Energy Disaggregation

Extract Energy consumption time-series for the Pool-Pump

Assumptions

1. The Pool Pump starts and stops at fix timings everyday.
2. It maintains consistent power consumption during its operations.
3. Its Power rating is between 1000W to 3000W

Import required packages

In [229]:

```
# imports

import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import sklearn
import datetime
```

Read the energy-consumption CSV file into dataframe and converting energy(Wh) into Power(W)

In [443]:

```
csv_file = 'test_data.csv'
df = pd.read_csv(csv_file)
df['date'] = pd.to_datetime(df['epoch'],unit='s')
df['power'] = df['energy'] * 4
df.drop(['epoch', 'energy'], axis=1, inplace=True)
df.set_index('date', inplace=True)
df.head()
```

Out[443]:

	power
date	
2016-11-03 07:00:00	328.0
2016-11-03 07:15:00	292.0
2016-11-03 07:30:00	296.0
2016-11-03 07:45:00	240.0
2016-11-03 08:00:00	176.0

Taking rolling average of 5, to smoothen out the noise

In [444]:

```
# rolling average to smoothen out the noise
df['power_SMA_5'] = df.loc[:,'power'].rolling(window=5).mean().round(2)
df.head()
```

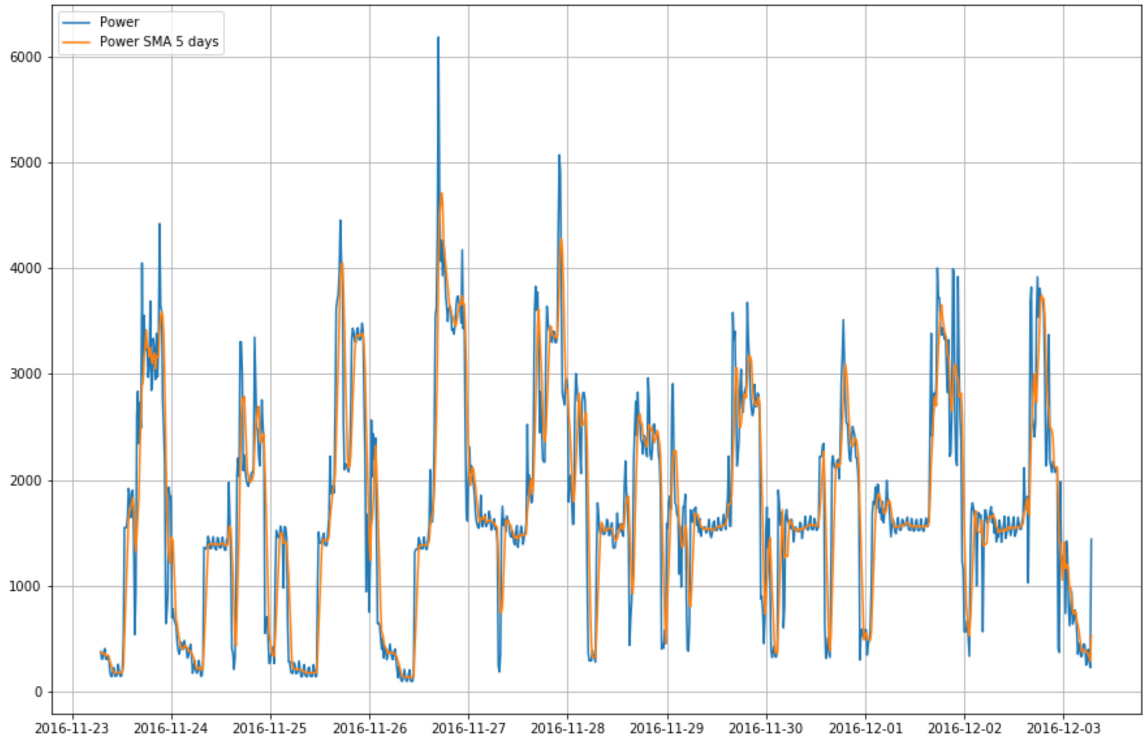
Out[444]:

	power	power_SMA_5
date		
2016-11-03 07:00:00	328.0	NaN
2016-11-03 07:15:00	292.0	NaN
2016-11-03 07:30:00	296.0	NaN
2016-11-03 07:45:00	240.0	NaN
2016-11-03 08:00:00	176.0	266.4

Plot smoothened power for 10 consequetive days

In [447]:

```
j = 20
plt.figure(figsize=[15,10])
plt.grid(True)
plt.plot(df['power'][96*j:96*(j+10)],label='Power')
plt.plot(df['power_SMA_5'][96*j:96*(j+10)],label='Power SMA 5 days')
plt.legend(loc=2)
plt.show()
```



Take 1st derivative on smoothened power to generate power-delta series

```
In [452]:
```

```
df['diff1_SMA_5'] = df.loc[:,'power_SMA_5'].diff()
df.head(10)
```

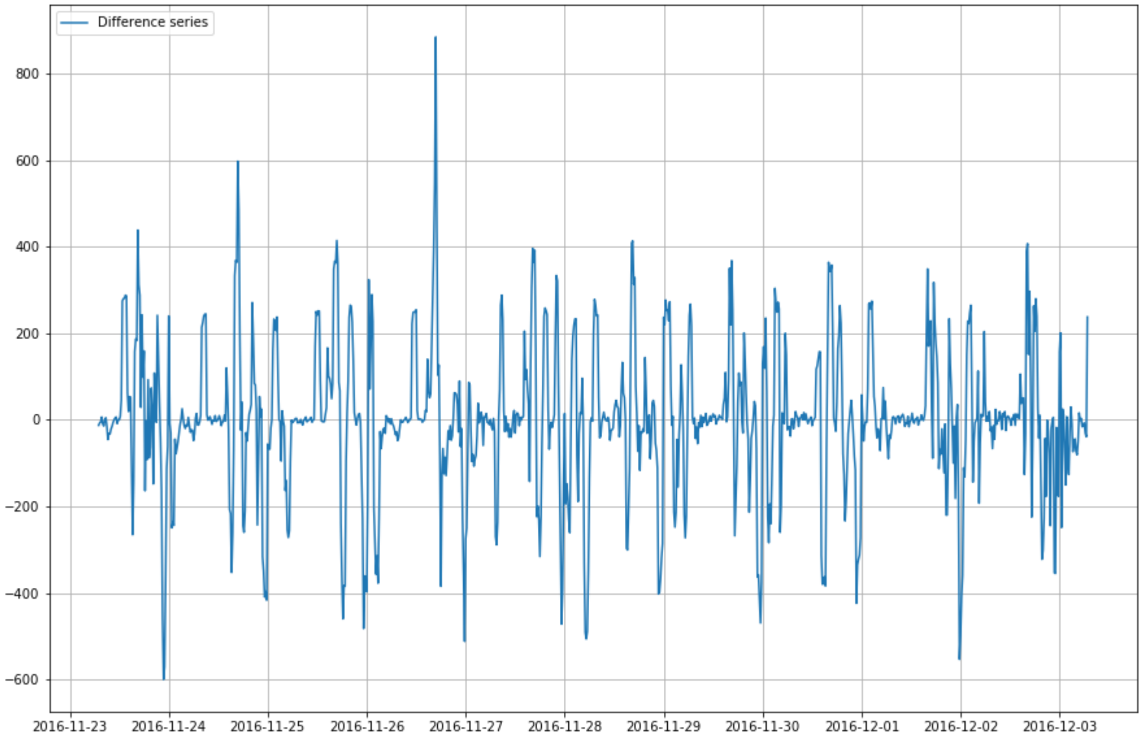
```
Out[452]:
```

```
                     power  power_SMA_5  diff1_SMA_5
               date
2016-11-03 07:00:00  328.0          NaN          NaN
2016-11-03 07:15:00  292.0          NaN          NaN
2016-11-03 07:30:00  296.0          NaN          NaN
2016-11-03 07:45:00  240.0          NaN          NaN
2016-11-03 08:00:00  176.0        266.4          NaN
2016-11-03 08:15:00  180.0        236.8        -29.6
2016-11-03 08:30:00  276.0        233.6         -3.2
2016-11-03 08:45:00  260.0        226.4         -7.2
2016-11-03 09:00:00  148.0        208.0        -18.4
2016-11-03 09:15:00  144.0        201.6         -6.4
```

Plot power-delta series for 10 consequetive days

In [453]:

```
j = 20
plt.figure(figsize=[15,10])
plt.grid(True)
plt.plot(df['diff1_SMA_5'][96*j:96*(j+10)],label='Difference series')
plt.legend(loc=2)
plt.show()
```



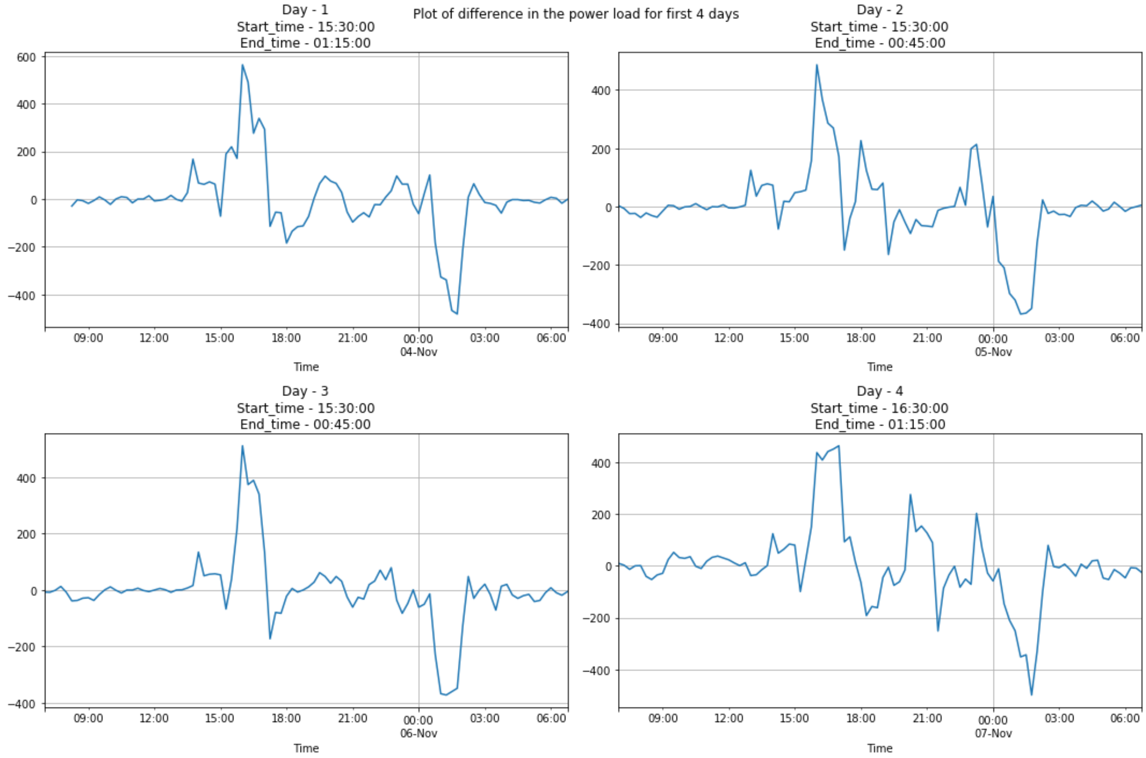
Plot power-delta series for individual days

Estimate start-time and end-time of the pump when there is maximum power-delta in the +ve and -ve directions respectively

In [459]:

```
fig, ax = plt.subplots(nrows=2, ncols=2, sharex=True, sharey=True, figsize=[15,10])

for i in range(4):
    day_diff = df['diff1_SMA_5'][96*i:96*(i+1)]
    start_time = day_diff.index[day_diff.argmax()-2]
    end_time = day_diff.index[day_diff.argmin()-2]
    plt.subplot(2,2,i+1)
    day_diff.plot()
    plt.xlabel("Time")
    plt.grid()
    plt.title("Day - %d\nStart_time - %s\nEnd_time - %s" % (i+1, start_time.time(), end_time.time()))
#     ax.flatten()[i].plot(daday_diff)
# fig.text(0.5, 0.0, 'Date', ha='center')
plt.suptitle("Plot of difference in the power load for first 4 days")
plt.tight_layout()
```



Plot of difference in the power load for first 4 days

Day - 1
Start_time - 15:30:00
End_time - 01:15:00

Day - 2
Start_time - 15:30:00
End_time - 00:45:00

Day - 3
Start_time - 15:30:00
End_time - 00:45:00

Day - 4
Start_time - 16:30:00
End_time - 01:15:00

Visualizing Power-data vis-a-vis estimated start-time and end-time of the pump

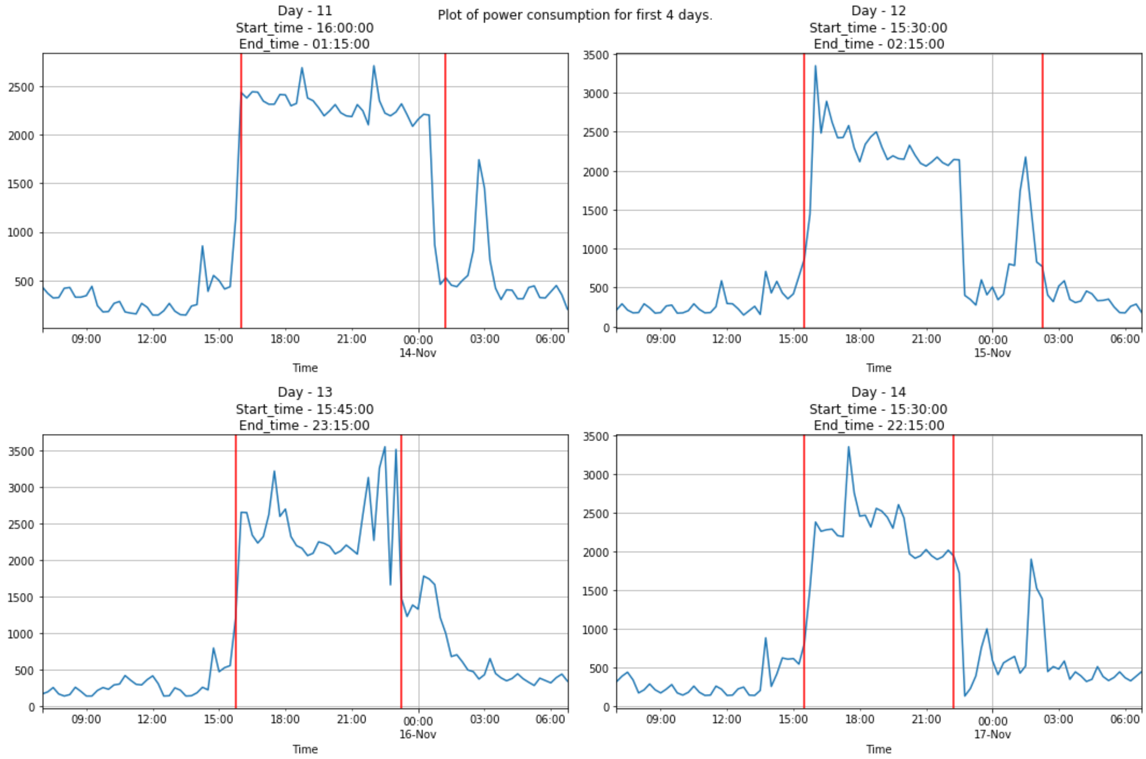
In [457]:

```
fig, ax = plt.subplots(nrows=2, ncols=2, sharex=True, sharey=True, figsize=[15,1
0])

k=10
for i in range(k, k+4):
    day_diff = df['diff1_SMA_5'][96*i:96*(i+1)]
    day_power = df['power'][96*i:96*(i+1)]
    start_time = day_diff.index[day_diff.argmax()-2]
    end_time = day_diff.index[day_diff.argmin()-2]
    plt.subplot(2,2,i+1-k)
    day_power.plot()
    plt.axvline(x=start_time, color='red'); plt.axvline(x=end_time, color='red')
    plt.xlabel("Time")
    plt.grid()
    plt.title("Day - %d\nStart_time - %s\nEnd_time - %s" % (i+1, start_time.time
(), end_time.time()))

plt.suptitle("Plot of power consumption for first 4 days.")

plt.tight_layout()
```



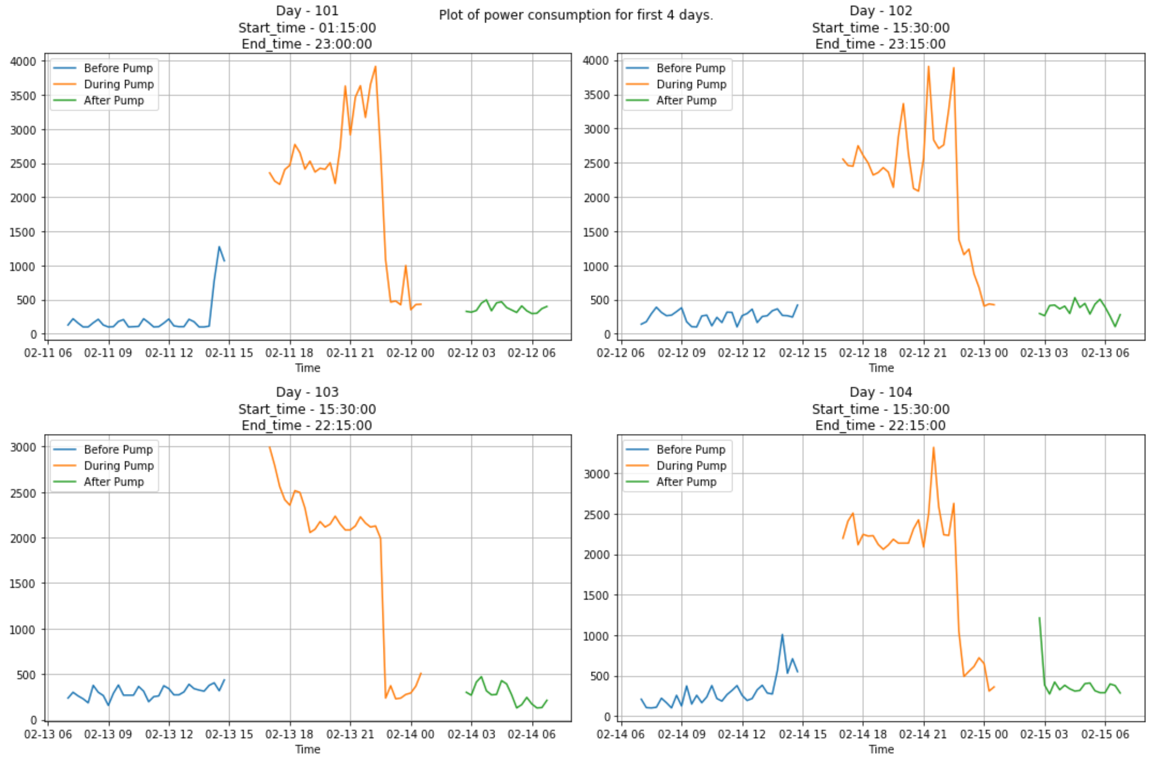
Visualizing power-load patter - before Pump operation, during and after the pump is stopped.

In [463]:

```
fig, ax = plt.subplots(nrows=2, ncols=2, sharex=True, sharey=True, figsize=[15,10])

k=100
for i in range(k,k+4):
    day_diff = df['diff1_SMA_5'][96*i:96*(i+1)]
    day_power = df['power'][96*i:96*(i+1)]
    start_time = day_diff.index[day_diff.argmax()-2]
    end_time = day_diff.index[day_diff.argmin()-2]
    plt.subplot(2,2,i+1-k)
    before_pump = day_power[:day1_diff.argmax()-4]; plt.plot(before_pump, label="Before Pump")
    during_pump = day_power[day1_diff.argmax()+4:day1_diff.argmin()-4]; plt.plot(during_pump, label="During Pump" )
    after_pump = day_power[day1_diff.argmin()+4:]; plt.plot(after_pump, label="After Pump" )
#     df['power_SMA_5'][96*i:96*(i+1)].plot()
    plt.xlabel("Time")
    plt.grid()
    plt.legend(loc=2)
    plt.title("Day - %d\nStart_time - %s\nEnd_time - %s" % (i+1, start_time.time(), end_time.time()))

plt.suptitle("Plot of power consumption for first 4 days.")
plt.tight_layout()
```



Datadrame of daily pump start and endtimes and average power-consumption before Pump operation, during and after the pump is stopped.

In [464]:

```
df_day = pd.DataFrame(columns=['Day', 'Pump_start_time', 'Pump_end_time',
                               'before_pump_avgW', 'during_pump_avgW',
                              'after_pump_avgW'])
num_days = int(df.shape[0]/96)
for i in range(num_days):
    day_diff = df['diff1_SMA_5'][96*i:96*(i+1)]
    day_power = df['power'][96*i:96*(i+1)]

    start_time = day_diff.index[day_diff.argmax()-2].time()
    end_time = day_diff.index[day_diff.argmin()-2].time()

    before_pump = day_power[:day1_diff.argmax()-6]
    during_pump = day_power[day1_diff.argmax()+4:day1_diff.argmin()-4]
    after_pump = day_power[day1_diff.argmin()+6:]

    data_dict = {'Day':day_power.index[0].date(),
           'Pump_start_time':start_time,
           'Pump_end_time':end_time,
           'before_pump_avgW':before_pump.mean().round(2),
           'during_pump_avgW':during_pump.mean().round(2),
           'after_pump_avgW':after_pump.mean().round(2)}
    df_day = df_day.append(data_dict, ignore_index=True)
```

In [465]:

```
df_day.head()
```

Out[465]:

	Day	Pump_start_time	Pump_end_time	before_pump_avgW	during_pump_avgW	after_p
0	2016-11-03	15:30:00	01:15:00	261.20	2437.94	
1	2016-11-04	15:30:00	00:45:00	285.87	2435.35	
2	2016-11-05	15:30:00	00:45:00	257.33	2270.32	
3	2016-11-06	16:30:00	01:15:00	251.33	2775.10	
4	2016-11-07	16:00:00	01:15:00	264.80	2343.74	

In [275]:

```
df_day.to_csv('Df_Day.csv', index=False)
```

Based on the majority voting (highest frequency), choose the start and end timing of the pump across all days.

In [466]:

```
# Datadrame of global pump start and endtimes
df_day_global = pd.DataFrame(columns=['Day', 'Pump_start_time', 'Pump_end_time',
                                      'before_pump_avgW', 'during_pump_avgW',
                                     'after_pump_avgW'])
num_days = int(df.shape[0]/96)
Pump_start_tab = df_day['Pump_start_time'].value_counts()
Pump_end_tab = df_day['Pump_end_time'].value_counts()

Pump_start_timeG = Pump_start_tab.index[0]
Pump_end_timeG = Pump_end_tab.index[0]

Pump_start_idx=pd.Series(df.index).apply(lambda x: x.time()==Pump_start_timeG).a
rgmax()
Pump_end_idx=pd.Series(df.index).apply(lambda x: x.time()==Pump_end_timeG).argma
x()

for i in range(num_days):
    day_diff = df['diff1_SMA_5'][96*i:96*(i+1)]
    day_power = df['power'][96*i:96*(i+1)]

    before_pump = day_power[:Pump_start_idx-2]
    during_pump = day_power[Pump_start_idx+2:
                            Pump_end_idx+2]
    after_pump = day_power[Pump_end_idx+8:]

    data_dict = {'Day':day_power.index[0].date(),
           'Pump_start_time':Pump_start_timeG,
           'Pump_end_time':Pump_end_timeG,
           'before_pump_avgW':before_pump.mean().round(2),
           'during_pump_avgW':during_pump.mean().round(2),
           'after_pump_avgW':after_pump.mean().round(2)}
    df_day_global = df_day_global.append(data_dict, ignore_index=True)
```

In [467]:

```
df_day_global.head()
```

Out[467]:

	Day	Pump_start_time	Pump_end_time	before_pump_avgW	during_pump_avgW	after_p
0	2016-11-03	15:30:00	22:15:00	280.12	2528.15	
1	2016-11-04	15:30:00	22:15:00	302.62	2418.81	
2	2016-11-05	15:30:00	22:15:00	270.25	2316.59	
3	2016-11-06	15:30:00	22:15:00	270.62	2797.48	
4	2016-11-07	15:30:00	22:15:00	289.62	2266.52	

In [295]:

```
df_day_global.to_csv('Df_Day_global.csv', index=False)
```

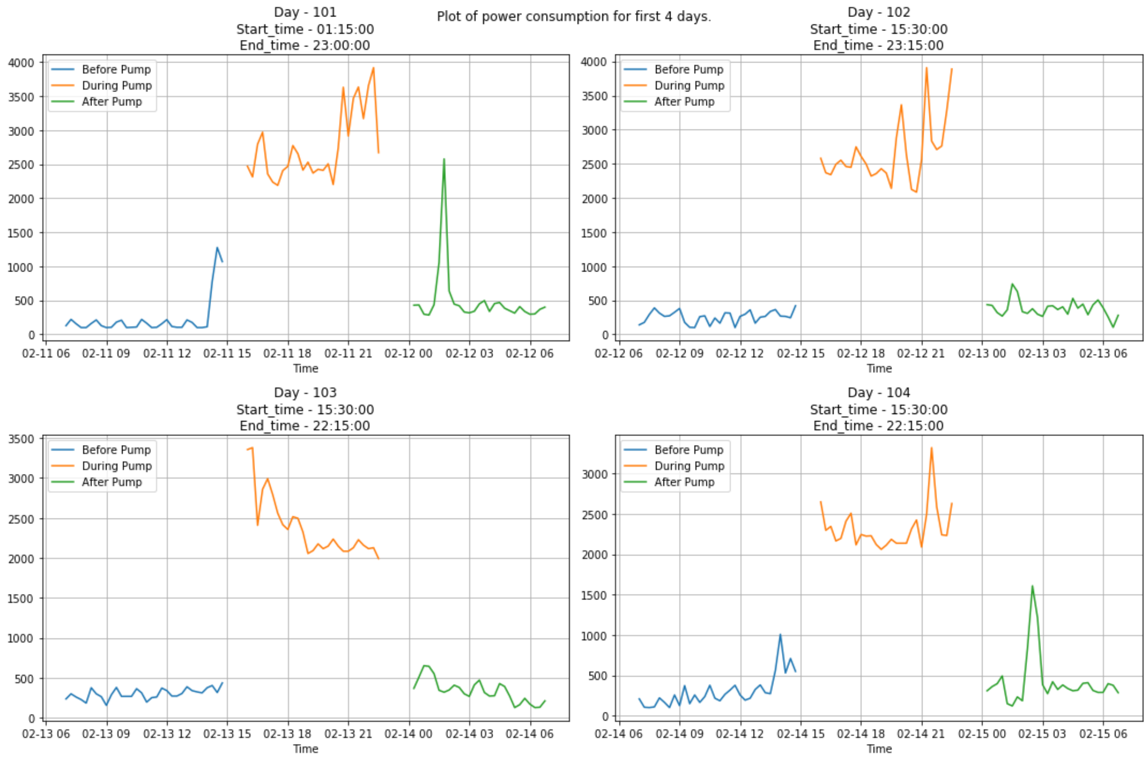
Visualizing power-load patter - before Pump operation, during and after the pump is stopped, at the global start and stop timings, caalculated above

In [469]:

```
fig, ax = plt.subplots(nrows=2, ncols=2, sharex=True, sharey=True, figsize=[15,10])

k=100
for i in range(k,k+4):
    day_diff = df['diff1_SMA_5'][96*i:96*(i+1)]
    day_power = df['power'][96*i:96*(i+1)]
    start_time = day_diff.index[day_diff.argmax()-2]
    end_time = day_diff.index[day_diff.argmin()-2]
    plt.subplot(2,2,i+1-k)
    before_pump = day_power[:Pump_start_idx-2]; plt.plot(before_pump, label="Before Pump")
    during_pump = day_power[Pump_start_idx+2:Pump_end_idx+2]; plt.plot(during_pump, label="During Pump" )
    after_pump = day_power[Pump_end_idx+8:]; plt.plot(after_pump, label="After Pump" )
#     df['power_SMA_5'][96*i:96*(i+1)].plot()
    plt.xlabel("Time")
    plt.grid()
    plt.legend(loc=2)
    plt.title("Day - %d\nStart_time - %s\nEnd_time - %s" % (i+1, start_time.time(), end_time.time()))

plt.suptitle("Plot of power consumption for first 4 days.")
plt.tight_layout()
```



Remove the power values before and after the estimated pump operational timings , from the main series

In [473]:

```
df_2 = df['power'].copy().reset_index()
df_2['Day'] = df_2['date'].apply(lambda x: x.date())
df_2['Time'] = df_2['date'].apply(lambda x: x.time())
df_2 = df_2.drop('date', axis=1)
```

In [474]:

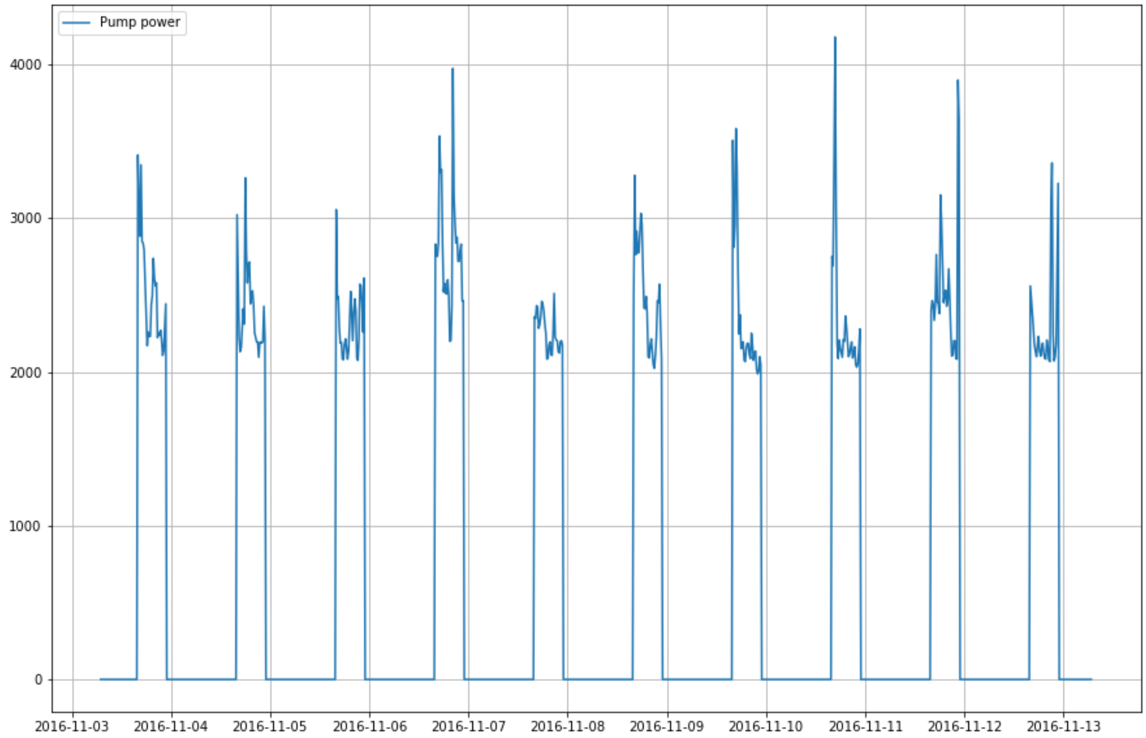
```
df_2['power_pump'] = df_2.apply(lambda x: 0.0 if x.Time < (datetime.datetime.combine(datetime.date.today(),Pump_start_timeG) + datetime.timedelta(minutes=30)).time()
                                        or x.Time > (datetime.datetime.combine(datetime.date.today(),Pump_end_timeG) + datetime.timedelta(minutes=30)).time()
                                        else x.power, axis=1)
df_2.head()
```

Out[474]:

	power	Day	Time	power_pump
0	328.0	2016-11-03	07:00:00	0.0
1	292.0	2016-11-03	07:15:00	0.0
2	296.0	2016-11-03	07:30:00	0.0
3	240.0	2016-11-03	07:45:00	0.0
4	176.0	2016-11-03	08:00:00	0.0

In [477]:

```
plt.figure(figsize=[15,10])
plt.grid(True)
plt.plot(df.index[:96*10], df_2['power_pump'][:96*10],label='Pump power')
plt.legend(loc=2)
plt.show()
```



Remove power-load of other appliance from the total power during (estimated) pump operational timings

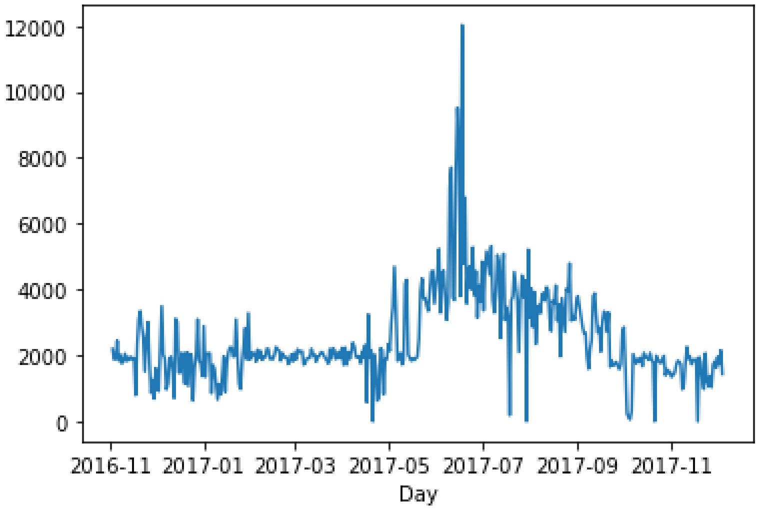
In [478]:

```
def get_pump_power_day(data):
    power_during_median = data['power'].loc[(data['Time'] >= (datetime.datetime.
combine(datetime.date.today(),Pump_start_timeG) + datetime.timedelta(minutes=30
)).time())
                                & (data['Time'] <= (datetime.datetime.combine(date
time.date.today(),Pump_end_timeG) + datetime.timedelta(minutes=30)).time())].med
ian()

    power_remaining_median = data['power'].loc[(data['Time'] < (datetime.datetim
e.combine(datetime.date.today(),Pump_start_timeG) + datetime.timedelta(minutes=3
0)).time())
                                | (data['Time'] > (datetime.datetime.combine(datet
ime.date.today(),Pump_end_timeG) + datetime.timedelta(minutes=30)).time())].medi
an()
    return power_during_median - power_remaining_median
pump_power_s = df_2.groupby('Day').apply(get_pump_power_day)
```

In [481]:

```
# Estimated pump power on daily basis
pump_power_s.plot()
plt.show()
```



Fix lower and upper limit of estimated pump-power series

In [482]:

```
lower_limit = max(pump_power_s.quantile(0.25), 1000)
upper_limit = min(pump_power_s.quantile(0.75), 3000)
print("Pump Power lower-limit - {}W, upper-limit - {}W".format(lower_limit, uppe
r_limit))
```

```
Pump Power lower-limit - 1810.0W, upper-limit - 3000W
```

At any day, if estimated pump power is < lower-limit -> make it 0

If > upper-limit -> cap it to the upper-limit

In [483]:

```
def power_mod(data, lower_limit, upper_limit):
    if data < lower_limit:
        return 0.0
    elif data <= upper_limit:
        return data
    else:
        return upper_limit
pump_power_s = pump_power_s.apply(power_mod, args=(lower_limit, upper_limit))
```

In [484]:

```
df_2['power_pump_final'] = df_2.apply(lambda x: 0.0 if x.Time < (datetime.dateti
me.combine(datetime.date.today(),Pump_start_timeG) + datetime.timedelta(minutes=
30)).time()
                                        or x.Time > (datetime.datetime.combine(d
atetime.date.today(),Pump_end_timeG) + datetime.timedelta(minutes=30)).time()
                                        else pump_power_s.loc[x.Day], axis=1)
df_2.head()
```

Out[484]:

	power	Day	Time	power_pump	power_pump_final
0	328.0	2016-11-03	07:00:00	0.0	0.0
1	292.0	2016-11-03	07:15:00	0.0	0.0
2	296.0	2016-11-03	07:30:00	0.0	0.0
3	240.0	2016-11-03	07:45:00	0.0	0.0
4	176.0	2016-11-03	08:00:00	0.0	0.0

Extract Estimated Pump-power series and convert to the energy consumption

In [485]:

```
energy_pump_final = df_2['power_pump_final']/4
energy_pump_final.index = df.index
energy_pump_final.head()
```

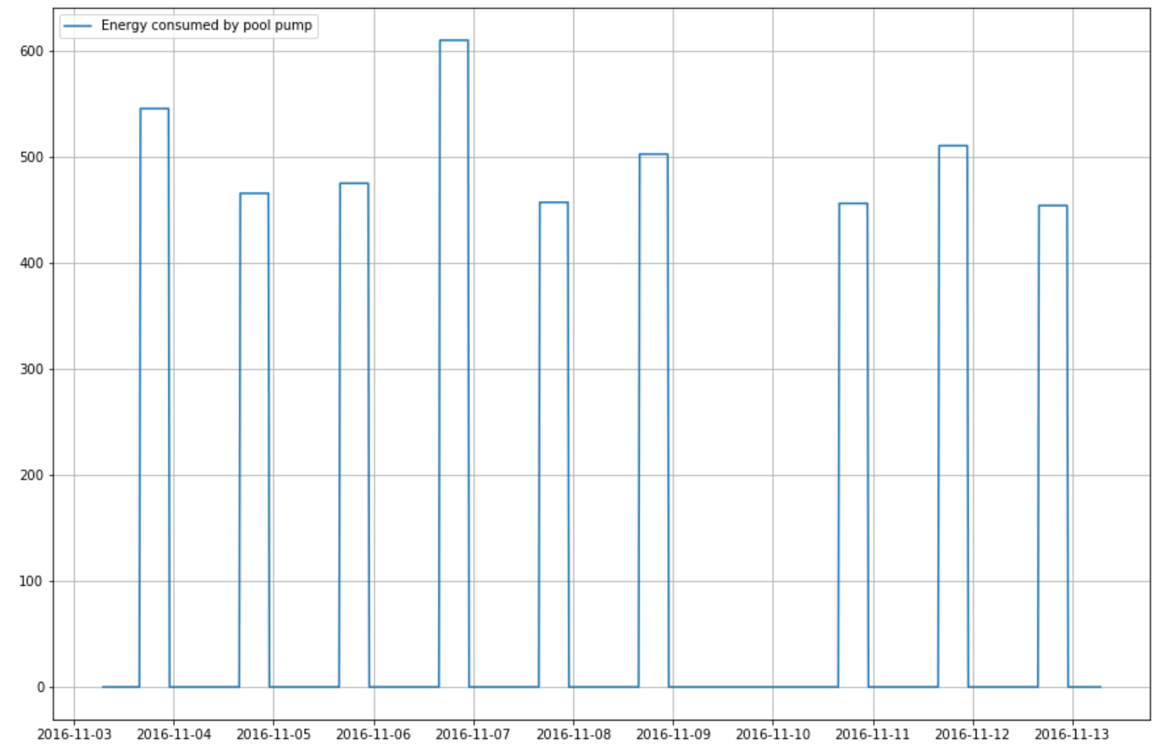
Out[485]:

```
date
2016-11-03 07:00:00    0.0
2016-11-03 07:15:00    0.0
2016-11-03 07:30:00    0.0
2016-11-03 07:45:00    0.0
2016-11-03 08:00:00    0.0
Name: power_pump_final, dtype: float64
```

Visualize first 10-day energy consumption of the pump

In [486]:

```
plt.figure(figsize=[15,10])
plt.grid(True)
plt.plot(energy_pump_final[:96*10],label='Energy consumed by pool pump')
plt.legend(loc=2)
plt.show()
```



Save results into CSV file

In [488]:

```
energy_pump_final.to_csv("Pump_energy_series.csv")
```

In [ ]:

```

```