
---------- Beginning tests for gru2_20 ----------
Testing on Normal data.
The mean error for gru2_20_normal_ is 0.007807341381850342 for length 68279
====================
```

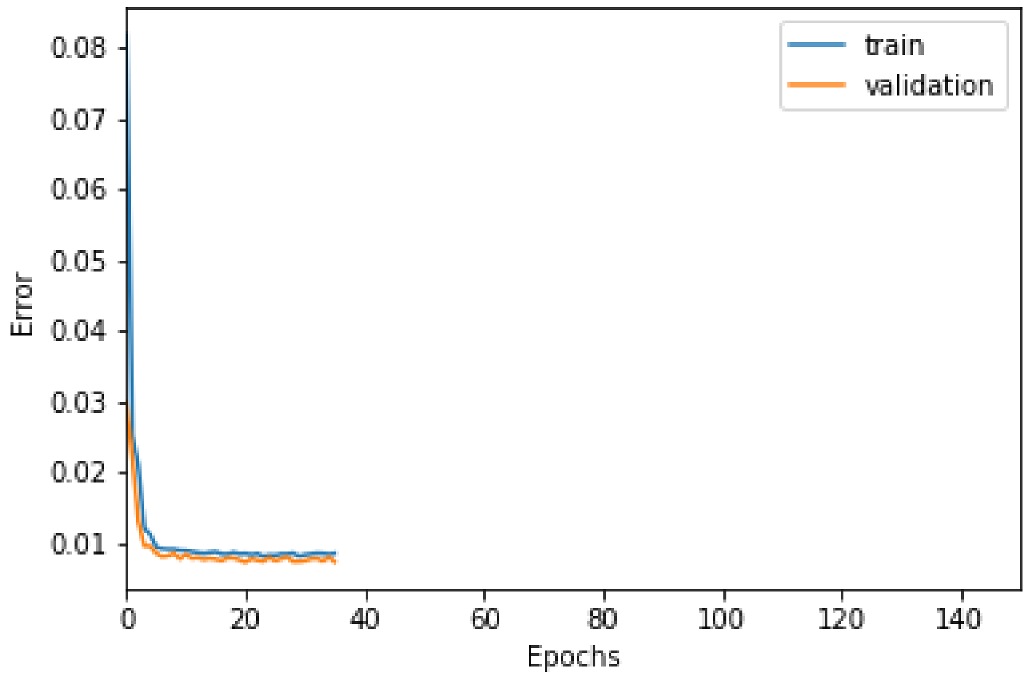
50 steps

```
In [197]: TIMESTEPS = 50
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru2_50"
```

```
In [198]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [199]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [200]:
```
train(model, tgen, vgen, name=name)
test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008501599075389095
Validation loss for final epoch is 0.007305883733206429
---------- Beginning tests for gru2_50 ----------
Testing on Normal data.
The mean error for gru2_50_normal_ is 0.007478376398318241 for length 68249
====================
```

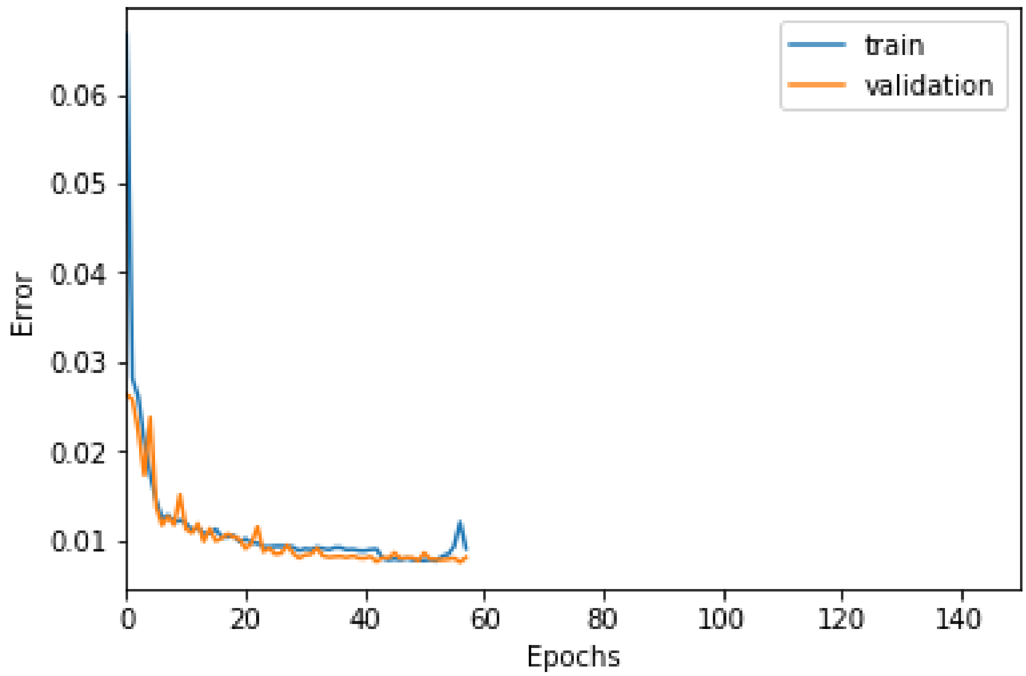
100 steps

In [201]:
```
TIMESTEPS = 100
DIM = 29
tgen = flat_generator(X, TIMESTEPS,0)
vgen = flat_generator(val_X, TIMESTEPS,0)
name = "gru2_100"
```

In [202]:
```
input_layer = Input(shape=(TIMESTEPS,DIM))
hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
hidden = GRU(10, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [203]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [204]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```

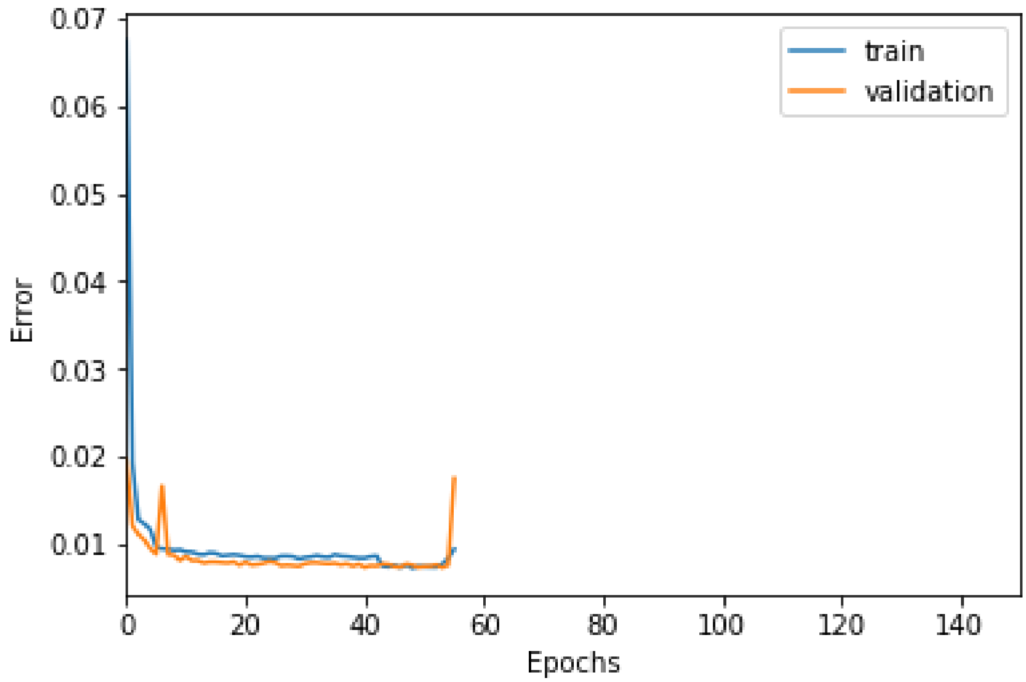



```
Training loss for final epoch is 0.009000581403728574
Validation loss for final epoch is 0.00802975850342773
---------- Beginning tests for gru2_100 ----------
Testing on Normal data.
The mean error for gru2_100_normal_ is 0.00790599778056267 for length 68199
====================
```

200 steps

```
In [205]: TIMESTEPS = 200
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru2_200"
```

```
In [206]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [207]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [208]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```

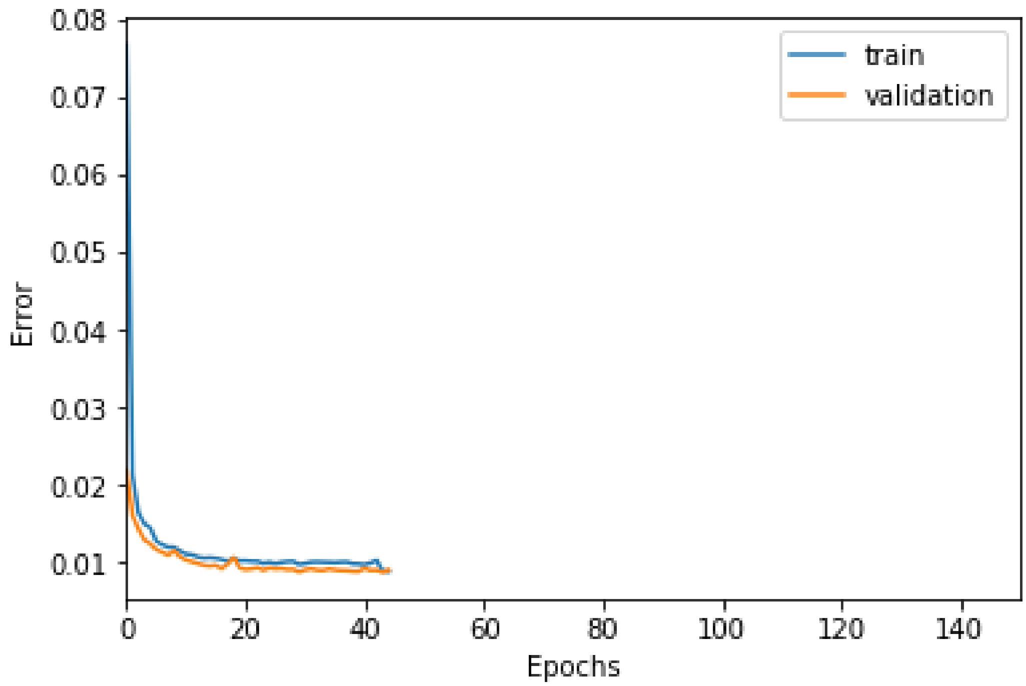



```
Training loss for final epoch is 0.009445819566608407
Validation loss for final epoch is 0.017511844133026897
---------- Beginning tests for gru2_200 ----------
Testing on Normal data.
The mean error for gru2_200_normal_ is 0.018348760026304353 for length 68099
====================
```

1.11.7 RNN with 3 GRU layers

2 steps

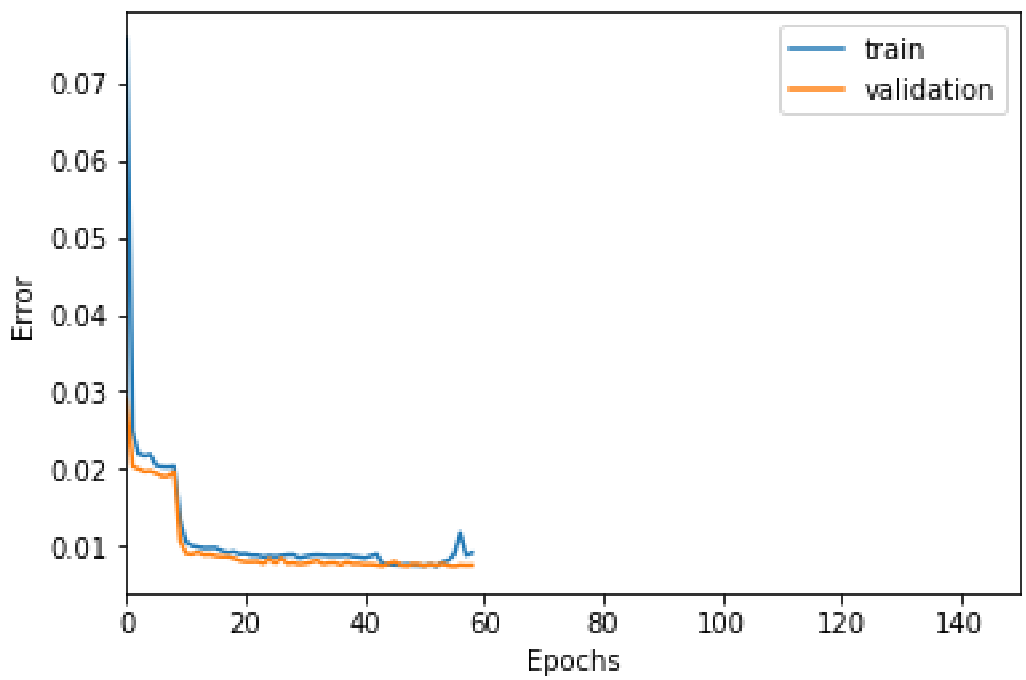
```
In [209]: TIMESTEPS = 2
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru3_2"

In [210]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu', return_sequences=True)(hidden)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [211]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [212]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008843629790702835
Validation loss for final epoch is 0.009052777277538553
---------- Beginning tests for gru3_2 ----------
Testing on Normal data.
The mean error for gru3_2_normal_ is 0.009473623802419293 for length 68297
====================
```

5 steps

```
In [213]: TIMESTEPS = 5
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS, 0)
          vgen = flat_generator(val_X, TIMESTEPS, 0)
          name = "gru3_5"

In [214]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu', return_sequences=True)(hidden)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [215]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [216]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.009115311296773143
Validation loss for final epoch is 0.0074810532400151715
---------- Beginning tests for gru3_5 ----------
Testing on Normal data.
The mean error for gru3_5_normal_ is 0.0075476083905910395 for length 68294
====================
```

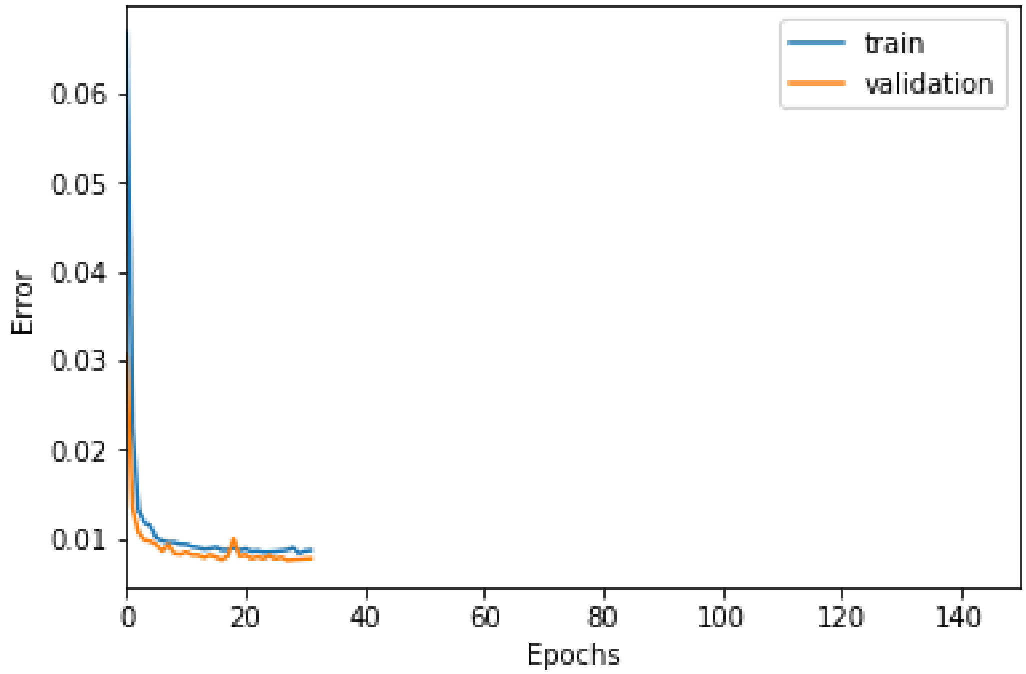
10 steps

In [217]:
```
TIMESTEPS = 10
DIM = 29
tgen = flat_generator(X, TIMESTEPS, 0)
vgen = flat_generator(val_X, TIMESTEPS, 0)
name = "gru3_10"
```

In [218]:
```
input_layer = Input(shape=(TIMESTEPS,DIM))
hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
hidden = GRU(10, activation='relu', return_sequences=True)(hidden)
hidden = GRU(10, activation='relu')(hidden)
output = Dense(DIM, activation='sigmoid')(hidden)
```

In [219]:
```
model = Model(input_layer, output)
model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

In [220]:
```
train(model, tgen, vgen, name=name)
test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008746968768769875
Validation loss for final epoch is 0.007804992166813463
---------- Beginning tests for gru3_10 ----------
Testing on Normal data.
The mean error for gru3_10_normal_ is 0.007801755871874415 for length 68289
====================
```

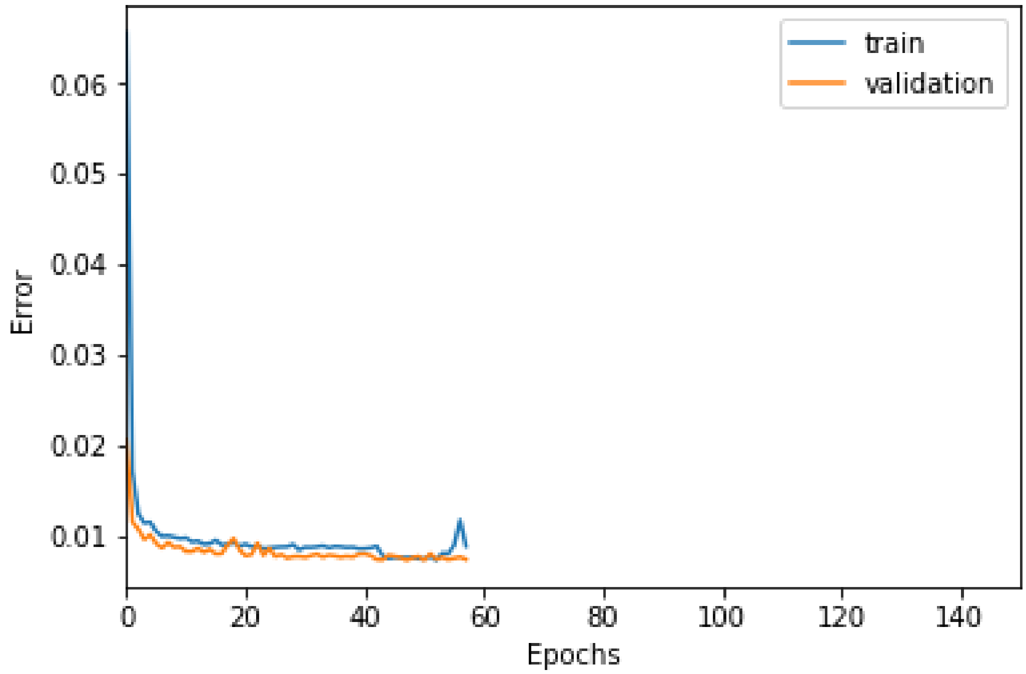
20 steps

```
In [221]: TIMESTEPS = 20
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru3_20"
```

```
In [222]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu', return_sequences=True)(hidden)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [223]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [224]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```

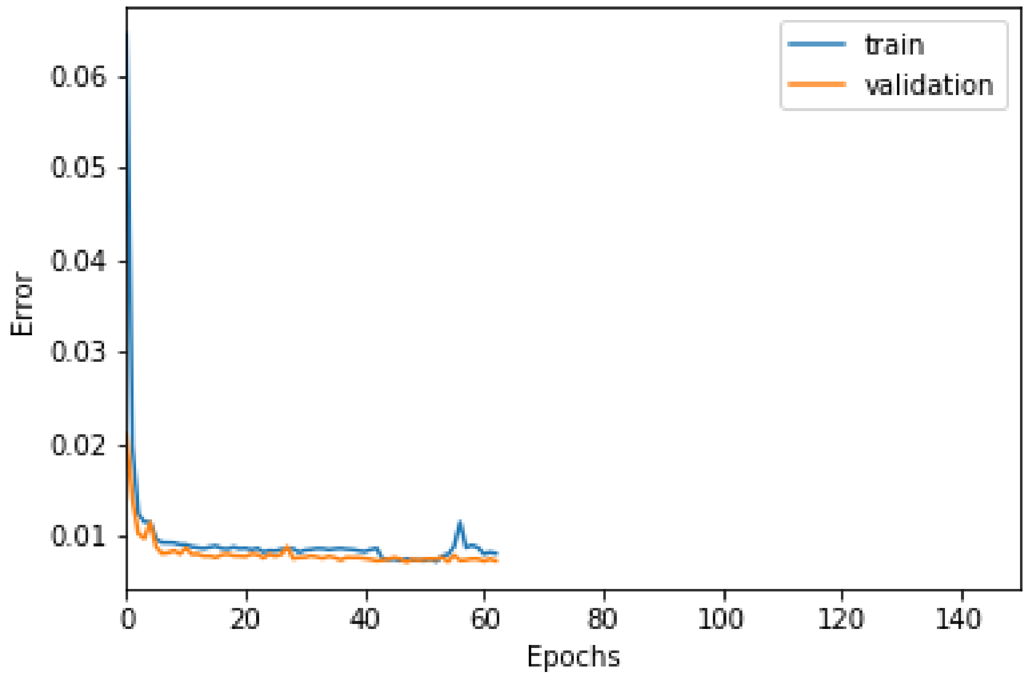



```
Training loss for final epoch is 0.008760190748842434
Validation loss for final epoch is 0.007315428807632997 5
---------- Beginning tests for gru3_20 ----------
Testing on Normal data.
The mean error for gru3_20_normal_ is 0.007688186565486547 for length 68279
====================
```

50 steps

```
In [225]: TIMESTEPS = 50
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru3_50"
```

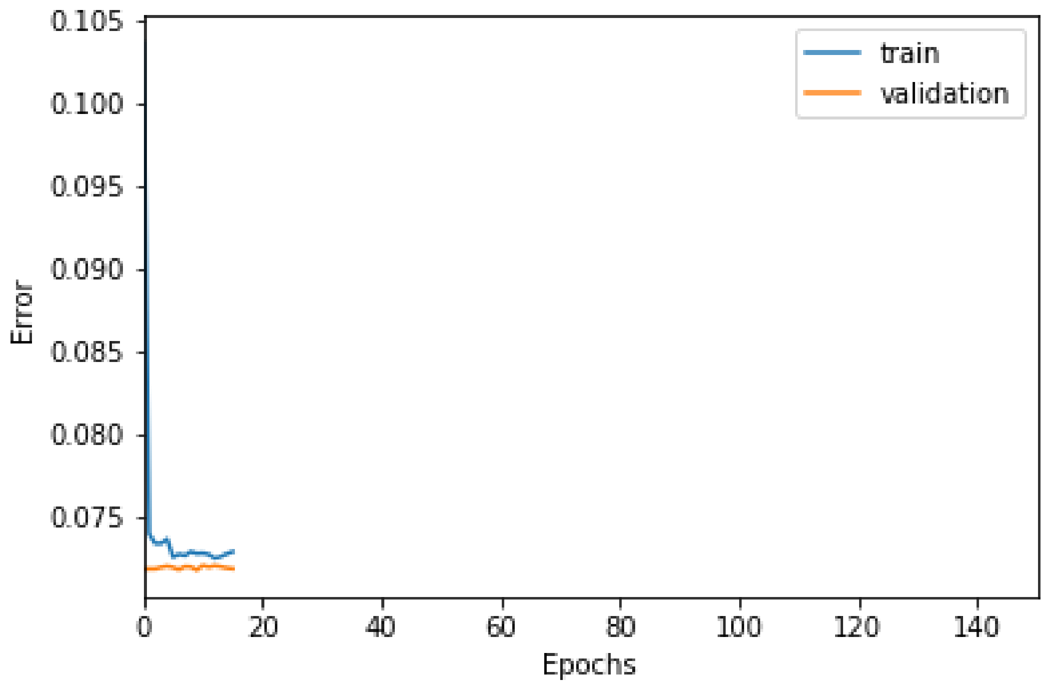
```
In [226]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu', return_sequences=True)(hidden)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [227]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [228]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.008108793774968944
Validation loss for final epoch is 0.007307445683283732
---------- Beginning tests for gru3_50 ----------
Testing on Normal data.
The mean error for gru3_50_normal_ is 0.007553005030857614 for length 68249
====================
```

100 steps

```
In [229]: TIMESTEPS = 100
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru3_100"

In [230]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu', return_sequences=True)(hidden)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)

In [231]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])

In [232]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```




```
Training loss for final epoch is 0.07286714933440089
Validation loss for final epoch is 0.07184143787622452
---------- Beginning tests for gru3_100 ----------
Testing on Normal data.
The mean error for gru3_100_normal_ is 0.07120430445496657 for length 68199
====================
```

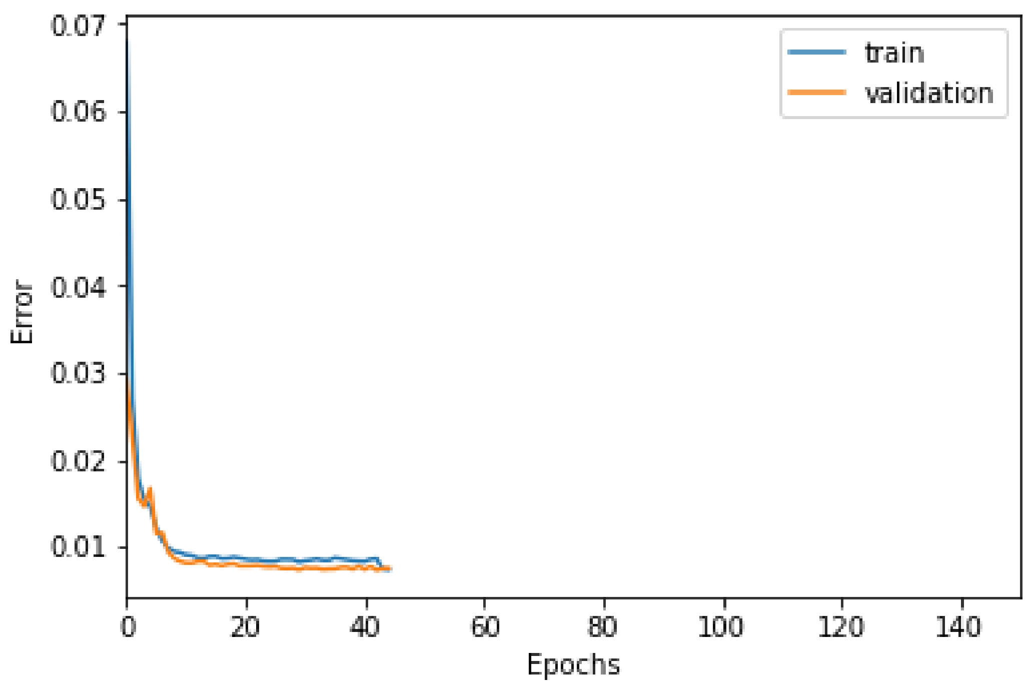
200 steps

```
In [233]: TIMESTEPS = 200
          DIM = 29
          tgen = flat_generator(X, TIMESTEPS,0)
          vgen = flat_generator(val_X, TIMESTEPS,0)
          name = "gru3_200"
```

```
In [234]: input_layer = Input(shape=(TIMESTEPS,DIM))
          hidden = GRU(10, activation='relu', return_sequences=True)(input_layer)
          hidden = GRU(10, activation='relu', return_sequences=True)(hidden)
          hidden = GRU(10, activation='relu')(hidden)
          output = Dense(DIM, activation='sigmoid')(hidden)
```

```
In [235]: model = Model(input_layer, output)
          model.compile(loss='mean_absolute_error', optimizer='adam', metrics=['mae'])
```

```
In [236]: train(model, tgen, vgen, name=name)
          test(model, ravel=0, name=name, window=TIMESTEPS)
```



```
Training loss for final epoch is 0.007368435216718353
Validation loss for final epoch is 0.007526277523837052
---------- Beginning tests for gru3_200 ----------
Testing on Normal data.
The mean error for gru3_200_normal_ is 0.007548149244849392 for length 68099
====================
```