Prediction of steel temperature on steel manufacturing

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Project Description

Steel manufacturing company requested to develop the system for the prediction of steel temperature for the optimization of electricity costs. Based on the provided data from company it's required to conduct an analysis and train a models for the prediction of the steel temperature.

Project goal: *train a model for the prediction of the steel temperature for optimization of electricity cost during production.*

Project tasks are following:

- To connect to database and load the initial data;
- Overview the data and conduct the exploratory data analysis;
- To prepare the data, select the target and features;
- Train the models;
- Select the best model and test it.

1. Exploratory data analysis

import of libraries

```
In [1]:  pip install phik
```

```
Collecting phik
  Downloading phik-0.12.3-cp310-cp310-win_amd64.whl (663 kB)
     ------------------------------------ 663.4/663.4 kB 746.4 kB/s eta 0:00:00
Requirement already satisfied: matplotlib>=2.2.3 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from ph
ik) (3.5.2)
Requirement already satisfied: scipy>=1.5.2 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from phik)
(1.8.1)
Requirement already satisfied: pandas>=0.25.1 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from phik)
(1.4.2)
Requirement already satisfied: numpy>=1.18.0 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from phik)
(1.22.4)
Requirement already satisfied: joblib>=0.14.1 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from phik)
(1.1.0)
Requirement already satisfied: python-dateutil>=2.7 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from
matplotlib>=2.2.3->phik) (2.8.2)
Requirement already satisfied: pillow>=6.2.0 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from matplo
tlib>=2.2.3->phik) (9.1.1)
Requirement already satisfied: packaging>=20.0 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from matp
lotlib>=2.2.3->phik) (21.3)
Requirement already satisfied: pyparsing>=2.2.1 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from mat
plotlib>=2.2.3->phik) (3.0.9)
Requirement already satisfied: fonttools>=4.22.0 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from ma
tplotlib>=2.2.3->phik) (4.33.3)
Requirement already satisfied: cycler>=0.10 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from matplot
lib>=2.2.3->phik) (0.11.0)
Requirement already satisfied: kiwisolver>=1.0.1 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from ma
tplotlib>=2.2.3->phik) (1.4.2)
Requirement already satisfied: pytz>=2020.1 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from pandas>
=0.25.1->phik) (2022.1)
Requirement already satisfied: six>=1.5 in c:\users\sazon\appdata\local\programs\python\python310\lib\site-packages (from python-date
util>=2.7->matplotlib>=2.2.3->phik) (1.16.0)
Installing collected packages: phik
Successfully installed phik-0.12.3
Note: you may need to restart the kernel to use updated packages.
```

In [2]:
```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
from sqlalchemy import create_engine
import matplotlib.pyplot as plt
import torch
import torch.nn as nn
import datetime
from sklearn.model_selection import train_test_split
from sklearn.tree import DecisionTreeRegressor
from sklearn.model_selection import RandomizedSearchCV
from sklearn.metrics import mean_squared_error
from sklearn.metrics import mean_absolute_error
import lightgbm as lgb
from sklearn.preprocessing import MinMaxScaler
from phik import resources, report
import phik
import seaborn as sns
```

In [3]:
```
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)
warnings.simplefilter(action='ignore', category=DeprecationWarning)
warnings.simplefilter(action='ignore', category=RuntimeWarning)
```

connection to data base

In [4]:
```
db_config = {
'user': '*********', # имя пользователя,
'pwd': '******', # пароль,
'host': '*************',
'port': ****, # порт подключения,
'db': '*********' # название базы данных,
}
```

In [5]:
```
connection_string = 'postgresql://{}:{}@{}:{}/{}'.format(
    db_config['user'],
    db_config['pwd'],
    db_config['host'],
    db_config['port'],
    db_config['db'],
)
```

In [6]:
```
engine = create_engine(connection_string)
```

1.1 Data loading

In [7]:
```
query = '''
SELECT *
FROM steel.data_arc
'''

arc_df = pd.read_sql_query(query, con=engine)
```

In [8]:
```
query = '''
SELECT *
FROM steel.data_bulk
'''

bulk_df = pd.read_sql_query(query, con=engine)
```

In [9]:
```
query = '''
SELECT *
FROM steel.data_bulk_time
'''

bulk_time_df = pd.read_sql_query(query, con=engine)
```

In [10]:
```
query = '''
SELECT *
FROM steel.data_gas
'''

gas_df = pd.read_sql_query(query, con=engine)
```

In [11]:
```
query = '''
SELECT *
FROM steel.data_temp
'''

tempperature_df = pd.read_sql_query(query, con=engine)
```

In [12]:
```
query = '''
SELECT *
FROM steel.data_wire
'''

wire_df = pd.read_sql_query(query, con=engine)
```

In [13]:
```
query = '''
SELECT *
FROM steel.data_wire_time
'''

wire_time_df = pd.read_sql_query(query, con=engine)
```

1.2 Data overview

1.2.1 data_arc dataset overview

In [14]:
```
query = '''

    SELECT *,
    ROW_NUMBER() OVER () as row
    FROM steel.data_arc
    ORDER BY row
'''

temp_df = pd.read_sql_query(query, con=engine)
```

In [15]:
```
temp_df
```

Out[15]:

	key	BeginHeat	EndHeat	ActivePower	ReactivePower	row
0	1	11:02:14	11:06:02	0.976059	0.687084	1
1	1	11:07:28	11:10:33	0.805607	0.520285	2
2	1	11:11:44	11:14:36	0.744363	0.498805	3
3	1	11:18:14	11:24:19	1.659363	1.062669	4
4	1	11:26:09	11:28:37	0.692755	0.414397	5
...	...	...	...	...	...	...
14871	3241	03:58:58	04:01:35	0.533670	0.354439	14872
14872	3241	04:05:04	04:08:04	0.676604	0.523631	14873
14873	3241	04:16:41	04:19:45	0.733899	0.475654	14874
14874	3241	04:31:51	04:32:48	0.220694	0.145768	14875
14875	3241	04:34:47	04:36:08	0.306580	0.196708	14876

14876 rows × 6 columns

In [16]:
```
len(temp_df['key'].unique())
```

Out[16]:
```
3214
```

Data_arc dataset has:

- information on batch number
- start and finish heating time of batch in format hh:mm:ss;
- used active and reactive powers;
- the total of 148876 rows;
- information on 3214 batches of steel.

1.2.2 Additionally to the data analysis client requested tp calculate the following information:

• for every value of key column:

1) Calculate the time between first and last temperature measurement

2) Total cumulative heating time.

3) Total quantity of heating.

4) Average ratio of active and reactive power;

5) For all obtained information to calculate: average, minimal, maximum, median and 25% and 75 % quartiles.

Query for loading of data required to execute tasks specified above:

In [17]:

```
query = '''

WITH table_1 AS (
    SELECT ROW_NUMBER() OVER () as row,*
    FROM steel.data_arc
    ORDER BY row
    ),

heat_time AS (
           SELECT key, row,
                  FIRST_VALUE("BeginHeat") OVER ( PARTITION BY key ORDER BY row) AS heat_start,
                  FIRST_VALUE("EndHeat") OVER (PARTITION BY key ORDER BY row DESC) AS heat_finish,
                  "ActivePower",
                  "ReactivePower",
                  CASE
                      WHEN
                        ((DATE_TRUNC('second' , "EndHeat") - DATE_TRUNC('second' ,"BeginHeat")) > '00:00:00')
                        THEN
                           DATE_TRUNC('second' , "EndHeat") - DATE_TRUNC('second' ,"BeginHeat")
                      ELSE
                           DATE_TRUNC('second' , "EndHeat") + '24:00:00' - DATE_TRUNC('second' ,"BeginHeat")
                END as heat_time
             FROM table_1),

time_temp AS (SELECT *,
                     ROW_NUMBER() OVER () as row
                FROM steel.data_temp
               ORDER BY row),


temp_st_fn AS   (SELECT key,
                       FIRST_VALUE("MesaureTime") OVER (PARTITION BY key ORDER BY row DESC) AS measure_temp_finish,
                       FIRST_VALUE("MesaureTime") OVER ( PARTITION BY key ORDER BY row) AS measure_temp_start
                  FROM time_temp),

total_time_mes AS (SELECT DISTINCT key,
                          CASE
                              WHEN
                                  DATE_TRUNC('second' ,measure_temp_start) > DATE_TRUNC('second' , measure_temp_finish)
                                  THEN
                                      DATE_TRUNC('second' , measure_temp_finish) +'24:00:00' - DATE_TRUNC('second' ,measure_temp_s
                              ELSE
                                      DATE_TRUNC('second' , measure_temp_finish) - DATE_TRUNC('second' ,measure_temp_start)
                              END AS ttl_msr_time
                     FROM temp_st_fn
                     ),

key_count AS (SELECT key,
                     COUNT(key) as heat_qty
               FROM table_1 as t
               GROUP BY key),


cumul_table  AS  (SELECT DISTINCT ht.key,
                         kc.heat_qty,
                         (DATE_TRUNC('second', SUM (heat_time))) AS ttl_heat_time,
                         heat_start,
                         heat_finish,
                         CASE
                             WHEN
                                 DATE_TRUNC('second' ,heat_start) > DATE_TRUNC('second' , heat_finish)
                                 THEN
                                     DATE_TRUNC('second' , heat_finish) +'24:00:00' - DATE_TRUNC('second' ,heat_start)
                             ELSE
                                     DATE_TRUNC('second' , heat_finish) - DATE_TRUNC('second' ,heat_start)
                             END AS total_time,
                         SUM("ActivePower")/SUM("ReactivePower") AS avg_cumul_power
                    FROM heat_time as ht
                         INNER JOIN key_count as kc
                            ON ht.key = kc.key
                   GROUP BY ht.key,heat_qty, heat_start,heat_finish,total_time)

SELECT
       t.key,
       ms.ttl_msr_time,
       c.heat_qty,
       c.ttl_heat_time,
       c.avg_cumul_power
  FROM table_1 AS t
       LEFT JOIN
            cumul_table AS c
         ON c.key = t.key
       LEFT JOIN
            total_time_mes AS ms
         ON ms.key = t.key
 ORDER BY t.row
'''

arc_df = pd.read_sql_query(query, con=engine)
```

In [18]:
```
# display of loaded dataset
arc_df.head(10)
```

Out[18]:

	key	ttl_msr_time	heat_qty	ttl_heat_time	avg_cumul_power
0	1	0 days 00:14:21	5	0 days 00:18:18	1.532447
1	1	0 days 00:14:21	5	0 days 00:18:18	1.532447
2	1	0 days 00:14:21	5	0 days 00:18:18	1.532447
3	1	0 days 00:14:21	5	0 days 00:18:18	1.532447
4	1	0 days 00:14:21	5	0 days 00:18:18	1.532447
5	2	0 days 00:21:45	4	0 days 00:13:31	1.527741
6	2	0 days 00:21:45	4	0 days 00:13:31	1.527741
7	2	0 days 00:21:45	4	0 days 00:13:31	1.527741
8	2	0 days 00:21:45	4	0 days 00:13:31	1.527741
9	3	0 days 00:21:40	5	0 days 00:10:55	1.579589

In [19]:
```
arc_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 14876 entries, 0 to 14875
Data columns (total 5 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   key              14876 non-null  int64
 1   ttl_msr_time     14876 non-null  timedelta64[ns]
 2   heat_qty         14876 non-null  int64
 3   ttl_heat_time    14876 non-null  timedelta64[ns]
 4   avg_cumul_power  14876 non-null  float64
dtypes: float64(1), int64(2), timedelta64[ns](2)
memory usage: 581.2 KB
```

In [20]:
```
# display of statistic for arc_df
arc_df[['heat_qty','ttl_heat_time','ttl_msr_time','avg_cumul_power']].describe(include= 'all')
```

Out[20]:

	heat_qty	ttl_heat_time	ttl_msr_time	avg_cumul_power
count	14876.000000	14876	14876	14876.000000
mean	5.187416	0 days 00:14:44.377251949	0 days 00:35:01.399569776	1.347103
std	1.749516	0 days 00:06:01.987921323	0 days 00:27:52.649173821	0.140887
min	1.000000	0 days 00:00:57	0 days 00:03:17	-0.002587
25%	4.000000	0 days 00:10:52	0 days 00:21:32	1.279535
50%	5.000000	0 days 00:14:06	0 days 00:29:06	1.362585
75%	6.000000	0 days 00:17:42	0 days 00:40:57	1.435037
max	16.000000	0 days 01:09:49	0 days 06:32:17	1.777119

The conclusions are following:

1) quantity of heating:

- Minimal - 1;
- Maximal - 16;
- Median - 5;

2) Interval from from first to last temperature measurement:

- Minimal time - 3 min. 17 sec.;
- Maximal - 6 h. 32 min. 17 sec.;
- Median value - 29 min. 6 sec;

3) total heating time:

- Minimal - 57 sec;
- Maximal - 1 ч 9 min 49 sec;
- Median - 14 min 6 sec;

4) Average ratio of active power to reactive power:

- Minimal -0,02;
- Maximal 1,77;
- Median 1,36.

1.3 data bulk (quantity) overview

In [21]:
```
bulk_df.head()
```

Out[21]:

	key	Bulk 1	Bulk 2	Bulk 3	Bulk 4	Bulk 5	Bulk 6	Bulk 7	Bulk 8	Bulk 9	Bulk 10	Bulk 11	Bulk 12	Bulk 13	Bulk 14	Bulk 15
0	1	NaN	NaN	NaN	43.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	206.0	NaN	150.0	154.0
1	2	NaN	NaN	NaN	73.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	206.0	NaN	149.0	154.0
2	3	NaN	NaN	NaN	34.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	205.0	NaN	152.0	153.0
3	4	NaN	NaN	NaN	81.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	207.0	NaN	153.0	154.0
4	5	NaN	NaN	NaN	78.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	203.0	NaN	151.0	152.0

```
In [22]:  bulk_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3129 entries, 0 to 3128
Data columns (total 16 columns):
 #   Column   Non-Null Count  Dtype  
---  ------   --------------  -----  
 0   key      3129 non-null   int64  
 1   Bulk 1   252 non-null    float64
 2   Bulk 2   22 non-null     float64
 3   Bulk 3   1298 non-null   float64
 4   Bulk 4   1014 non-null   float64
 5   Bulk 5   77 non-null     float64
 6   Bulk 6   576 non-null    float64
 7   Bulk 7   25 non-null     float64
 8   Bulk 8   1 non-null      float64
 9   Bulk 9   19 non-null     float64
 10  Bulk 10  176 non-null    float64
 11  Bulk 11  177 non-null    float64
 12  Bulk 12  2450 non-null   float64
 13  Bulk 13  18 non-null     float64
 14  Bulk 14  2806 non-null   float64
 15  Bulk 15  2248 non-null   float64
dtypes: float64(15), int64(1)
memory usage: 391.2 KB
```

The dataset has the following information:

- information on batch number - 3129 unique values;
- Columns with specified quantity of bulk for every batch;
- dataset has nulls - it's acceptable and not required to fill in - every batch is different to other and requires different bulk materials as well as quantity.

1.4 data bulk (time) overview

In [23]:
```
bulk_time_df.head()
```

Out[23]:

	key	Bulk 1	Bulk 2	Bulk 3	Bulk 4	Bulk 5	Bulk 6	Bulk 7	Bulk 8	Bulk 9	Bulk 10	Bulk 11	Bulk 12	Bulk 13	Bulk 14	Bulk 15
0	1	None	None	None	11:21:30	None	None	None	None	None	None	None	11:03:52	None	11:03:52	11:03:52
1	2	None	None	None	11:46:38	None	None	None	None	None	None	None	11:40:20	None	11:40:20	11:40:20
2	3	None	None	None	12:31:06	None	None	None	None	None	None	None	12:09:40	None	12:09:40	12:09:40
3	4	None	None	None	12:48:43	None	None	None	None	None	None	None	12:41:24	None	12:41:24	12:41:24
4	5	None	None	None	13:18:50	None	None	None	None	None	None	None	13:12:56	None	13:12:56	13:12:56

In [24]:
```
bulk_time_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3129 entries, 0 to 3128
Data columns (total 16 columns):
 #   Column   Non-Null Count  Dtype
---  ------   --------------  -----
 0   key      3129 non-null   int64
 1   Bulk 1   252 non-null    object
 2   Bulk 2   22 non-null     object
 3   Bulk 3   1298 non-null   object
 4   Bulk 4   1014 non-null   object
 5   Bulk 5   77 non-null     object
 6   Bulk 6   576 non-null    object
 7   Bulk 7   25 non-null     object
 8   Bulk 8   1 non-null      object
 9   Bulk 9   19 non-null     object
 10  Bulk 10  176 non-null    object
 11  Bulk 11  177 non-null    object
 12  Bulk 12  2450 non-null   object
 13  Bulk 13  18 non-null     object
 14  Bulk 14  2806 non-null   object
 15  Bulk 15  2248 non-null   object
dtypes: int64(1), object(15)
memory usage: 391.2+ KB
```

Bulk (time) dataset has:

- info on batch number - 3129 unique values;

- columns with specified time of bulk insertion for every batch;
- dataset has nulls - it's acceptable and not required to fill in - every batch is different to other and requires different bulk materials as well as quantity.

1.5 gas dataset overview

In [25]:
```
gas_df.head()
```

Out[25]:

	key	gas
0	1	29.749986
1	2	12.555561
2	3	28.554793
3	4	18.841219
4	5	5.413692

In [26]:
```
gas_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3239 entries, 0 to 3238
Data columns (total 2 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   key     3239 non-null   int64  
 1   gas     3239 non-null   float64
dtypes: float64(1), int64(1)
memory usage: 50.7 KB
```

Gas dataset has:

- information on batch number and quantity of used gas - total 3239 rows.

1.6 Temperature dataset overview

In [27]:
```
tempperature_df.head()
```

Out[27]:

	key	MesaureTime	Temperature
0	1	11:16:18	1571.0
1	1	11:25:53	1604.0
2	1	11:29:11	1618.0
3	1	11:30:01	1601.0
4	1	11:30:39	1613.0

In [28]:
```
tempperature_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 15907 entries, 0 to 15906
Data columns (total 3 columns):
 #   Column       Non-Null Count  Dtype  
---  ------       --------------  -----  
 0   key          15907 non-null  int64  
 1   MesaureTime  15907 non-null  object 
 2   Temperature  13006 non-null  float64
dtypes: float64(1), int64(1), object(1)
memory usage: 372.9+ KB
```

In [29]:
```
len(tempperature_df['key'].unique())
```

Out[29]:
```
3216
```

In [30]:
```
tempperature_df[tempperature_df['key']==1]
```

Out[30]:

	key	MesaureTime	Temperature
0	1	11:16:18	1571.0
1	1	11:25:53	1604.0
2	1	11:29:11	1618.0
3	1	11:30:01	1601.0
4	1	11:30:39	1613.0

temperature dataset has:

- information on batch number - 3216 unique values;
- temperature measurement for every batch - with time measurement; and temperature the total quantity of records is 15907.

1.7 Wire dataset (quantity) oveview

In [31]:
```
wire_df.head()
```

Out[31]:

	key	Wire 1	Wire 2	Wire 3	Wire 4	Wire 5	Wire 6	Wire 7	Wire 8	Wire 9
0	1	60.059998	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1	2	96.052315	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	3	91.160157	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
3	4	89.063515	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4	5	89.238236	9.11456	NaN	NaN	NaN	NaN	NaN	NaN	NaN

In [32]:
```
wire_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3081 entries, 0 to 3080
Data columns (total 10 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   key     3081 non-null   int64  
 1   Wire 1  3055 non-null   float64
 2   Wire 2  1079 non-null   float64
 3   Wire 3  63 non-null     float64
 4   Wire 4  14 non-null     float64
 5   Wire 5  1 non-null      float64
 6   Wire 6  73 non-null     float64
 7   Wire 7  11 non-null     float64
 8   Wire 8  19 non-null     float64
 9   Wire 9  29 non-null     float64
dtypes: float64(9), int64(1)
memory usage: 240.8 KB
```

Wire (quantity) dataset has:

- information on quantity of insertion of 9 different types o wire materials;
- information on batch number - 3081 of unique values;
- dataset has nulls - it's acceptable and not required to fill in - every batch is different to other and requires different wire materials as well as quantity.

1.8 Wire dataset (time) oveview

In [33]:
```
wire_time_df.head()
```

Out[33]:

	key	Wire 1	Wire 2	Wire 3	Wire 4	Wire 5	Wire 6	Wire 7	Wire 8	Wire 9
0	1	11:11:41	None	None	None	None	None	None	None	None
1	2	11:46:10	None	None	None	None	None	None	None	None
2	3	12:13:47	None	None	None	None	None	None	None	None
3	4	12:48:05	None	None	None	None	None	None	None	None
4	5	13:18:15	13:32:06	None	None	None	None	None	None	None

In [34]:
```
wire_time_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3081 entries, 0 to 3080
Data columns (total 10 columns):
 #   Column  Non-Null Count  Dtype 
---  ------  --------------  ----- 
 0   key     3081 non-null   int64 
 1   Wire 1  3055 non-null   object
 2   Wire 2  1079 non-null   object
 3   Wire 3  63 non-null     object
 4   Wire 4  14 non-null     object
 5   Wire 5  1 non-null      object
 6   Wire 6  73 non-null     object
 7   Wire 7  11 non-null     object
 8   Wire 8  19 non-null     object
 9   Wire 9  29 non-null     object
dtypes: int64(1), object(9)
memory usage: 240.8+ KB
```

Wire (time) dataset has:

- information on time of insertion of wired materials;
- information on number of batch - 3081 unique values;

- dataset has nulls - it's acceptable and not required to fill in - every batch is different to other and requires different wire materials as well as quantity.

2 Data preparation

Goal of this section to prepare one dataset with target and features for the further models training.

Project target is temperature.

Due to the fact that every bath has several quantity of temperature measurement, all features to be prepared in accordance with relevant duration for each production batch and number of temperature measurement.

The time of start of production to be used as 0 time.

For the obtaining of correct features the following actions required to complete:

1) Create dataset with unique batch number and temperature measurement related to number of measurement;

2) To merge the dataset of quantity and time of bulk materials and add to dataset with target;

3) To merge the dataset of quantity and time of wire materials and add to dataset with target;

4) To merge heating dataset with obtained dataset considering the batch number and time of insertion of materials;;

4) To add gas dataset to the dataset with target;

5) To unify the format of dataset values, process the nulls.

2.1 Create dataset with unique batch numer and temperature considering the number of temperture measurement.

In [35]:
```
query = '''
WITH time_temp AS (SELECT *,
                          ROW_NUMBER() OVER (PARTITION BY key) as msr_num
                     FROM steel.data_temp
                    ORDER BY key)

SELECT DISTINCT key,
       FIRST_VALUE("Temperature") OVER ( PARTITION BY key ORDER BY msr_num) AS first_temperature,
       FIRST_VALUE("Temperature") OVER ( PARTITION BY key ORDER BY msr_num DESC) AS final_temperature,


       FIRST_VALUE("MesaureTime") OVER ( PARTITION BY key ORDER BY msr_num) AS first_temp_time,
       FIRST_VALUE("MesaureTime") OVER ( PARTITION BY key ORDER BY msr_num DESC) AS final_temp_time
  FROM time_temp
 ORDER BY key

'''

temperature_df = pd.read_sql_query(query, con=engine)
```

In [36]:
```
temperature_df.head(10)
```

Out[36]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time
0	1	1571.0	1613.0	11:16:18	11:30:39
1	2	1581.0	1602.0	11:37:27	11:59:12
2	3	1596.0	1599.0	12:13:17	12:34:57
3	4	1601.0	1625.0	12:52:57	12:59:25
4	5	1576.0	1602.0	13:23:19	13:36:01
5	6	1543.0	1596.0	13:49:24	14:12:29
6	7	1586.0	1599.0	14:19:43	14:42:37
7	8	1577.0	1598.0	15:07:18	15:22:52
8	9	1587.0	1592.0	15:37:03	16:01:16
9	10	1574.0	1593.0	16:14:29	16:36:08

```
In [37]: temperature_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3216 entries, 0 to 3215
Data columns (total 5 columns):
 #   Column             Non-Null Count  Dtype  
---  ------             --------------  -----  
 0   key                3216 non-null   int64  
 1   first_temperature  3216 non-null   float64
 2   final_temperature  2477 non-null   float64
 3   first_temp_time    3216 non-null   object 
 4   final_temp_time    3216 non-null   object 
dtypes: float64(2), int64(1), object(2)
memory usage: 125.8+ KB
```

Deletion of nulls

```
In [38]: temperature_df['na_check'] = temperature_df['final_temperature'].isna()
```

```
In [39]: keys_to_drop = temperature_df[temperature_df['na_check'] == 1]['key'].drop_duplicates()
```

```
In [40]: keys_check = []
         for i in range(len(temperature_df['key'])):
             if temperature_df['key'][i] in set(keys_to_drop):
                 keys_check.append('drop')
             else:
                 keys_check.append('ok')
```

```
In [41]: temperature_df['key_check'] = keys_check
```

```
In [42]: temperature_df = temperature_df[temperature_df['key_check'] == 'ok']
```

```
In [43]: temperature_df = temperature_df.drop(columns = ['na_check','key_check']).reset_index(drop = True)
```

```
In [44]: for i in temperature_df.loc[:,'first_temperature':'final_temperature'].columns:
             temperature_df[i] = temperature_df[i].fillna('0')
```

In [45]:
```
for i in temperature_df.loc[:,'first_temp_time':].columns:
    temperature_df[i] = temperature_df[i].fillna(pd.to_datetime(0, unit='s', errors='coerce').time())
```

In [46]:
```
temperature_df.head()
```

Out[46]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time
0	1	1571.0	1613.0	11:16:18	11:30:39
1	2	1581.0	1602.0	11:37:27	11:59:12
2	3	1596.0	1599.0	12:13:17	12:34:57
3	4	1601.0	1625.0	12:52:57	12:59:25
4	5	1576.0	1602.0	13:23:19	13:36:01

In [47]:
```
temperature_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2477 entries, 0 to 2476
Data columns (total 5 columns):
 #   Column             Non-Null Count  Dtype  
---  ------             --------------  -----  
 0   key                2477 non-null   int64  
 1   first_temperature  2477 non-null   float64
 2   final_temperature  2477 non-null   float64
 3   first_temp_time    2477 non-null   object 
 4   final_temp_time    2477 non-null   object 
dtypes: float64(2), int64(1), object(2)
memory usage: 96.9+ KB
```

In [48]:
```
len(temperature_df['key'].unique())
```

Out[48]:
```
2477
```

Conclusion:

- Prepared dataset has the size 33*2477;
- it has information on 2477 batches;
- Dataset to be used later for the creating of final table of features and target.
- The final dataset has to have the quantity of rows equal to 2477 or less.

2.2 Merging the datasets with quantity and time of insertion of bulk materials and add it to dataset with target

In [49]:
```
bulk_jnt = bulk_df.merge(bulk_time_df,how = 'left',left_on='key', right_on='key',
          suffixes=('','_time'))
```

In [50]:
```
col_list = ['key']
for i in range(15):
    col_list.append(bulk_jnt.columns[1:16][i])
    col_list.append(bulk_jnt.columns[16:][i])

bulk_jnt = bulk_jnt[col_list]
```

```
In [51]: bulk_jnt.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3129 entries, 0 to 3128
Data columns (total 31 columns):
 #   Column        Non-Null Count  Dtype  
---  ------        --------------  -----  
 0   key           3129 non-null   int64  
 1   Bulk 1        252 non-null    float64
 2   Bulk 1_time   252 non-null    object 
 3   Bulk 2        22 non-null     float64
 4   Bulk 2_time   22 non-null     object 
 5   Bulk 3        1298 non-null   float64
 6   Bulk 3_time   1298 non-null   object 
 7   Bulk 4        1014 non-null   float64
 8   Bulk 4_time   1014 non-null   object 
 9   Bulk 5        77 non-null     float64
 10  Bulk 5_time   77 non-null     object 
 11  Bulk 6        576 non-null    float64
 12  Bulk 6_time   576 non-null    object 
 13  Bulk 7        25 non-null     float64
 14  Bulk 7_time   25 non-null     object 
 15  Bulk 8        1 non-null      float64
 16  Bulk 8_time   1 non-null      object 
 17  Bulk 9        19 non-null     float64
 18  Bulk 9_time   19 non-null     object 
 19  Bulk 10       176 non-null    float64
 20  Bulk 10_time  176 non-null    object 
 21  Bulk 11       177 non-null    float64
 22  Bulk 11_time  177 non-null    object 
 23  Bulk 12       2450 non-null   float64
 24  Bulk 12_time  2450 non-null   object 
 25  Bulk 13       18 non-null     float64
 26  Bulk 13_time  18 non-null     object 
 27  Bulk 14       2806 non-null   float64
 28  Bulk 14_time  2806 non-null   object 
 29  Bulk 15       2248 non-null   float64
 30  Bulk 15_time  2248 non-null   object 
dtypes: float64(15), int64(1), object(15)
memory usage: 782.2+ KB
```

In [52]:
```
bulk_jnt.head(15)
```

Out[52]:

	key	Bulk 1	Bulk 1_time	Bulk 2	Bulk 2_time	Bulk 3	Bulk 3_time	Bulk 4	Bulk 4_time	Bulk 5	...	Bulk 11	Bulk 11_time	Bulk 12	Bulk 12_time	Bulk 13	Bulk 13_time	Bulk 14	Bulk 14_time	Bulk 15	Bulk 15_time
0	1	NaN	None	NaN	None	NaN	None	43.0	11:21:30	NaN	...	NaN	None	206.0	11:03:52	NaN	None	150.0	11:03:52	154.0	11:03:52
1	2	NaN	None	NaN	None	NaN	None	73.0	11:46:38	NaN	...	NaN	None	206.0	11:40:20	NaN	None	149.0	11:40:20	154.0	11:40:20
2	3	NaN	None	NaN	None	NaN	None	34.0	12:31:06	NaN	...	NaN	None	205.0	12:09:40	NaN	None	152.0	12:09:40	153.0	12:09:40
3	4	NaN	None	NaN	None	NaN	None	81.0	12:48:43	NaN	...	NaN	None	207.0	12:41:24	NaN	None	153.0	12:41:24	154.0	12:41:24
4	5	NaN	None	NaN	None	NaN	None	78.0	13:18:50	NaN	...	NaN	None	203.0	13:12:56	NaN	None	151.0	13:12:56	152.0	13:12:56
5	6	NaN	None	NaN	None	NaN	None	117.0	13:59:24	NaN	...	NaN	None	204.0	13:53:27	NaN	None	201.0	13:53:27	154.0	13:53:27
6	7	NaN	None	NaN	None	NaN	None	117.0	14:29:14	NaN	...	NaN	None	204.0	14:22:19	NaN	None	152.0	14:22:19	154.0	14:22:19
7	8	NaN	None	NaN	None	NaN	None	99.0	15:04:05	NaN	...	NaN	None	410.0	14:55:46	NaN	None	252.0	14:55:46	153.0	14:55:46
8	9	NaN	None	NaN	None	NaN	None	117.0	15:47:34	NaN	...	NaN	None	107.0	15:41:00	NaN	None	99.0	15:41:00	203.0	15:41:00
9	10	NaN	None	NaN	None	NaN	None	NaN	None	NaN	...	NaN	None	203.0	16:18:52	NaN	None	102.0	16:18:52	204.0	16:18:52
10	11	NaN	None	NaN	None	NaN	None	69.0	17:16:34	NaN	...	NaN	None	207.0	17:03:52	NaN	None	101.0	17:03:52	202.0	17:03:52
11	12	46.0	17:50:19	NaN	None	NaN	None	34.0	18:03:59	NaN	...	NaN	None	618.0	17:45:21	NaN	None	406.0	17:45:21	203.0	17:45:21
12	13	NaN	None	NaN	None	NaN	None	NaN	None	NaN	...	NaN	None	410.0	18:43:48	NaN	None	151.0	18:43:48	204.0	18:43:48
13	14	NaN	None	NaN	None	71.0	20:13:36	NaN	None	NaN	...	NaN	None	204.0	20:05:47	NaN	None	152.0	20:05:47	203.0	20:05:47
14	15	NaN	None	NaN	None	NaN	None	NaN	None	NaN	...	NaN	None	NaN	None	NaN	None	251.0	21:03:07	203.0	21:03:07

15 rows × 31 columns

Merging of dataset with temperature_df

In [53]:
```
tmp_jnt_df = pd.merge(temperature_df,bulk_jnt,how = 'outer',on='key',indicator=True)
```

In [54]:

```python
tmp_jnt_df.head()
```

Out[54]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time	Bulk 1	Bulk 1_time	Bulk 2	Bulk 2_time	Bulk 3	...	Bulk 11_time	Bulk 12	Bulk 12_time	Bulk 13	Bulk 13_time	Bulk 14	14
0	1	1571.0	1613.0	11:16:18	11:30:39	NaN	None	NaN	None	NaN	...	None	206.0	11:03:52	NaN	None	150.0	11:
1	2	1581.0	1602.0	11:37:27	11:59:12	NaN	None	NaN	None	NaN	...	None	206.0	11:40:20	NaN	None	149.0	11:
2	3	1596.0	1599.0	12:13:17	12:34:57	NaN	None	NaN	None	NaN	...	None	205.0	12:09:40	NaN	None	152.0	12:
3	4	1601.0	1625.0	12:52:57	12:59:25	NaN	None	NaN	None	NaN	...	None	207.0	12:41:24	NaN	None	153.0	12:
4	5	1576.0	1602.0	13:23:19	13:36:01	NaN	None	NaN	None	NaN	...	None	203.0	13:12:56	NaN	None	151.0	13:

5 rows × 36 columns

In [55]:

```python
tmp_jnt_df = tmp_jnt_df[tmp_jnt_df['_merge'] != 'right_only']
```

In [56]:

```python
# deleting of column merge
tmp_jnt_df['_merge'].unique()
```

Out[56]:

```
['both', 'left_only']
Categories (3, object): ['left_only', 'right_only', 'both']
```

In [57]:

```python
tmp_jnt_df = tmp_jnt_df.drop(columns = '_merge')
```

In [58]:

```python
# fill nulls with zero value
for i in bulk_df.columns[1:]:
    tmp_jnt_df[i] = tmp_jnt_df[i].fillna(0)
    tmp_jnt_df[i] = tmp_jnt_df[i].replace(np.nan, 0)
```

In [59]:

```python
for i in bulk_time_df.columns[1:]:
    tmp_jnt_df[i+'_time'] = tmp_jnt_df[i+'_time'].fillna(pd.to_datetime(0, unit='s', errors='coerce').time())
```

```
In [60]:  tmp_jnt_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 2477 entries, 0 to 2476
Data columns (total 35 columns):
 #   Column             Non-Null Count  Dtype  
---  ------             --------------  -----  
 0   key                2477 non-null   int64  
 1   first_temperature  2477 non-null   float64
 2   final_temperature  2477 non-null   float64
 3   first_temp_time    2477 non-null   object 
 4   final_temp_time    2477 non-null   object 
 5   Bulk 1             2477 non-null   float64
 6   Bulk 1_time        2477 non-null   object 
 7   Bulk 2             2477 non-null   float64
 8   Bulk 2_time        2477 non-null   object 
 9   Bulk 3             2477 non-null   float64
 10  Bulk 3_time        2477 non-null   object 
 11  Bulk 4             2477 non-null   float64
 12  Bulk 4_time        2477 non-null   object 
 13  Bulk 5             2477 non-null   float64
 14  Bulk 5_time        2477 non-null   object 
 15  Bulk 6             2477 non-null   float64
 16  Bulk 6_time        2477 non-null   object 
 17  Bulk 7             2477 non-null   float64
 18  Bulk 7_time        2477 non-null   object 
 19  Bulk 8             2477 non-null   float64
 20  Bulk 8_time        2477 non-null   object 
 21  Bulk 9             2477 non-null   float64
 22  Bulk 9_time        2477 non-null   object 
 23  Bulk 10            2477 non-null   float64
 24  Bulk 10_time       2477 non-null   object 
 25  Bulk 11            2477 non-null   float64
 26  Bulk 11_time       2477 non-null   object 
 27  Bulk 12            2477 non-null   float64
 28  Bulk 12_time       2477 non-null   object 
 29  Bulk 13            2477 non-null   float64
 30  Bulk 13_time       2477 non-null   object 
 31  Bulk 14            2477 non-null   float64
 32  Bulk 14_time       2477 non-null   object 
 33  Bulk 15            2477 non-null   float64
 34  Bulk 15_time       2477 non-null   object 
dtypes: float64(17), int64(1), object(17)
memory usage: 696.7+ KB
```

In [61]:
```
tmp_jnt_df.head()
```

Out[61]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time	Bulk 1	Bulk 1_time	Bulk 2	Bulk 2_time	Bulk 3	...	Bulk 11	Bulk 11_time	Bulk 12	Bulk 12_time	Bulk 13	Bulk 13_time
0	1	1571.0	1613.0	11:16:18	11:30:39	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	206.0	11:03:52	0.0	00:00:00
1	2	1581.0	1602.0	11:37:27	11:59:12	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	206.0	11:40:20	0.0	00:00:00
2	3	1596.0	1599.0	12:13:17	12:34:57	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	205.0	12:09:40	0.0	00:00:00
3	4	1601.0	1625.0	12:52:57	12:59:25	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	207.0	12:41:24	0.0	00:00:00
4	5	1576.0	1602.0	13:23:19	13:36:01	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	203.0	13:12:56	0.0	00:00:00

5 rows × 35 columns

Conclusion:

- After merging of datasets the new dataset was obtained with size of 2447*62;
- The information on quantity and time of insertion of bulk materials were added to dataset.

2.3 Merging the datasets with quantity and time of insertion of wired materials and add it to dataset with target

In [62]:
```
wire_jnt = wire_df.merge(wire_time_df,how = 'left',left_on='key', right_on='key',
          suffixes=('','_time'))
```

In [63]:
```
col_list = ['key']
for i in range(9):
    col_list.append(wire_jnt.columns[1:10][i])
    col_list.append(wire_jnt.columns[10:][i])

wire_jnt = wire_jnt[col_list]
```

In [64]:
```
wire_jnt.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3081 entries, 0 to 3080
Data columns (total 19 columns):
 #   Column       Non-Null Count  Dtype  
---  ------       --------------  -----  
 0   key          3081 non-null   int64  
 1   Wire 1       3055 non-null   float64
 2   Wire 1_time  3055 non-null   object 
 3   Wire 2       1079 non-null   float64
 4   Wire 2_time  1079 non-null   object 
 5   Wire 3       63 non-null     float64
 6   Wire 3_time  63 non-null     object 
 7   Wire 4       14 non-null     float64
 8   Wire 4_time  14 non-null     object 
 9   Wire 5       1 non-null      float64
 10  Wire 5_time  1 non-null      object 
 11  Wire 6       73 non-null     float64
 12  Wire 6_time  73 non-null     object 
 13  Wire 7       11 non-null     float64
 14  Wire 7_time  11 non-null     object 
 15  Wire 8       19 non-null     float64
 16  Wire 8_time  19 non-null     object 
 17  Wire 9       29 non-null     float64
 18  Wire 9_time  29 non-null     object 
dtypes: float64(9), int64(1), object(9)
memory usage: 481.4+ KB
```

In [65]:
```
wire_jnt.head()
```

Out[65]:

	key	Wire 1	Wire 1_time	Wire 2	Wire 2_time	Wire 3	Wire 3_time	Wire 4	Wire 4_time	Wire 5	Wire 5_time	Wire 6	Wire 6_time	Wire 7	Wire 7_time	Wire 8	Wire 8_time	Wire 9	Wire 9_time
0	1	60.059998	11:11:41	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None
1	2	96.052315	11:46:10	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None
2	3	91.160157	12:13:47	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None
3	4	89.063515	12:48:05	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None
4	5	89.238236	13:18:15	9.11456	13:32:06	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None	NaN	None

Merging of dataset with temperature_df

In [66]:

```python
tmp_jnt_df = pd.merge(tmp_jnt_df,wire_jnt,how = 'outer',on='key',indicator=True)
```

In [67]:

```python
tmp_jnt_df.head()
```

Out[67]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time	Bulk 1	Bulk 1_time	Bulk 2	Bulk 2_time	Bulk 3	...	Wire 5_time	Wire 6	Wire 6_time	Wire 7	Wire 7_time	Wire 8	Wi 8_tim
0	1	1571.0	1613.0	11:16:18	11:30:39	0.0	00:00:00	0.0	00:00:00	0.0	...	None	NaN	None	NaN	None	NaN	Nor
1	2	1581.0	1602.0	11:37:27	11:59:12	0.0	00:00:00	0.0	00:00:00	0.0	...	None	NaN	None	NaN	None	NaN	Nor
2	3	1596.0	1599.0	12:13:17	12:34:57	0.0	00:00:00	0.0	00:00:00	0.0	...	None	NaN	None	NaN	None	NaN	Nor
3	4	1601.0	1625.0	12:52:57	12:59:25	0.0	00:00:00	0.0	00:00:00	0.0	...	None	NaN	None	NaN	None	NaN	Nor
4	5	1576.0	1602.0	13:23:19	13:36:01	0.0	00:00:00	0.0	00:00:00	0.0	...	None	NaN	None	NaN	None	NaN	Nor

5 rows × 54 columns

In [68]:
```
tmp_jnt_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3185 entries, 0 to 3184
Data columns (total 54 columns):
 #   Column             Non-Null Count  Dtype  
---  ------             --------------  -----  
 0   key                3185 non-null   int64  
 1   first_temperature  2477 non-null   float64
 2   final_temperature  2477 non-null   float64
 3   first_temp_time    2477 non-null   object 
 4   final_temp_time    2477 non-null   object 
 5   Bulk 1             2477 non-null   float64
 6   Bulk 1_time        2477 non-null   object 
 7   Bulk 2             2477 non-null   float64
 8   Bulk 2_time        2477 non-null   object 
 9   Bulk 3             2477 non-null   float64
 10  Bulk 3_time        2477 non-null   object 
 11  Bulk 4             2477 non-null   float64
 12  Bulk 4_time        2477 non-null   object 
 13  Bulk 5             2477 non-null   float64
 14  Bulk 5_time        2477 non-null   object 
 15  Bulk 6             2477 non-null   float64
 16  Bulk 6_time        2477 non-null   object 
 17  Bulk 7             2477 non-null   float64
 18  Bulk 7_time        2477 non-null   object 
 19  Bulk 8             2477 non-null   float64
 20  Bulk 8_time        2477 non-null   object 
 21  Bulk 9             2477 non-null   float64
 22  Bulk 9_time        2477 non-null   object 
 23  Bulk 10            2477 non-null   float64
 24  Bulk 10_time       2477 non-null   object 
 25  Bulk 11            2477 non-null   float64
 26  Bulk 11_time       2477 non-null   object 
 27  Bulk 12            2477 non-null   float64
 28  Bulk 12_time       2477 non-null   object 
 29  Bulk 13            2477 non-null   float64
 30  Bulk 13_time       2477 non-null   object 
 31  Bulk 14            2477 non-null   float64
 32  Bulk 14_time       2477 non-null   object 
 33  Bulk 15            2477 non-null   float64
 34  Bulk 15_time       2477 non-null   object 
 35  Wire 1             3055 non-null   float64
 36  Wire 1_time        3055 non-null   object 
 37  Wire 2             1079 non-null   float64
 38  Wire 2_time        1079 non-null   object 
 39  Wire 3             63 non-null     float64
 40  Wire 3_time        63 non-null     object
 41  Wire 4             14 non-null     float64
 42  Wire 4_time        14 non-null     object
 43  Wire 5             1 non-null      float64
 44  Wire 5_time        1 non-null      object
 45  Wire 6             73 non-null     float64
 46  Wire 6_time        73 non-null     object
 47  Wire 7             11 non-null     float64
 48  Wire 7_time        11 non-null     object
 49  Wire 8             19 non-null     float64
 50  Wire 8_time        19 non-null     object
 51  Wire 9             29 non-null     float64
 52  Wire 9_time        29 non-null     object
 53  _merge             3185 non-null   category
dtypes: category(1), float64(26), int64(1), object(26)
memory usage: 1.3+ MB
```

In [69]:
```python
tmp_jnt_df = tmp_jnt_df[tmp_jnt_df['_merge'] != 'right_only']
```

In [70]:
```python
# deletion of column merge
tmp_jnt_df['_merge'].unique()
```

Out[70]:
```
['both', 'left_only']
Categories (3, object): ['left_only', 'right_only', 'both']
```

In [71]:
```python
tmp_jnt_df = tmp_jnt_df.drop(columns = '_merge')
```

Deleting the values of quantity inserted material in case the insertion happend after temperature measurement

In [72]:
```python
# fill the nulls with zero
for i in wire_df.columns[1:]:
    tmp_jnt_df[i] = tmp_jnt_df[i].fillna(0)
    tmp_jnt_df[i] = tmp_jnt_df[i].replace(np.nan, 0)
```

In [73]:
```python
for i in wire_time_df.columns[1:]:
    tmp_jnt_df[i+'_time'] = tmp_jnt_df[i+'_time'].fillna(pd.to_datetime(0, unit='s', errors='coerce').time())
```

In [74]:
```python
tmp_jnt_df.head()
```

Out[74]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time	Bulk 1	Bulk 1_time	Bulk 2	Bulk 2_time	Bulk 3	...	Wire 5	Wire 5_time	Wire 6	Wire 6_time	Wire 7	Wire 7_time
0	1	1571.0	1613.0	11:16:18	11:30:39	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	0.0	00:00:00	0.0	00:00:00
1	2	1581.0	1602.0	11:37:27	11:59:12	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	0.0	00:00:00	0.0	00:00:00
2	3	1596.0	1599.0	12:13:17	12:34:57	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	0.0	00:00:00	0.0	00:00:00
3	4	1601.0	1625.0	12:52:57	12:59:25	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	0.0	00:00:00	0.0	00:00:00
4	5	1576.0	1602.0	13:23:19	13:36:01	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	00:00:00	0.0	00:00:00	0.0	00:00:00

5 rows × 53 columns

```
In [75]: tmp_jnt_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 2477 entries, 0 to 2476
Data columns (total 53 columns):
 #   Column             Non-Null Count  Dtype  
---  ------             --------------  -----  
 0   key                2477 non-null   int64  
 1   first_temperature  2477 non-null   float64
 2   final_temperature  2477 non-null   float64
 3   first_temp_time    2477 non-null   object 
 4   final_temp_time    2477 non-null   object 
 5   Bulk 1             2477 non-null   float64
 6   Bulk 1_time        2477 non-null   object 
 7   Bulk 2             2477 non-null   float64
 8   Bulk 2_time        2477 non-null   object 
 9   Bulk 3             2477 non-null   float64
 10  Bulk 3_time        2477 non-null   object 
 11  Bulk 4             2477 non-null   float64
 12  Bulk 4_time        2477 non-null   object 
 13  Bulk 5             2477 non-null   float64
 14  Bulk 5_time        2477 non-null   object 
 15  Bulk 6             2477 non-null   float64
 16  Bulk 6_time        2477 non-null   object 
 17  Bulk 7             2477 non-null   float64
 18  Bulk 7_time        2477 non-null   object 
 19  Bulk 8             2477 non-null   float64
 20  Bulk 8_time        2477 non-null   object 
 21  Bulk 9             2477 non-null   float64
 22  Bulk 9_time        2477 non-null   object 
 23  Bulk 10            2477 non-null   float64
 24  Bulk 10_time       2477 non-null   object 
 25  Bulk 11            2477 non-null   float64
 26  Bulk 11_time       2477 non-null   object 
 27  Bulk 12            2477 non-null   float64
 28  Bulk 12_time       2477 non-null   object 
 29  Bulk 13            2477 non-null   float64
 30  Bulk 13_time       2477 non-null   object 
 31  Bulk 14            2477 non-null   float64
 32  Bulk 14_time       2477 non-null   object 
 33  Bulk 15            2477 non-null   float64
 34  Bulk 15_time       2477 non-null   object 
 35  Wire 1             2477 non-null   float64
 36  Wire 1_time        2477 non-null   object 
 37  Wire 2             2477 non-null   float64
 38  Wire 2_time        2477 non-null   object 
 39  Wire 3             2477 non-null   float64
 40  Wire 3_time        2477 non-null   object 
 41  Wire 4             2477 non-null   float64
 42  Wire 4_time        2477 non-null   object 
 43  Wire 5             2477 non-null   float64
 44  Wire 5_time        2477 non-null   object 
 45  Wire 6             2477 non-null   float64
 46  Wire 6_time        2477 non-null   object 
 47  Wire 7             2477 non-null   float64
 48  Wire 7_time        2477 non-null   object 
 49  Wire 8             2477 non-null   float64
 50  Wire 8_time        2477 non-null   object 
 51  Wire 9             2477 non-null   float64
 52  Wire 9_time        2477 non-null   object 
dtypes: float64(26), int64(1), object(26)
memory usage: 1.0+ MB
```

Conclusion:

- The prepared dataset has size of 2447*80;
- Tha quantity and time of insertion of wired materials were added to dataset.

2.4 Merging of heating dataset and prepared dataset;

Query for obtaining of the information on quantity af heating for every batch, start of heating, finish of heating considering the quantity of heating, cumulative heating time, cumulative active and reactive power.

In [76]:
```
query = '''
WITH

table_1 AS (SELECT ROW_NUMBER() OVER () as row,
                  *
              FROM steel.data_arc
             ORDER BY row),

heat_time AS (
           SELECT DISTINCT key,row,
                  COUNT(key) OVER ( PARTITION BY key) heating_qty,
                  FIRST_VALUE("BeginHeat") OVER ( PARTITION BY key ORDER BY row) AS heat_start,
                  FIRST_VALUE("EndHeat") OVER ( PARTITION BY key ORDER BY row DESC) AS heat_finish,
                  CASE WHEN FIRST_VALUE("BeginHeat") OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE FIRST_VALUE("BeginHeat") OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_1_start,
                  CASE WHEN FIRST_VALUE("EndHeat") OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE FIRST_VALUE("EndHeat") OVER (PARTITION BY key ORDER BY row)
                  END AS heat_1_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",2) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",2) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_2_start,
                  CASE WHEN NTH_VALUE("EndHeat",2) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",2) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_2_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",3) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",3) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_3_start,
                  CASE WHEN NTH_VALUE("EndHeat",3) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",3) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_3_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",4) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",4) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_4_start,
                  CASE WHEN NTH_VALUE("EndHeat",4) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",4) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_4_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",5) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",5) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_5_start,
                  CASE WHEN NTH_VALUE("EndHeat",5) OVER (PARTITION BY key ORDER BY row)  is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",5) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_5_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",6) OVER ( PARTITION BY key ORDER BY row)  is null
                           THEN '00:00:00'
                       ELSE  NTH_VALUE("BeginHeat",6) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_6_start,
                  CASE WHEN NTH_VALUE("EndHeat",6) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",6) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_6_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",7) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",7) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_7_start,
                  CASE WHEN NTH_VALUE("EndHeat",7) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",7) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_7_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",8) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",8) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_8_start,
                  CASE WHEN NTH_VALUE("EndHeat",8) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",8) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_8_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",9) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",9) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_9_start,
                  CASE WHEN NTH_VALUE("EndHeat",9) OVER (PARTITION BY key ORDER BY row)  is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",9) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_9_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",10) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",9) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_10_start,
                  CASE WHEN NTH_VALUE("EndHeat",10) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",10) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_10_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",11) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",11) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_11_start,
                  CASE WHEN NTH_VALUE("EndHeat",11) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",11) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_11_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",12) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",12) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_12_start,
                  CASE WHEN NTH_VALUE("EndHeat",12) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",12) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_12_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",13) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",13) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_13_start,
                  CASE WHEN NTH_VALUE("EndHeat",13) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",13) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_13_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",14) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",14) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_14_start,
                  CASE WHEN NTH_VALUE("EndHeat",14) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",14) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_14_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",15) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",15) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_15_start,
                  CASE WHEN NTH_VALUE("EndHeat",15) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",15) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_15_finish,
                  CASE WHEN NTH_VALUE("BeginHeat",16) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("BeginHeat",16) OVER ( PARTITION BY key ORDER BY row)
                  END AS heat_16_start,
                  CASE WHEN NTH_VALUE("EndHeat",16) OVER (PARTITION BY key ORDER BY row) is null
                           THEN '00:00:00'
                       ELSE NTH_VALUE("EndHeat",16) OVER (PARTITION BY key ORDER BY row)
                  END AS heat_16_finish,

                  CASE WHEN FIRST_VALUE("ActivePower") OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                        ELSE FIRST_VALUE("ActivePower") OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_1,
                  CASE WHEN NTH_VALUE("ActivePower",2) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",2) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_2,
                  CASE WHEN NTH_VALUE("ActivePower",3) OVER ( PARTITION BY key ORDER BY row)  is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",3) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_3,
                  CASE WHEN NTH_VALUE("ActivePower",4) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",4) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_4,
                  CASE WHEN NTH_VALUE("ActivePower",5) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",5) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_5,
                  CASE WHEN NTH_VALUE("ActivePower",6) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",6) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_6,
                  CASE WHEN NTH_VALUE("ActivePower",7) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",7) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_7,
                  CASE WHEN NTH_VALUE("ActivePower",8) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",8) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_8,
                  CASE WHEN NTH_VALUE("ActivePower",9) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",9) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_9,
                  CASE WHEN NTH_VALUE("ActivePower",10) OVER ( PARTITION BY key ORDER BY row) is null
                          THEN '0'
                       ELSE NTH_VALUE("ActivePower",10) OVER ( PARTITION BY key ORDER BY row)
                  END AS act_pwr_10,
                  CASE WHEN NTH_VALUE("ActivePower",11) OVER ( PARTITION BY key ORDER BY row) is null
```

```
                THEN '0'
             ELSE NTH_VALUE("ActivePower",11) OVER ( PARTITION BY key ORDER BY row)
        END AS act_pwr_11,
        CASE WHEN NTH_VALUE("ActivePower",12) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ActivePower",12) OVER ( PARTITION BY key ORDER BY row)
        END AS act_pwr_12,
        CASE WHEN NTH_VALUE("ActivePower",13) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ActivePower",13) OVER ( PARTITION BY key ORDER BY row)
        END AS act_pwr_13,
        CASE WHEN NTH_VALUE("ActivePower",14) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ActivePower",14) OVER ( PARTITION BY key ORDER BY row)
        END AS act_pwr_14,
        CASE WHEN NTH_VALUE("ActivePower",15) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ActivePower",15) OVER ( PARTITION BY key ORDER BY row)
        END AS act_pwr_15,
        CASE WHEN NTH_VALUE("ActivePower",16) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ActivePower",16) OVER ( PARTITION BY key ORDER BY row)
        END AS act_pwr_16,

             CASE WHEN FIRST_VALUE("ReactivePower") OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE FIRST_VALUE("ReactivePower") OVER ( PARTITION BY key ORDER BY row)
        END AS react_pwr_1,
        CASE WHEN NTH_VALUE("ReactivePower",2) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ReactivePower",2) OVER ( PARTITION BY key ORDER BY row)
        END AS react_pwr_2,
        CASE WHEN NTH_VALUE("ReactivePower",3) OVER ( PARTITION BY key ORDER BY row)  is null
                THEN '0'
             ELSE NTH_VALUE("ReactivePower",3) OVER ( PARTITION BY key ORDER BY row)
        END AS react_pwr_3,
        CASE WHEN NTH_VALUE("ReactivePower",4) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ReactivePower",4) OVER ( PARTITION BY key ORDER BY row)
        END AS react_pwr_4,
        CASE WHEN NTH_VALUE("ReactivePower",5) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
             ELSE NTH_VALUE("ReactivePower",5) OVER ( PARTITION BY key ORDER BY row)
        END AS react_pwr_5,
        CASE WHEN NTH_VALUE("ReactivePower",6) OVER ( PARTITION BY key ORDER BY row) is null
                THEN '0'
```

```
                        ELSE NTH_VALUE("ReactivePower",6) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_6,
                   CASE WHEN NTH_VALUE("ReactivePower",7) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",7) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_7,
                   CASE WHEN NTH_VALUE("ReactivePower",8) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",8) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_8,
                   CASE WHEN NTH_VALUE("ReactivePower",9) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",9) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_9,
                   CASE WHEN NTH_VALUE("ReactivePower",10) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",10) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_10,
                   CASE WHEN NTH_VALUE("ReactivePower",11) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",11) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_11,
                   CASE WHEN NTH_VALUE("ReactivePower",12) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",12) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_12,
                   CASE WHEN NTH_VALUE("ReactivePower",13) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",13) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_13,
                   CASE WHEN NTH_VALUE("ReactivePower",14) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",14) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_14,
                   CASE WHEN NTH_VALUE("ReactivePower",15) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",15) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_15,
                   CASE WHEN NTH_VALUE("ReactivePower",16) OVER ( PARTITION BY key ORDER BY row) is null
                           THEN '0'
                        ELSE NTH_VALUE("ReactivePower",16) OVER ( PARTITION BY key ORDER BY row)
                   END AS react_pwr_16
              FROM table_1
             ORDER BY row)


```

```

SELECT *
  FROM heat_time
'''

arc_new_df = pd.read_sql_query(query, con=engine)
```

```
In [77]:  arc_new_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 14876 entries, 0 to 14875
Data columns (total 69 columns):
 #   Column          Non-Null Count  Dtype  
---  ------          --------------  -----  
 0   key             14876 non-null  int64  
 1   row             14876 non-null  int64  
 2   heating_qty     14876 non-null  int64  
 3   heat_start      14876 non-null  object 
 4   heat_finish     14876 non-null  object 
 5   heat_1_start    14876 non-null  object 
 6   heat_1_finish   14876 non-null  object 
 7   heat_2_start    14876 non-null  object 
 8   heat_2_finish   14876 non-null  object 
 9   heat_3_start    14876 non-null  object 
 10  heat_3_finish   14876 non-null  object 
 11  heat_4_start    14876 non-null  object 
 12  heat_4_finish   14876 non-null  object 
 13  heat_5_start    14876 non-null  object 
 14  heat_5_finish   14876 non-null  object 
 15  heat_6_start    14876 non-null  object 
 16  heat_6_finish   14876 non-null  object 
 17  heat_7_start    14876 non-null  object 
 18  heat_7_finish   14876 non-null  object 
 19  heat_8_start    14876 non-null  object 
 20  heat_8_finish   14876 non-null  object 
 21  heat_9_start    14876 non-null  object 
 22  heat_9_finish   14876 non-null  object 
 23  heat_10_start   14876 non-null  object 
 24  heat_10_finish  14876 non-null  object 
 25  heat_11_start   14876 non-null  object 
 26  heat_11_finish  14876 non-null  object 
 27  heat_12_start   14876 non-null  object 
 28  heat_12_finish  14876 non-null  object 
 29  heat_13_start   14876 non-null  object 
 30  heat_13_finish  14876 non-null  object 
 31  heat_14_start   14876 non-null  object 
 32  heat_14_finish  14876 non-null  object 
 33  heat_15_start   14876 non-null  object 
 34  heat_15_finish  14876 non-null  object 
 35  heat_16_start   14876 non-null  object 
 36  heat_16_finish  14876 non-null  object 
 37  act_pwr_1       14876 non-null  float64
 38  act_pwr_2       14876 non-null  float64
 39  act_pwr_3       14876 non-null  float64
 40  act_pwr_4       14876 non-null  float64
 41  act_pwr_5       14876 non-null  float64
 42  act_pwr_6       14876 non-null  float64
 43  act_pwr_7       14876 non-null  float64
 44  act_pwr_8       14876 non-null  float64
 45  act_pwr_9       14876 non-null  float64
 46  act_pwr_10      14876 non-null  float64
 47  act_pwr_11      14876 non-null  float64
 48  act_pwr_12      14876 non-null  float64
 49  act_pwr_13      14876 non-null  float64
 50  act_pwr_14      14876 non-null  float64
 51  act_pwr_15      14876 non-null  float64
 52  act_pwr_16      14876 non-null  float64
 53  react_pwr_1     14876 non-null  float64
 54  react_pwr_2     14876 non-null  float64
 55  react_pwr_3     14876 non-null  float64
 56  react_pwr_4     14876 non-null  float64
 57  react_pwr_5     14876 non-null  float64
 58  react_pwr_6     14876 non-null  float64
 59  react_pwr_7     14876 non-null  float64
 60  react_pwr_8     14876 non-null  float64
 61  react_pwr_9     14876 non-null  float64
 62  react_pwr_10    14876 non-null  float64
 63  react_pwr_11    14876 non-null  float64
 64  react_pwr_12    14876 non-null  float64
 65  react_pwr_13    14876 non-null  float64
 66  react_pwr_14    14876 non-null  float64
 67  react_pwr_15    14876 non-null  float64
 68  react_pwr_16    14876 non-null  float64
dtypes: float64(32), int64(3), object(34)
memory usage: 7.8+ MB
```

In [78]:
```python
# display of datset
arc_new_df.head(15)
```

Out[78]:

	key	row	heating_qty	heat_start	heat_finish	heat_1_start	heat_1_finish	heat_2_start	heat_2_finish	heat_3_start	...	react_pwr_7	react_pwr_8	react_pwr_9	rea
0	1	1	5	11:02:14	11:28:37	11:02:14	11:06:02	00:00:00	00:00:00	00:00:00	...	0.0	0.0	0.0	
1	1	2	5	11:02:14	11:28:37	11:02:14	11:06:02	11:07:28	11:10:33	00:00:00	...	0.0	0.0	0.0	
2	1	3	5	11:02:14	11:28:37	11:02:14	11:06:02	11:07:28	11:10:33	11:11:44	...	0.0	0.0	0.0	
3	1	4	5	11:02:14	11:28:37	11:02:14	11:06:02	11:07:28	11:10:33	11:11:44	...	0.0	0.0	0.0	
4	1	5	5	11:02:14	11:28:37	11:02:14	11:06:02	11:07:28	11:10:33	11:11:44	...	0.0	0.0	0.0	
5	2	6	4	11:34:14	11:53:18	11:34:14	11:36:31	00:00:00	00:00:00	00:00:00	...	0.0	0.0	0.0	
6	2	7	4	11:34:14	11:53:18	11:34:14	11:36:31	11:38:50	11:44:28	00:00:00	...	0.0	0.0	0.0	
7	2	8	4	11:34:14	11:53:18	11:34:14	11:36:31	11:38:50	11:44:28	11:46:19	...	0.0	0.0	0.0	
8	2	9	4	11:34:14	11:53:18	11:34:14	11:36:31	11:38:50	11:44:28	11:46:19	...	0.0	0.0	0.0	
9	3	10	5	12:06:54	12:32:19	12:06:54	12:11:34	00:00:00	00:00:00	00:00:00	...	0.0	0.0	0.0	
10	3	11	5	12:06:54	12:32:19	12:06:54	12:11:34	12:13:52	12:15:56	00:00:00	...	0.0	0.0	0.0	
11	3	12	5	12:06:54	12:32:19	12:06:54	12:11:34	12:13:52	12:15:56	12:18:56	...	0.0	0.0	0.0	
12	3	13	5	12:06:54	12:32:19	12:06:54	12:11:34	12:13:52	12:15:56	12:18:56	...	0.0	0.0	0.0	
13	3	14	5	12:06:54	12:32:19	12:06:54	12:11:34	12:13:52	12:15:56	12:18:56	...	0.0	0.0	0.0	
14	4	15	4	12:39:37	12:57:50	12:39:37	12:43:04	00:00:00	00:00:00	00:00:00	...	0.0	0.0	0.0	

15 rows × 69 columns

In [79]:
```python
# creating a new row
arc_new_df['row_max'] = arc_new_df['row']
```

In [80]:
```python
# loop for check of the number of heating was it the last or not
max_check = []
for i in range(len(arc_new_df['key'])):
    max_check.append(arc_new_df[arc_new_df['key'] == arc_new_df['key'][i]]['row'].max())
```

In [81]:
```python
arc_new_df['max_check'] = max_check
```

In [82]:
```
# selection of columns with information after last heating
arc_new_df = arc_new_df[arc_new_df['row'] == arc_new_df['max_check']]
```

In [83]:
```
# deleting the useless columns
arc_new_df = arc_new_df.drop(columns = ['row','max_check','row_max', 'heat_1_start'])
```

Merging of dataset with temperature_df

In [84]:
```
arc_tmp_jnt = pd.merge(tmp_jnt_df,arc_new_df,how = 'outer',on='key',indicator=True)
```

In [85]:

```
arc_tmp_jnt.info(1)
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3216 entries, 0 to 3215
Data columns (total 120 columns):
 #    Column             Dtype
---   ------             -----
 0    key                int64
 1    first_temperature  float64
 2    final_temperature  float64
 3    first_temp_time    object
 4    final_temp_time    object
 5    Bulk 1             float64
 6    Bulk 1_time        object
 7    Bulk 2             float64
 8    Bulk 2_time        object
 9    Bulk 3             float64
 10   Bulk 3_time        object
 11   Bulk 4             float64
 12   Bulk 4_time        object
 13   Bulk 5             float64
 14   Bulk 5_time        object
 15   Bulk 6             float64
 16   Bulk 6_time        object
 17   Bulk 7             float64
 18   Bulk 7_time        object
 19   Bulk 8             float64
 20   Bulk 8_time        object
 21   Bulk 9             float64
 22   Bulk 9_time        object
 23   Bulk 10            float64
 24   Bulk 10_time       object
 25   Bulk 11            float64
 26   Bulk 11_time       object
 27   Bulk 12            float64
 28   Bulk 12_time       object
 29   Bulk 13            float64
 30   Bulk 13_time       object
 31   Bulk 14            float64
 32   Bulk 14_time       object
 33   Bulk 15            float64
 34   Bulk 15_time       object
 35   Wire 1             float64
 36   Wire 1_time        object
 37   Wire 2             float64
 38   Wire 2_time        object
 39   Wire 3             float64
```

```
40   Wire 3_time        object
41   Wire 4             float64
42   Wire 4_time        object
43   Wire 5             float64
44   Wire 5_time        object
45   Wire 6             float64
46   Wire 6_time        object
47   Wire 7             float64
48   Wire 7_time        object
49   Wire 8             float64
50   Wire 8_time        object
51   Wire 9             float64
52   Wire 9_time        object
53   heating_qty        float64
54   heat_start         object
55   heat_finish        object
56   heat_1_finish      object
57   heat_2_start       object
58   heat_2_finish      object
59   heat_3_start       object
60   heat_3_finish      object
61   heat_4_start       object
62   heat_4_finish      object
63   heat_5_start       object
64   heat_5_finish      object
65   heat_6_start       object
66   heat_6_finish      object
67   heat_7_start       object
68   heat_7_finish      object
69   heat_8_start       object
70   heat_8_finish      object
71   heat_9_start       object
72   heat_9_finish      object
73   heat_10_start      object
74   heat_10_finish     object
75   heat_11_start      object
76   heat_11_finish     object
77   heat_12_start      object
78   heat_12_finish     object
79   heat_13_start      object
80   heat_13_finish     object
81   heat_14_start      object
82   heat_14_finish     object
83   heat_15_start      object
84   heat_15_finish     object
85   heat_16_start      object
```

```
 86   heat_16_finish     object
 87   act_pwr_1          float64
 88   act_pwr_2          float64
 89   act_pwr_3          float64
 90   act_pwr_4          float64
 91   act_pwr_5          float64
 92   act_pwr_6          float64
 93   act_pwr_7          float64
 94   act_pwr_8          float64
 95   act_pwr_9          float64
 96   act_pwr_10         float64
 97   act_pwr_11         float64
 98   act_pwr_12         float64
 99   act_pwr_13         float64
 100  act_pwr_14         float64
 101  act_pwr_15         float64
 102  act_pwr_16         float64
 103  react_pwr_1        float64
 104  react_pwr_2        float64
 105  react_pwr_3        float64
 106  react_pwr_4        float64
 107  react_pwr_5        float64
 108  react_pwr_6        float64
 109  react_pwr_7        float64
 110  react_pwr_8        float64
 111  react_pwr_9        float64
 112  react_pwr_10       float64
 113  react_pwr_11       float64
 114  react_pwr_12       float64
 115  react_pwr_13       float64
 116  react_pwr_14       float64
 117  react_pwr_15       float64
 118  react_pwr_16       float64
 119  _merge             category
dtypes: category(1), float64(59), int64(1), object(59)
memory usage: 2.9+ MB
```

In [86]:
```
arc_tmp_jnt.head(15)
```

Out[86]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time	Bulk 1	Bulk 1_time	Bulk 2	Bulk 2_time	Bulk 3	...	react_pwr_8	react_pwr_9	react_pwr_10	react_
0	1	1571.0	1613.0	11:16:18	11:30:39	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
1	2	1581.0	1602.0	11:37:27	11:59:12	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
2	3	1596.0	1599.0	12:13:17	12:34:57	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
3	4	1601.0	1625.0	12:52:57	12:59:25	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
4	5	1576.0	1602.0	13:23:19	13:36:01	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
5	6	1543.0	1596.0	13:49:24	14:12:29	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
6	7	1586.0	1599.0	14:19:43	14:42:37	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
7	8	1577.0	1598.0	15:07:18	15:22:52	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
8	9	1587.0	1592.0	15:37:03	16:01:16	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
9	10	1574.0	1593.0	16:14:29	16:36:08	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
10	11	1616.0	1597.0	16:54:18	17:27:23	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
11	12	1606.0	1591.0	17:40:54	18:13:03	46.0	17:50:19	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
12	13	1596.0	1619.0	18:38:59	19:06:15	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	
13	14	1583.0	1606.0	20:00:42	20:38:22	0.0	00:00:00	0.0	00:00:00	71.0	...	0.0	0.0	0.0	
14	15	1605.0	1598.0	20:58:40	21:33:01	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0	

15 rows × 120 columns

In [87]:
```
arc_tmp_jnt = arc_tmp_jnt[arc_tmp_jnt['_merge'] == 'both']
```

In [88]:
```
arc_tmp_jnt['_merge'].unique()
```

Out[88]:
```
['both']
Categories (3, object): ['left_only', 'right_only', 'both']
```

In [89]:
```
# deletion of column merge
arc_tmp_jnt = arc_tmp_jnt.drop(columns = '_merge')
```

```
In [90]: arc_tmp_jnt.info(1)
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 2475 entries, 0 to 2476
Data columns (total 119 columns):
 #    Column             Dtype  
---   ------             -----  
 0    key                int64  
 1    first_temperature  float64
 2    final_temperature  float64
 3    first_temp_time    object 
 4    final_temp_time    object 
 5    Bulk 1             float64
 6    Bulk 1_time        object 
 7    Bulk 2             float64
 8    Bulk 2_time        object 
 9    Bulk 3             float64
 10   Bulk 3_time        object 
 11   Bulk 4             float64
 12   Bulk 4_time        object 
 13   Bulk 5             float64
 14   Bulk 5_time        object 
 15   Bulk 6             float64
 16   Bulk 6_time        object 
 17   Bulk 7             float64
 18   Bulk 7_time        object 
 19   Bulk 8             float64
 20   Bulk 8_time        object 
 21   Bulk 9             float64
 22   Bulk 9_time        object 
 23   Bulk 10            float64
 24   Bulk 10_time       object 
 25   Bulk 11            float64
 26   Bulk 11_time       object 
 27   Bulk 12            float64
 28   Bulk 12_time       object 
 29   Bulk 13            float64
 30   Bulk 13_time       object 
 31   Bulk 14            float64
 32   Bulk 14_time       object 
 33   Bulk 15            float64
 34   Bulk 15_time       object 
 35   Wire 1             float64
 36   Wire 1_time        object 
 37   Wire 2             float64
 38   Wire 2_time        object 
 39   Wire 3             float64
```

```
40   Wire 3_time        object
41   Wire 4             float64
42   Wire 4_time        object
43   Wire 5             float64
44   Wire 5_time        object
45   Wire 6             float64
46   Wire 6_time        object
47   Wire 7             float64
48   Wire 7_time        object
49   Wire 8             float64
50   Wire 8_time        object
51   Wire 9             float64
52   Wire 9_time        object
53   heating_qty        float64
54   heat_start         object
55   heat_finish        object
56   heat_1_finish      object
57   heat_2_start       object
58   heat_2_finish      object
59   heat_3_start       object
60   heat_3_finish      object
61   heat_4_start       object
62   heat_4_finish      object
63   heat_5_start       object
64   heat_5_finish      object
65   heat_6_start       object
66   heat_6_finish      object
67   heat_7_start       object
68   heat_7_finish      object
69   heat_8_start       object
70   heat_8_finish      object
71   heat_9_start       object
72   heat_9_finish      object
73   heat_10_start      object
74   heat_10_finish     object
75   heat_11_start      object
76   heat_11_finish     object
77   heat_12_start      object
78   heat_12_finish     object
79   heat_13_start      object
80   heat_13_finish     object
81   heat_14_start      object
82   heat_14_finish     object
83   heat_15_start      object
84   heat_15_finish     object
85   heat_16_start      object
```

```
 86   heat_16_finish     object
 87   act_pwr_1          float64
 88   act_pwr_2          float64
 89   act_pwr_3          float64
 90   act_pwr_4          float64
 91   act_pwr_5          float64
 92   act_pwr_6          float64
 93   act_pwr_7          float64
 94   act_pwr_8          float64
 95   act_pwr_9          float64
 96   act_pwr_10         float64
 97   act_pwr_11         float64
 98   act_pwr_12         float64
 99   act_pwr_13         float64
 100  act_pwr_14         float64
 101  act_pwr_15         float64
 102  act_pwr_16         float64
 103  react_pwr_1        float64
 104  react_pwr_2        float64
 105  react_pwr_3        float64
 106  react_pwr_4        float64
 107  react_pwr_5        float64
 108  react_pwr_6        float64
 109  react_pwr_7        float64
 110  react_pwr_8        float64
 111  react_pwr_9        float64
 112  react_pwr_10       float64
 113  react_pwr_11       float64
 114  react_pwr_12       float64
 115  react_pwr_13       float64
 116  react_pwr_14       float64
 117  react_pwr_15       float64
 118  react_pwr_16       float64
dtypes: float64(59), int64(1), object(59)
memory usage: 2.3+ MB
```

```
In [91]: arc_tmp_jnt.head(15)
```

```
Out[91]:
    key  first_temperature  final_temperature  first_temp_time  final_temp_time  Bulk     Bulk  Bulk     Bulk  Bulk  ...  react_pwr_7  react_pwr_8  react_pwr_9  react_p
                                                                                    1   1_time     2   2_time     3
 0    1             1571.0             1613.0         11:16:18         11:30:39   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 1    2             1581.0             1602.0         11:37:27         11:59:12   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 2    3             1596.0             1599.0         12:13:17         12:34:57   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 3    4             1601.0             1625.0         12:52:57         12:59:25   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 4    5             1576.0             1602.0         13:23:19         13:36:01   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 5    6             1543.0             1596.0         13:49:24         14:12:29   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 6    7             1586.0             1599.0         14:19:43         14:42:37   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 7    8             1577.0             1598.0         15:07:18         15:22:52   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 8    9             1587.0             1592.0         15:37:03         16:01:16   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
 9   10             1574.0             1593.0         16:14:29         16:36:08   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
10   11             1616.0             1597.0         16:54:18         17:27:23   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
11   12             1606.0             1591.0         17:40:54         18:13:03  46.0  17:50:19   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
12   13             1596.0             1619.0         18:38:59         19:06:15   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0
13   14             1583.0             1606.0         20:00:42         20:38:22   0.0  00:00:00   0.0  00:00:00  71.0  ...          0.0          0.0          0.0
14   15             1605.0             1598.0         20:58:40         21:33:01   0.0  00:00:00   0.0  00:00:00   0.0  ...          0.0          0.0          0.0

15 rows × 119 columns
```

Conclusions

- The prepared dataset has size of 148 * 2475.
- The following features were added:
  - quantity of heating;
  - batch heating start time;
  - batch heating finish time;
  - cumulative heating time;
  - active power;
  - reactive power.

2.5 Adding of gas dataset to main dataset

In [92]:
```
arc_gas_temp_df = pd.merge(arc_tmp_jnt,gas_df,how = 'outer',on='key',indicator=True)
```

In [93]:
```
arc_gas_temp_df['gas'] = arc_gas_temp_df['gas'].fillna(0)
```

In [94]:
```
arc_gas_temp_df
```

Out[94]:

	key	first_temperature	final_temperature	first_temp_time	final_temp_time	Bulk 1	Bulk 1_time	Bulk 2	Bulk 2_time	Bulk 3	...	react_pwr_9	react_pwr_10	react_pwr_11
0	1	1571.0	1613.0	11:16:18	11:30:39	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0
1	2	1581.0	1602.0	11:37:27	11:59:12	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0
2	3	1596.0	1599.0	12:13:17	12:34:57	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0
3	4	1601.0	1625.0	12:52:57	12:59:25	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0
4	5	1576.0	1602.0	13:23:19	13:36:01	0.0	00:00:00	0.0	00:00:00	0.0	...	0.0	0.0	0.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3236	3237	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN	NaN
3237	3238	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN	NaN
3238	3239	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN	NaN
3239	3240	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN	NaN
3240	3241	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN	NaN

3241 rows × 121 columns

In [95]:
```
arc_gas_temp_df = arc_gas_temp_df[arc_gas_temp_df['_merge'] != 'right_only']
```

In [96]:
```
arc_gas_temp_df = arc_gas_temp_df.drop(columns = '_merge')
```

In [97]:
```
final_steel_df = arc_gas_temp_df.drop(columns = 'key')
```

```
In [98]:  final_steel_df.head()
```

```
Out[98]:
   first_temperature  final_temperature  first_temp_time  final_temp_time  Bulk     Bulk  Bulk     Bulk  Bulk     Bulk  ...  react_pwr_8  react_pwr_9  react_pwr_10  rea
                                                                               1   1_time     2   2_time     3   3_time
0             1571.0             1613.0         11:16:18         11:30:39   0.0 00:00:00   0.0 00:00:00   0.0 00:00:00  ...          0.0          0.0           0.0
1             1581.0             1602.0         11:37:27         11:59:12   0.0 00:00:00   0.0 00:00:00   0.0 00:00:00  ...          0.0          0.0           0.0
2             1596.0             1599.0         12:13:17         12:34:57   0.0 00:00:00   0.0 00:00:00   0.0 00:00:00  ...          0.0          0.0           0.0
3             1601.0             1625.0         12:52:57         12:59:25   0.0 00:00:00   0.0 00:00:00   0.0 00:00:00  ...          0.0          0.0           0.0
4             1576.0             1602.0         13:23:19         13:36:01   0.0 00:00:00   0.0 00:00:00   0.0 00:00:00  ...          0.0          0.0           0.0

5 rows × 119 columns
```

In [99]:
```
final_steel_df.info(verbose=True, show_counts=True)
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 2475 entries, 0 to 2474
Data columns (total 119 columns):
 #    Column             Non-Null Count  Dtype  
---   ------             --------------  -----  
 0    first_temperature  2475 non-null   float64
 1    final_temperature  2475 non-null   float64
 2    first_temp_time    2475 non-null   object 
 3    final_temp_time    2475 non-null   object 
 4    Bulk 1             2475 non-null   float64
 5    Bulk 1_time        2475 non-null   object 
 6    Bulk 2             2475 non-null   float64
 7    Bulk 2_time        2475 non-null   object 
 8    Bulk 3             2475 non-null   float64
 9    Bulk 3_time        2475 non-null   object 
 10   Bulk 4             2475 non-null   float64
 11   Bulk 4_time        2475 non-null   object 
 12   Bulk 5             2475 non-null   float64
 13   Bulk 5_time        2475 non-null   object 
 14   Bulk 6             2475 non-null   float64
 15   Bulk 6_time        2475 non-null   object 
 16   Bulk 7             2475 non-null   float64
 17   Bulk 7_time        2475 non-null   object 
 18   Bulk 8             2475 non-null   float64
 19   Bulk 8_time        2475 non-null   object 
 20   Bulk 9             2475 non-null   float64
 21   Bulk 9_time        2475 non-null   object 
 22   Bulk 10            2475 non-null   float64
 23   Bulk 10_time       2475 non-null   object 
 24   Bulk 11            2475 non-null   float64
 25   Bulk 11_time       2475 non-null   object 
 26   Bulk 12            2475 non-null   float64
 27   Bulk 12_time       2475 non-null   object 
 28   Bulk 13            2475 non-null   float64
 29   Bulk 13_time       2475 non-null   object 
 30   Bulk 14            2475 non-null   float64
 31   Bulk 14_time       2475 non-null   object 
 32   Bulk 15            2475 non-null   float64
 33   Bulk 15_time       2475 non-null   object 
 34   Wire 1             2475 non-null   float64
 35   Wire 1_time        2475 non-null   object 
 36   Wire 2             2475 non-null   float64
 37   Wire 2_time        2475 non-null   object 
 38   Wire 3             2475 non-null   float64
 39   Wire 3_time        2475 non-null   object 
```

```
40   Wire 4             2475 non-null   float64
41   Wire 4_time        2475 non-null   object
42   Wire 5             2475 non-null   float64
43   Wire 5_time        2475 non-null   object
44   Wire 6             2475 non-null   float64
45   Wire 6_time        2475 non-null   object
46   Wire 7             2475 non-null   float64
47   Wire 7_time        2475 non-null   object
48   Wire 8             2475 non-null   float64
49   Wire 8_time        2475 non-null   object
50   Wire 9             2475 non-null   float64
51   Wire 9_time        2475 non-null   object
52   heating_qty        2475 non-null   float64
53   heat_start         2475 non-null   object
54   heat_finish        2475 non-null   object
55   heat_1_finish      2475 non-null   object
56   heat_2_start       2475 non-null   object
57   heat_2_finish      2475 non-null   object
58   heat_3_start       2475 non-null   object
59   heat_3_finish      2475 non-null   object
60   heat_4_start       2475 non-null   object
61   heat_4_finish      2475 non-null   object
62   heat_5_start       2475 non-null   object
63   heat_5_finish      2475 non-null   object
64   heat_6_start       2475 non-null   object
65   heat_6_finish      2475 non-null   object
66   heat_7_start       2475 non-null   object
67   heat_7_finish      2475 non-null   object
68   heat_8_start       2475 non-null   object
69   heat_8_finish      2475 non-null   object
70   heat_9_start       2475 non-null   object
71   heat_9_finish      2475 non-null   object
72   heat_10_start      2475 non-null   object
73   heat_10_finish     2475 non-null   object
74   heat_11_start      2475 non-null   object
75   heat_11_finish     2475 non-null   object
76   heat_12_start      2475 non-null   object
77   heat_12_finish     2475 non-null   object
78   heat_13_start      2475 non-null   object
79   heat_13_finish     2475 non-null   object
80   heat_14_start      2475 non-null   object
81   heat_14_finish     2475 non-null   object
82   heat_15_start      2475 non-null   object
83   heat_15_finish     2475 non-null   object
84   heat_16_start      2475 non-null   object
85   heat_16_finish     2475 non-null   object
```

```
 86   act_pwr_1          2475 non-null   float64
 87   act_pwr_2          2475 non-null   float64
 88   act_pwr_3          2475 non-null   float64
 89   act_pwr_4          2475 non-null   float64
 90   act_pwr_5          2475 non-null   float64
 91   act_pwr_6          2475 non-null   float64
 92   act_pwr_7          2475 non-null   float64
 93   act_pwr_8          2475 non-null   float64
 94   act_pwr_9          2475 non-null   float64
 95   act_pwr_10         2475 non-null   float64
 96   act_pwr_11         2475 non-null   float64
 97   act_pwr_12         2475 non-null   float64
 98   act_pwr_13         2475 non-null   float64
 99   act_pwr_14         2475 non-null   float64
 100  act_pwr_15         2475 non-null   float64
 101  act_pwr_16         2475 non-null   float64
 102  react_pwr_1        2475 non-null   float64
 103  react_pwr_2        2475 non-null   float64
 104  react_pwr_3        2475 non-null   float64
 105  react_pwr_4        2475 non-null   float64
 106  react_pwr_5        2475 non-null   float64
 107  react_pwr_6        2475 non-null   float64
 108  react_pwr_7        2475 non-null   float64
 109  react_pwr_8        2475 non-null   float64
 110  react_pwr_9        2475 non-null   float64
 111  react_pwr_10       2475 non-null   float64
 112  react_pwr_11       2475 non-null   float64
 113  react_pwr_12       2475 non-null   float64
 114  react_pwr_13       2475 non-null   float64
 115  react_pwr_14       2475 non-null   float64
 116  react_pwr_15       2475 non-null   float64
 117  react_pwr_16       2475 non-null   float64
 118  gas                2475 non-null   float64
dtypes: float64(60), object(59)
memory usage: 2.3+ MB
```

2.5 Changing of features format

In [100]:
```
# loop for selection of time columns
time_cols = []
for i in final_steel_df.columns:
    if 'time' in i or 'heat_' in i:
        time_cols.append(i)
```

In [101]:
```
time_cols
```

```
Out[101]: ['first_temp_time',
            'final_temp_time',
            'Bulk 1_time',
            'Bulk 2_time',
            'Bulk 3_time',
            'Bulk 4_time',
            'Bulk 5_time',
            'Bulk 6_time',
            'Bulk 7_time',
            'Bulk 8_time',
            'Bulk 9_time',
            'Bulk 10_time',
            'Bulk 11_time',
            'Bulk 12_time',
            'Bulk 13_time',
            'Bulk 14_time',
            'Bulk 15_time',
            'Wire 1_time',
            'Wire 2_time',
            'Wire 3_time',
            'Wire 4_time',
            'Wire 5_time',
            'Wire 6_time',
            'Wire 7_time',
            'Wire 8_time',
            'Wire 9_time',
            'heat_start',
            'heat_finish',
            'heat_1_finish',
            'heat_2_start',
            'heat_2_finish',
            'heat_3_start',
            'heat_3_finish',
            'heat_4_start',
            'heat_4_finish',
            'heat_5_start',
            'heat_5_finish',
            'heat_6_start',
            'heat_6_finish',
            'heat_7_start',
            'heat_7_finish',
            'heat_8_start',
            'heat_8_finish',
            'heat_9_start',
            'heat_9_finish',
            'heat_10_start',
            'heat_10_finish',
            'heat_11_start',
            'heat_11_finish',
            'heat_12_start',
            'heat_12_finish',
            'heat_13_start',
            'heat_13_finish',
            'heat_14_start',
            'heat_14_finish',
            'heat_15_start',
            'heat_15_finish',
            'heat_16_start',
            'heat_16_finish']
```

In [102]:
```
final_steel_df[time_cols].head()
```

Out[102]:

	first_temp_time	final_temp_time	Bulk 1_time	Bulk 2_time	Bulk 3_time	Bulk 4_time	Bulk 5_time	Bulk 6_time	Bulk 7_time	Bulk 8_time	...	heat_12_start	heat_12_finish	heat_13_start	heat_1
0	11:16:18	11:30:39	00:00:00	00:00:00	00:00:00	11:21:30	00:00:00	00:00:00	00:00:00	00:00:00	...	00:00:00	00:00:00	00:00:00	
1	11:37:27	11:59:12	00:00:00	00:00:00	00:00:00	11:46:38	00:00:00	00:00:00	00:00:00	00:00:00	...	00:00:00	00:00:00	00:00:00	
2	12:13:17	12:34:57	00:00:00	00:00:00	00:00:00	12:31:06	00:00:00	00:00:00	00:00:00	00:00:00	...	00:00:00	00:00:00	00:00:00	
3	12:52:57	12:59:25	00:00:00	00:00:00	00:00:00	12:48:43	00:00:00	00:00:00	00:00:00	00:00:00	...	00:00:00	00:00:00	00:00:00	
4	13:23:19	13:36:01	00:00:00	00:00:00	00:00:00	13:18:50	00:00:00	00:00:00	00:00:00	00:00:00	...	00:00:00	00:00:00	00:00:00	

5 rows × 59 columns

In [103]:
```
# changing of time_cols datatype to str
for i in time_cols:
    final_steel_df[i] = pd.to_datetime(final_steel_df[i].astype('str'))
```

In [104]:
```python
# function for time rescale - 0 time is start of heating
def correct_time (column):
    time_list = []
    for i in range(len(final_steel_df[column])):
        if final_steel_df[column][i] == pd.to_datetime('00:00:00'):
            result = pd.Timedelta("0 seconds")
        elif final_steel_df[column][i] >  final_steel_df['heat_start'][i]:
            result = final_steel_df[column][i] -  final_steel_df['heat_start'][i]
        else:
            result = (final_steel_df[column][i] + pd.Timedelta("1 days") - final_steel_df['heat_start'][i])
        result = (pd.to_datetime('00:00:00') + result).time()
        time_list.append(result)
    return time_list
```

In [105]:
```python
# function for changing of datatype to time
def col_to_sec(final_steel_df,col_name):
    final_steel_df[col_name +'_seconds'] = final_steel_df[col_name]
    for i in range(len(final_steel_df[col_name])):
        if final_steel_df[col_name][i] == pd.to_datetime('00:00:00'):
            final_steel_df.iloc[i,-1] = 0
        else:
            final_steel_df.iloc[i,-1] = (final_steel_df[col_name][i].hour*3600 +
                                        final_steel_df[col_name][i].minute*60 +
                                        final_steel_df[col_name][i].second)
    final_steel_df = final_steel_df.drop(columns = col_name)
    final_steel_df[col_name +'_seconds']  = final_steel_df[col_name +'_seconds'].astype('float64')
    return(final_steel_df)
```

In [106]:
```python
# function applying
for i in time_cols:
    if i != 'heat_start':
        final_steel_df[i] = correct_time(i)
        final_steel_df =  col_to_sec(final_steel_df,i)
```

In [107]:
```python
# deletion of heat start columns
final_steel_df = final_steel_df.drop(columns = 'heat_start')
```

In [108]:
```python
final_steel_df = final_steel_df.reset_index(drop = True)
```

```
In [109]:  final_steel_df.head(10)
```

Out[109]:

	first_temperature	final_temperature	Bulk 1	Bulk 2	Bulk 3	Bulk 4	Bulk 5	Bulk 6	Bulk 7	Bulk 8	...	heat_12_start_seconds	heat_12_finish_seconds	heat_13_start_seconds	he
0	1571.0	1613.0	0.0	0.0	0.0	43.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
1	1581.0	1602.0	0.0	0.0	0.0	73.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
2	1596.0	1599.0	0.0	0.0	0.0	34.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
3	1601.0	1625.0	0.0	0.0	0.0	81.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
4	1576.0	1602.0	0.0	0.0	0.0	78.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
5	1543.0	1596.0	0.0	0.0	0.0	117.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
6	1586.0	1599.0	0.0	0.0	0.0	117.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
7	1577.0	1598.0	0.0	0.0	0.0	99.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
8	1587.0	1592.0	0.0	0.0	0.0	117.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	
9	1574.0	1593.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.0	

10 rows × 118 columns

In [110]:

```python
final_steel_df.tail(10)
```

Out[110]:

	first_temperature	final_temperature	Bulk 1	Bulk 2	Bulk 3	Bulk 4	Bulk 5	Bulk 6	Bulk 7	Bulk 8	...	heat_12_start_seconds	heat_12_finish_seconds	heat_13_start_seconds
2465	1613.0	1579.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	...	0.0	0.0	0.
2466	1602.0	1619.0	0.0	0.0	50.0	116.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2467	1618.0	1595.0	0.0	0.0	74.0	198.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2468	1599.0	1594.0	0.0	0.0	115.0	105.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2469	1585.0	1591.0	0.0	0.0	0.0	162.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2470	1570.0	1591.0	0.0	0.0	21.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2471	1554.0	1591.0	0.0	0.0	0.0	63.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2472	1571.0	1589.0	0.0	0.0	0.0	85.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2473	1591.0	1594.0	0.0	0.0	90.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.
2474	1569.0	1603.0	0.0	0.0	47.0	0.0	0.0	0.0	0.0	0.0	...	0.0	0.0	0.

10 rows × 118 columns

In [111]:

```python
# display the dataset info
mid = int(round(len(final_steel_df.columns)/2,0))
a = final_steel_df.iloc[:,:mid].info()
b = final_steel_df.iloc[:,mid:].info()
print(a,b)
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2475 entries, 0 to 2474
Data columns (total 59 columns):
 #   Column             Non-Null Count  Dtype  
---  ------             --------------  -----  
 0   first_temperature  2475 non-null   float64
 1   final_temperature  2475 non-null   float64
 2   Bulk 1             2475 non-null   float64
 3   Bulk 2             2475 non-null   float64
 4   Bulk 3             2475 non-null   float64
 5   Bulk 4             2475 non-null   float64
 6   Bulk 5             2475 non-null   float64
 7   Bulk 6             2475 non-null   float64
 8   Bulk 7             2475 non-null   float64
 9   Bulk 8             2475 non-null   float64
 10  Bulk 9             2475 non-null   float64
 11  Bulk 10            2475 non-null   float64
 12  Bulk 11            2475 non-null   float64
 13  Bulk 12            2475 non-null   float64
 14  Bulk 13            2475 non-null   float64
 15  Bulk 14            2475 non-null   float64
 16  Bulk 15            2475 non-null   float64
 17  Wire 1             2475 non-null   float64
 18  Wire 2             2475 non-null   float64
 19  Wire 3             2475 non-null   float64
 20  Wire 4             2475 non-null   float64
 21  Wire 5             2475 non-null   float64
 22  Wire 6             2475 non-null   float64
 23  Wire 7             2475 non-null   float64
 24  Wire 8             2475 non-null   float64
 25  Wire 9             2475 non-null   float64
 26  heating_qty        2475 non-null   float64
 27  act_pwr_1          2475 non-null   float64
 28  act_pwr_2          2475 non-null   float64
 29  act_pwr_3          2475 non-null   float64
 30  act_pwr_4          2475 non-null   float64
 31  act_pwr_5          2475 non-null   float64
 32  act_pwr_6          2475 non-null   float64
 33  act_pwr_7          2475 non-null   float64
 34  act_pwr_8          2475 non-null   float64
 35  act_pwr_9          2475 non-null   float64
 36  act_pwr_10         2475 non-null   float64
 37  act_pwr_11         2475 non-null   float64
 38  act_pwr_12         2475 non-null   float64
 39  act_pwr_13         2475 non-null   float64
 40  act_pwr_14         2475 non-null   float64
 41  act_pwr_15         2475 non-null   float64
 42  act_pwr_16         2475 non-null   float64
 43  react_pwr_1        2475 non-null   float64
 44  react_pwr_2        2475 non-null   float64
 45  react_pwr_3        2475 non-null   float64
 46  react_pwr_4        2475 non-null   float64
 47  react_pwr_5        2475 non-null   float64
 48  react_pwr_6        2475 non-null   float64
 49  react_pwr_7        2475 non-null   float64
 50  react_pwr_8        2475 non-null   float64
 51  react_pwr_9        2475 non-null   float64
 52  react_pwr_10       2475 non-null   float64
 53  react_pwr_11       2475 non-null   float64
 54  react_pwr_12       2475 non-null   float64
 55  react_pwr_13       2475 non-null   float64
 56  react_pwr_14       2475 non-null   float64
 57  react_pwr_15       2475 non-null   float64
 58  react_pwr_16       2475 non-null   float64
dtypes: float64(59)
memory usage: 1.1 MB
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2475 entries, 0 to 2474
Data columns (total 59 columns):
 #   Column                   Non-Null Count  Dtype  
---  ------                   --------------  -----  
 0   gas                      2475 non-null   float64
 1   first_temp_time_seconds  2475 non-null   float64
 2   final_temp_time_seconds  2475 non-null   float64
 3   Bulk 1_time_seconds      2475 non-null   float64
 4   Bulk 2_time_seconds      2475 non-null   float64
 5   Bulk 3_time_seconds      2475 non-null   float64
 6   Bulk 4_time_seconds      2475 non-null   float64
 7   Bulk 5_time_seconds      2475 non-null   float64
 8   Bulk 6_time_seconds      2475 non-null   float64
 9   Bulk 7_time_seconds      2475 non-null   float64
 10  Bulk 8_time_seconds      2475 non-null   float64
 11  Bulk 9_time_seconds      2475 non-null   float64
 12  Bulk 10_time_seconds     2475 non-null   float64
 13  Bulk 11_time_seconds     2475 non-null   float64
 14  Bulk 12_time_seconds     2475 non-null   float64
 15  Bulk 13_time_seconds     2475 non-null   float64
 16  Bulk 14_time_seconds     2475 non-null   float64
 17  Bulk 15_time_seconds     2475 non-null   float64
 18  Wire 1_time_seconds      2475 non-null   float64
 19  Wire 2_time_seconds      2475 non-null   float64
 20  Wire 3_time_seconds      2475 non-null   float64
 21  Wire 4_time_seconds      2475 non-null   float64
 22  Wire 5_time_seconds      2475 non-null   float64
 23  Wire 6_time_seconds      2475 non-null   float64
 24  Wire 7_time_seconds      2475 non-null   float64
 25  Wire 8_time_seconds      2475 non-null   float64
 26  Wire 9_time_seconds      2475 non-null   float64
 27  heat_finish_seconds      2475 non-null   float64
 28  heat_1_finish_seconds    2475 non-null   float64
 29  heat_2_start_seconds     2475 non-null   float64
 30  heat_2_finish_seconds    2475 non-null   float64
 31  heat_3_start_seconds     2475 non-null   float64
 32  heat_3_finish_seconds    2475 non-null   float64
 33  heat_4_start_seconds     2475 non-null   float64
 34  heat_4_finish_seconds    2475 non-null   float64
 35  heat_5_start_seconds     2475 non-null   float64
 36  heat_5_finish_seconds    2475 non-null   float64
 37  heat_6_start_seconds     2475 non-null   float64
 38  heat_6_finish_seconds    2475 non-null   float64
 39  heat_7_start_seconds     2475 non-null   float64
 40  heat_7_finish_seconds    2475 non-null   float64
 41  heat_8_start_seconds     2475 non-null   float64
 42  heat_8_finish_seconds    2475 non-null   float64
 43  heat_9_start_seconds     2475 non-null   float64
 44  heat_9_finish_seconds    2475 non-null   float64
 45  heat_10_start_seconds    2475 non-null   float64
 46  heat_10_finish_seconds   2475 non-null   float64
 47  heat_11_start_seconds    2475 non-null   float64
 48  heat_11_finish_seconds   2475 non-null   float64
 49  heat_12_start_seconds    2475 non-null   float64
 50  heat_12_finish_seconds   2475 non-null   float64
 51  heat_13_start_seconds    2475 non-null   float64
 52  heat_13_finish_seconds   2475 non-null   float64
 53  heat_14_start_seconds    2475 non-null   float64
 54  heat_14_finish_seconds   2475 non-null   float64
 55  heat_15_start_seconds    2475 non-null   float64
 56  heat_15_finish_seconds   2475 non-null   float64
 57  heat_16_start_seconds    2475 non-null   float64
 58  heat_16_finish_seconds   2475 non-null   float64
dtypes: float64(59)
memory usage: 1.1 MB
None None
```

Conclusion:

- The final dataset is prepared and has the size of 2475*144 with target and features.

3 Model training

In this section of project the models training to be executed - three models - decision tree, gradient boosting and neural network.

Due the fact that target is temperature the regression models to be used and MAE metrics for the comparison.

The MAE metric selected for the search of optimal score of Models - the less MAE score is the better is result of prediction of Model.

3.1 Splitting of the dataset on terget and features and on train, valid and test samples.

In [112]:
```
target = final_steel_df['final_temperature']
```

In [113]:
```
features = final_steel_df.drop(columns = 'final_temperature')
```

In [114]:
```
train_target,valid_target, train_features, valid_features = train_test_split(target, features, test_size = 0.4,
                                                                             random_state = 12345)
```

In [115]:
```
valid_target, test_target ,valid_features, test_features = train_test_split(valid_target, valid_features,
                                                                            test_size = 0.5, random_state = 12345)
```

3.2 Decision tree model training

In [116]:
```
dt_model = DecisionTreeRegressor(random_state = 146)
```

In [117]:
```
dt_model.fit(train_features,train_target)
```

Out[117]:
```
DecisionTreeRegressor(random_state=146)
```
In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

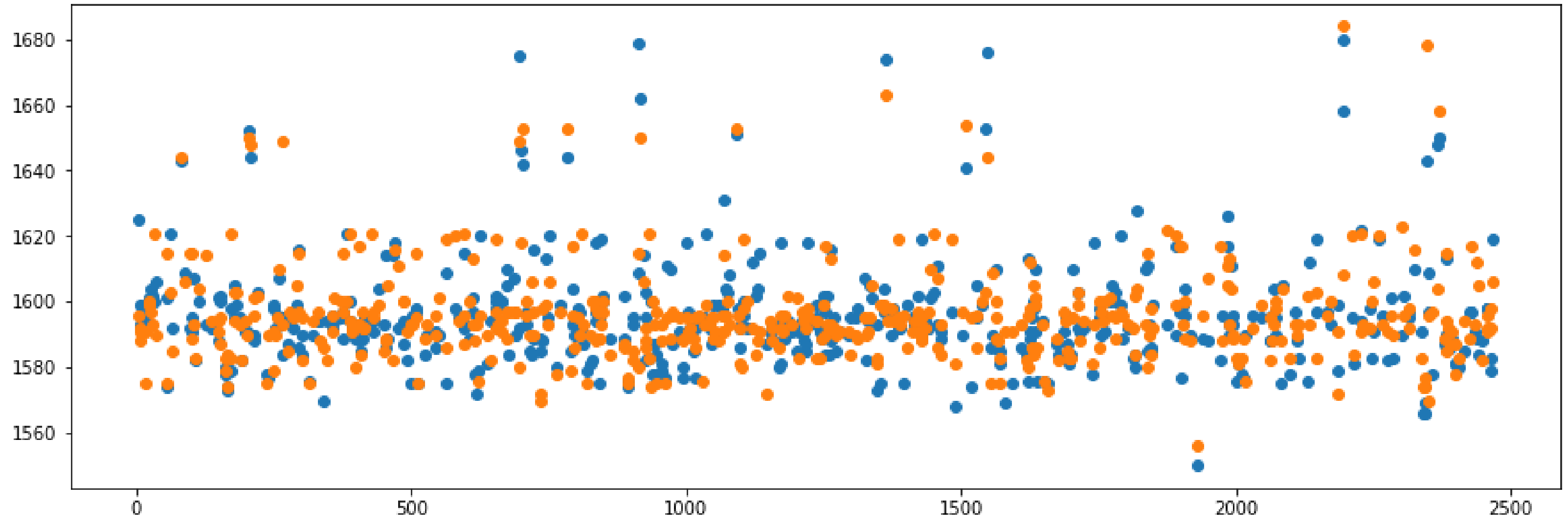
In [118]:
```
%%time
dt_prediction = dt_model.predict(valid_features)
```
```
CPU times: total: 0 ns
Wall time: 2.99 ms
```

In [119]:
```
dt_mae = mean_absolute_error(valid_target, dt_prediction)
```

In [120]:
```
dt_mae
```

Out[120]:
```
9.765656565656565
```

In [121]:
```
# plotting the prediction results
plt.figure(figsize=(15,5))
for i in [valid_target.values, dt_prediction]:
    plt.scatter(x = valid_target.index, y = i)
```



Hyperparameters tuning

In [122]:
```python
max_features = ['auto', 'sqrt']
max_depth = [int(x) for x in np.linspace(5, 60, num = 5)]
min_samples_split = [2, 5, 10, 15, 20, 25]
min_samples_leaf = [1, 2, 4, 5, 10, 15]
```

In [123]:
```python
random_grid = {'max_features': max_features,
               'max_depth': max_depth,
               'min_samples_split': min_samples_split,
               'min_samples_leaf': min_samples_leaf}
```

In [124]:
```python
tr_and_valid_target = train_features.append(valid_features)
tr_and_valid_features = train_features.append(valid_features)
```

In [125]:
```python
tuning_model = RandomizedSearchCV(estimator = dt_model, param_distributions = random_grid, random_state=42, scoring = 'neg_mean_ab
```

In [126]:
```python
%%time
tuning_model.fit(tr_and_valid_features,tr_and_valid_target)
```

```
CPU times: total: 5.81 s
Wall time: 5.86 s
```

Out[126]:
```
RandomizedSearchCV(estimator=DecisionTreeRegressor(random_state=146),
                   param_distributions={'max_depth': [5, 18, 32, 46, 60],
                                        'max_features': ['auto', 'sqrt'],
                                        'min_samples_leaf': [1, 2, 4, 5, 10,
                                                             15],
                                        'min_samples_split': [2, 5, 10, 15, 20,
                                                              25]},
                   random_state=42, scoring='neg_mean_absolute_error')
```

In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

In [127]:
```python
tuning_model.best_score_
```

Out[127]:
```
-55.82580461389911
```

In [128]:
```python
tuning_mae = abs(tuning_model.best_score_)
```

3.3 Gradient boosting model training.

In [129]:
```
param = {
    'task': 'train',
    'boosting': 'gbdt',
    'objective': 'regression',
    'verbose': -1,
    'metric' : 'mae',
    'learning_rate': 0.094,
    'max_depth': 150,
    'num_leaves': 20,
    'feature_fraction': 0.8,
    'subsample': 0.2
}
```

In [130]:
```
train_dataset = lgb.Dataset(train_features, train_target, feature_name=train_features.columns.tolist())
test_dataset = lgb.Dataset(valid_features, valid_target, feature_name=train_features.columns.tolist())
```

In [131]:
```
%%time
num_round = 144
bst = lgb.train(param, train_dataset, num_round,valid_sets= (test_dataset))
```

```
[1]	valid_0's l1: 10.3752
[2]	valid_0's l1: 10.0616
[3]	valid_0's l1: 9.83912
[4]	valid_0's l1: 9.62593
[5]	valid_0's l1: 9.4773
[6]	valid_0's l1: 9.28901
[7]	valid_0's l1: 9.05419
[8]	valid_0's l1: 8.87783
[9]	valid_0's l1: 8.69116
[10]	valid_0's l1: 8.53423
[11]	valid_0's l1: 8.38179
[12]	valid_0's l1: 8.24518
[13]	valid_0's l1: 8.1502
[14]	valid_0's l1: 8.02235
[15]	valid_0's l1: 7.93248
[16]	valid_0's l1: 7.85365
[17]	valid_0's l1: 7.83094
[18]	valid_0's l1: 7.76106
[19]	valid_0's l1: 7.67616
```

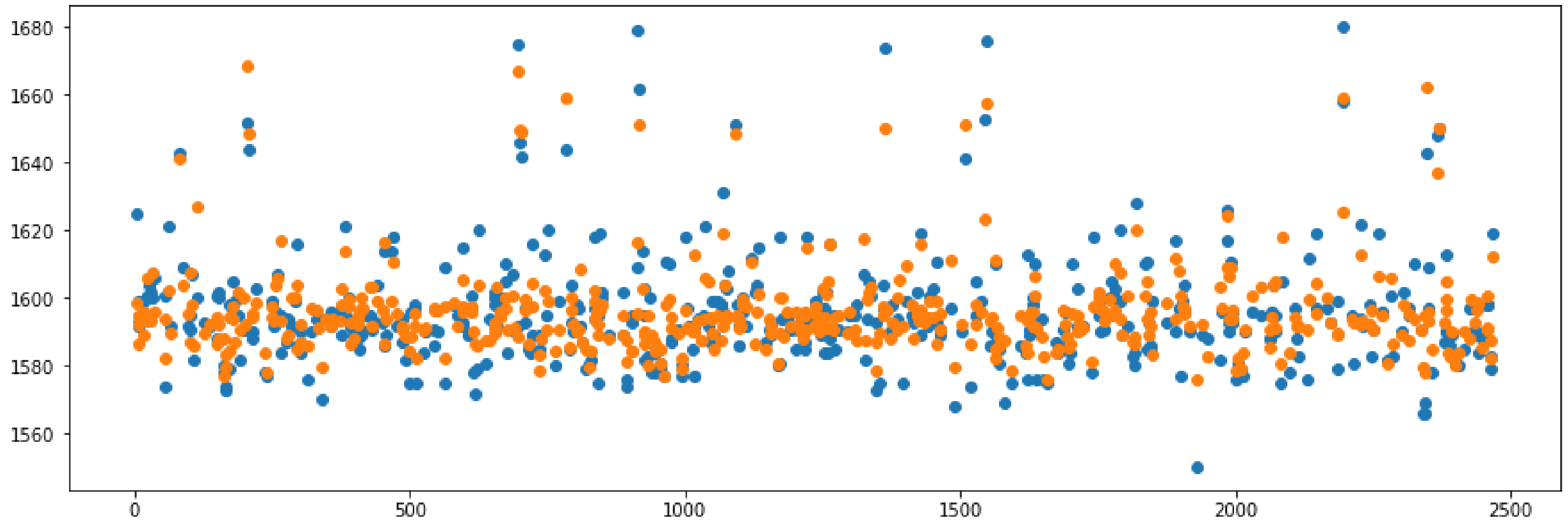
In [132]:
```
bst_pred = bst.predict(valid_features)
```

In [133]:
```
bst_mae = mean_absolute_error(valid_target, bst_pred)
```

In [134]:
```
bst_mae
```

Out[134]:
```
6.590727651085609
```

In [135]:
```
# Plotting of the results of prediction
plt.figure(figsize=(15,5))
for i in [valid_target.values, bst_pred]:
    plt.scatter(x = valid_target.index, y = i)
```



3.4 Training of neural network model

In [136]:
```
scaler = MinMaxScaler()
```

In [137]:
```
scaler.fit(features)
```

Out[137]:
```
MinMaxScaler()
```

In a Jupyter environment, please rerun this cell to show the HTML representation or trust the notebook.
On GitHub, the HTML representation is unable to render, please try loading this page with nbviewer.org.

In [138]:
```
train_features_nn = scaler.transform(train_features)
valid_features_nn = scaler.transform(valid_features)
test_features_nn = scaler.transform(test_features)
```

In [139]:
```
train_features_nn = torch.tensor(train_features_nn)
train_target_nn = torch.tensor(train_target.values)
valid_features_nn = torch.tensor(valid_features_nn)
valid_target_nn = torch.tensor(valid_target.values)
test_features_nn = torch.tensor(test_features_nn)
test_target_nn = torch.tensor(test_target.values)
```

In [140]:

```python
torch.manual_seed(1234)
input_size = 117
hidden_size_1 = 128
hidden_size_2 = 64
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.1)
        self.act1 = nn.ReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.dp2 = nn.Dropout(p = 0.05)
        self.act2 = nn.ReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.dp3 = nn.Dropout(p = 0.05)
        self.act3 = nn.ReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.dp2(x)
        x = self.act2(x)
        x = self.fc3(x)
        x = self.dp3(x)
        x = self.act3(x)
        return x

model_nn = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [141]:

```
%%time
optimizer = torch.optim.Adam(model_nn.parameters(),lr=0.01)

loss = torch.nn.L1Loss()

num_epochs = 1300

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = model_nn.forward(train_features_nn.float()).flatten()
    loss_value = loss(preds,train_target_nn.float())
    loss_value.backward()
    optimizer.step()
    if (epoch % 8 == 0) or (epoch == 1300):
            model_nn.eval()
            valid_preds_nn = model_nn.forward(valid_features_nn.float()).flatten()
            loss_preds = loss(valid_preds_nn,valid_target_nn.float())
            print('valid_loss:',loss_preds)
```

```
valid_loss: tensor(1595.6625, grad_fn=<L1LossBackward0>)
valid_loss: tensor(1580.7507, grad_fn=<L1LossBackward0>)
valid_loss: tensor(1486.3174, grad_fn=<L1LossBackward0>)
valid_loss: tensor(1180.2782, grad_fn=<L1LossBackward0>)
valid_loss: tensor(477.6735, grad_fn=<L1LossBackward0>)
valid_loss: tensor(469.3812, grad_fn=<L1LossBackward0>)
valid_loss: tensor(267.5082, grad_fn=<L1LossBackward0>)
valid_loss: tensor(245.1849, grad_fn=<L1LossBackward0>)
valid_loss: tensor(223.9449, grad_fn=<L1LossBackward0>)
valid_loss: tensor(179.3494, grad_fn=<L1LossBackward0>)
valid_loss: tensor(155.8438, grad_fn=<L1LossBackward0>)
valid_loss: tensor(134.5383, grad_fn=<L1LossBackward0>)
valid_loss: tensor(117.7064, grad_fn=<L1LossBackward0>)
valid_loss: tensor(103.4455, grad_fn=<L1LossBackward0>)
valid_loss: tensor(90.4386, grad_fn=<L1LossBackward0>)
valid_loss: tensor(76.6585, grad_fn=<L1LossBackward0>)
valid_loss: tensor(63.7841, grad_fn=<L1LossBackward0>)
valid_loss: tensor(52.0735, grad_fn=<L1LossBackward0>)
valid_loss: tensor(41.9455, grad_fn=<L1LossBackward0>)
```

In [142]:

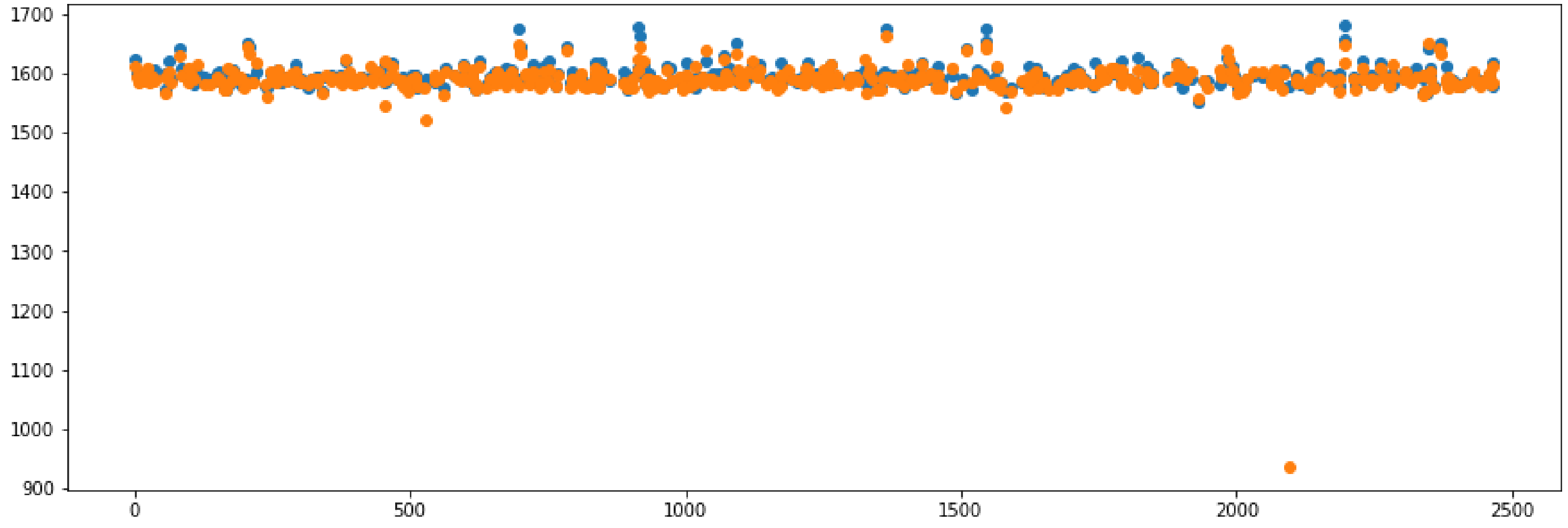
```
mae_nn = mean_absolute_error(valid_preds_nn.detach().numpy(), valid_target)
```

In [143]:
```
mae_nn
```

Out[143]:
```
8.804002549913195
```

In [144]:
```
valid_preds_nn_ = valid_preds_nn.detach().numpy()
```

In [145]:
```
# Plotting the results of prediction
plt.figure(figsize=(15,5))
for i in [valid_target.values, valid_preds_nn_]:
    plt.scatter(x = valid_target.index, y = i)
```



3.5 Selection of the best model.

In [146]:
```
models = [dt_model,tuning_model,bst,model_nn]
mae_list = [dt_mae,tuning_mae,bst_mae,mae_nn]
```

In [147]:
```
models_df = pd.DataFrame({'model': models,'mae': mae_list})
```

In [148]:
```
models_df.sort_values(by='mae')
```
Out[148]:

	model	mae
2	<lightgbm.basic.Booster object at 0x000001F84A...	6.590728
3	NeuralNet(\n (fc1): Linear(in_features=117, o...	8.804003
0	DecisionTreeRegressor(random_state=146)	9.765657
1	RandomizedSearchCV(estimator=DecisionTreeRegre...	55.825805

In [149]:
```
best_model_df = models_df[models_df['mae'] == models_df['mae'].min()]
```
In [150]:
```
best_model_df
```
Out[150]:

	model	mae
2	<lightgbm.basic.Booster object at 0x000001F84A...	6.590728

In [151]:
```
best_model = best_model_df['model'].values[0]
```
In [152]:
```
best_model
```
Out[152]:
```
<lightgbm.basic.Booster at 0x1f84acece50>
```

4 Model testing and demonstration of work:

- Prediction of test data on the selected best model;
- To conduct the analysis of features affecting the target;
- Plot the graph of dependance of features with highest affect on the target.

4.1 Model testing

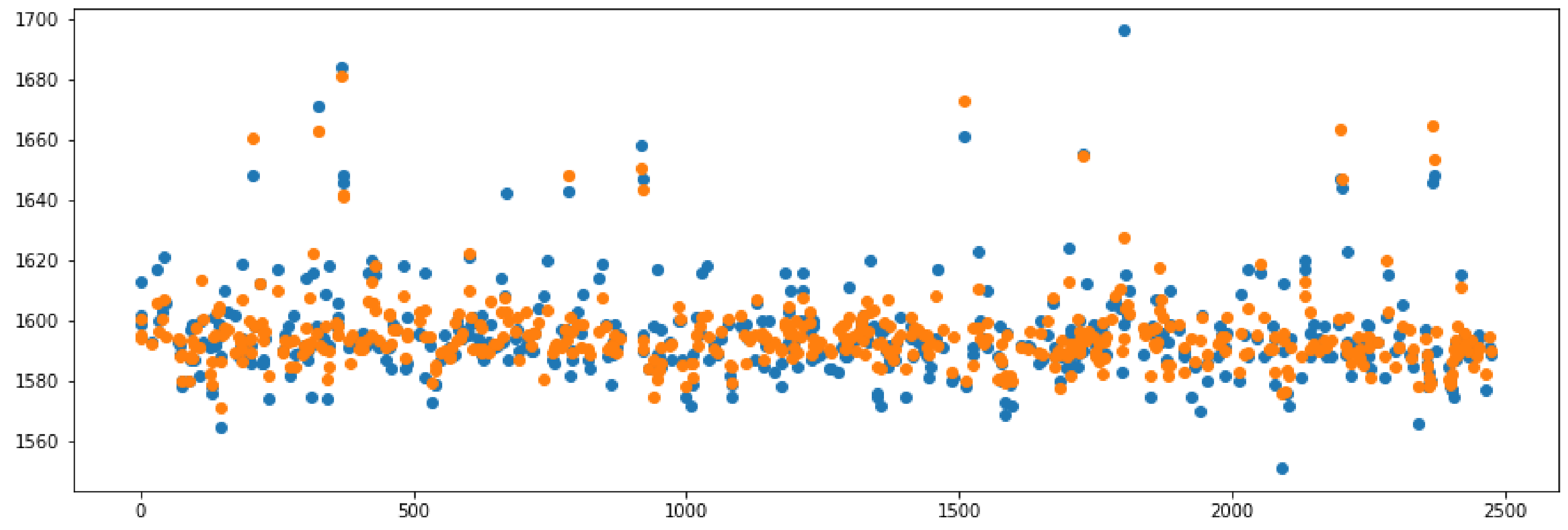
In [153]:
```
test_preds = best_model.predict(test_features)
```

In [154]:
```
test_mae = mean_absolute_error(test_preds, test_target)
```

In [155]:
```
test_mae
```

Out[155]:
```
5.957256233949206
```

In [156]:
```
plt.figure(figsize=(15,5))
for i in [test_target.values, test_preds]:
    plt.scatter(x = test_target.index, y = i)
```



4.2 Analysis of affect of features on the target value

In [157]:
```
influence_factors_df = test_features.copy()
```

In [158]:
```
influence_factors_df['prediction'] = test_preds
```

In [159]:

```python
# selection of columns for the check of affect on target
data_list = influence_factors_df.drop(columns = 'prediction').columns

# Loop for display of correlation value of feature to target
for data in data_list:
    print(data, 'coeff:', round(influence_factors_df['prediction'].corr(influence_factors_df[data])*100,2),'%')
```

```
first_temperature coeff: 47.53 %
Bulk 1 coeff: -4.21 %
Bulk 2 coeff: 0.2 %
Bulk 3 coeff: -9.7 %
Bulk 4 coeff: 5.94 %
Bulk 5 coeff: 0.11 %
Bulk 6 coeff: -22.06 %
Bulk 7 coeff: 1.81 %
Bulk 8 coeff: nan %
Bulk 9 coeff: -3.08 %
Bulk 10 coeff: -1.2 %
Bulk 11 coeff: -9.57 %
Bulk 12 coeff: 20.6 %
Bulk 13 coeff: 2.65 %
Bulk 14 coeff: 4.66 %
Bulk 15 coeff: -0.99 %
Wire 1 coeff: -10.08 %
Wire 2 coeff: -15.84 %
Wire 3 coeff: -1.16 %
Wire 4 coeff: -1.64 %
Wire 5 coeff: nan %
Wire 6 coeff: -5.14 %
Wire 7 coeff: -6.78 %
Wire 8 coeff: -3.07 %
Wire 9 coeff: -6.17 %
heating_qty coeff: 8.91 %
act_pwr_1 coeff: -9.64 %
act_pwr_2 coeff: 26.82 %
act_pwr_3 coeff: 26.3 %
act_pwr_4 coeff: 10.73 %
act_pwr_5 coeff: 6.21 %
act_pwr_6 coeff: 11.84 %
act_pwr_7 coeff: 8.38 %
act_pwr_8 coeff: 8.95 %
act_pwr_9 coeff: 6.25 %
act_pwr_10 coeff: 7.86 %
act_pwr_11 coeff: 9.89 %
act_pwr_12 coeff: 10.03 %
act_pwr_13 coeff: 10.2 %
act_pwr_14 coeff: 4.23 %
act_pwr_15 coeff: 4.23 %
act_pwr_16 coeff: nan %
react_pwr_1 coeff: -11.14 %
react_pwr_2 coeff: 24.44 %
react_pwr_3 coeff: 22.31 %
```

```
react_pwr_4 coeff: 7.67 %
react_pwr_5 coeff: 3.14 %
react_pwr_6 coeff: 9.92 %
react_pwr_7 coeff: 7.74 %
react_pwr_8 coeff: 8.7 %
react_pwr_9 coeff: 6.04 %
react_pwr_10 coeff: 8.78 %
react_pwr_11 coeff: 9.81 %
react_pwr_12 coeff: 10.29 %
react_pwr_13 coeff: 10.16 %
react_pwr_14 coeff: 4.23 %
react_pwr_15 coeff: 4.23 %
react_pwr_16 coeff: nan %
gas coeff: 3.53 %
first_temp_time_seconds coeff: -6.65 %
final_temp_time_seconds coeff: 6.45 %
Bulk 1_time_seconds coeff: -7.5 %
Bulk 2_time_seconds coeff: 0.47 %
Bulk 3_time_seconds coeff: -2.32 %
Bulk 4_time_seconds coeff: -1.28 %
Bulk 5_time_seconds coeff: 1.35 %
Bulk 6_time_seconds coeff: -22.2 %
Bulk 7_time_seconds coeff: 1.82 %
Bulk 8_time_seconds coeff: nan %
Bulk 9_time_seconds coeff: -2.88 %
Bulk 10_time_seconds coeff: 1.27 %
Bulk 11_time_seconds coeff: -6.41 %
Bulk 12_time_seconds coeff: 0.49 %
Bulk 13_time_seconds coeff: 4.05 %
Bulk 14_time_seconds coeff: -0.31 %
Bulk 15_time_seconds coeff: -0.12 %
Wire 1_time_seconds coeff: -2.93 %
Wire 2_time_seconds coeff: -3.77 %
Wire 3_time_seconds coeff: -0.73 %
Wire 4_time_seconds coeff: -0.38 %
Wire 5_time_seconds coeff: nan %
Wire 6_time_seconds coeff: -4.66 %
Wire 7_time_seconds coeff: -6.78 %
Wire 8_time_seconds coeff: -2.9 %
Wire 9_time_seconds coeff: -3.25 %
heat_finish_seconds coeff: 7.99 %
heat_1_finish_seconds coeff: -9.62 %
heat_2_start_seconds coeff: -8.26 %
heat_2_finish_seconds coeff: 4.54 %
heat_3_start_seconds coeff: -0.89 %
heat_3_finish_seconds coeff: 2.98 %
```

```
heat_4_start_seconds coeff: 1.25 %
heat_4_finish_seconds coeff: 2.04 %
heat_5_start_seconds coeff: 5.27 %
heat_5_finish_seconds coeff: 5.34 %
heat_6_start_seconds coeff: 9.56 %
heat_6_finish_seconds coeff: 9.7 %
heat_7_start_seconds coeff: 7.59 %
heat_7_finish_seconds coeff: 7.69 %
heat_8_start_seconds coeff: 6.24 %
heat_8_finish_seconds coeff: 6.36 %
heat_9_start_seconds coeff: 5.01 %
heat_9_finish_seconds coeff: 5.08 %
heat_10_start_seconds coeff: 5.17 %
heat_10_finish_seconds coeff: 5.7 %
heat_11_start_seconds coeff: 4.79 %
heat_11_finish_seconds coeff: 4.9 %
heat_12_start_seconds coeff: 6.68 %
heat_12_finish_seconds coeff: 6.75 %
heat_13_start_seconds coeff: 6.66 %
heat_13_finish_seconds coeff: 6.71 %
heat_14_start_seconds coeff: 4.23 %
heat_14_finish_seconds coeff: 4.23 %
heat_15_start_seconds coeff: 4.23 %
heat_15_finish_seconds coeff: 4.23 %
heat_16_start_seconds coeff: nan %
heat_16_finish_seconds coeff: nan %
```

Analysis using phik matrix

In [160]:
```
phik_mx = influence_factors_df.drop(columns = ['Bulk 8','Wire 5','act_pwr_16','react_pwr_16','Bulk 8_time_seconds',
                                     'heat_16_start_seconds','heat_16_finish_seconds','Wire 5_time_seconds']).phik_matrix()
```

```
interval columns not set, guessing: ['first_temperature', 'Bulk 1', 'Bulk 2', 'Bulk 3', 'Bulk 4', 'Bulk 5', 'Bulk 6', 'Bulk 7', 'Bulk
9', 'Bulk 10', 'Bulk 11', 'Bulk 12', 'Bulk 13', 'Bulk 14', 'Bulk 15', 'Wire 1', 'Wire 2', 'Wire 3', 'Wire 4', 'Wire 6', 'Wire 7', 'Wi
re 8', 'Wire 9', 'heating_qty', 'act_pwr_1', 'act_pwr_2', 'act_pwr_3', 'act_pwr_4', 'act_pwr_5', 'act_pwr_6', 'act_pwr_7', 'act_pwr_
8', 'act_pwr_9', 'act_pwr_10', 'act_pwr_11', 'act_pwr_12', 'act_pwr_13', 'act_pwr_14', 'act_pwr_15', 'react_pwr_1', 'react_pwr_2', 'r
eact_pwr_3', 'react_pwr_4', 'react_pwr_5', 'react_pwr_6', 'react_pwr_7', 'react_pwr_8', 'react_pwr_9', 'react_pwr_10', 'react_pwr_1
1', 'react_pwr_12', 'react_pwr_13', 'react_pwr_14', 'react_pwr_15', 'gas', 'first_temp_time_seconds', 'final_temp_time_seconds', 'Bul
k 1_time_seconds', 'Bulk 2_time_seconds', 'Bulk 3_time_seconds', 'Bulk 4_time_seconds', 'Bulk 5_time_seconds', 'Bulk 6_time_seconds',
'Bulk 7_time_seconds', 'Bulk 9_time_seconds', 'Bulk 10_time_seconds', 'Bulk 11_time_seconds', 'Bulk 12_time_seconds', 'Bulk 13_time_s
econds', 'Bulk 14_time_seconds', 'Bulk 15_time_seconds', 'Wire 1_time_seconds', 'Wire 2_time_seconds', 'Wire 3_time_seconds', 'Wire 4
_time_seconds', 'Wire 6_time_seconds', 'Wire 7_time_seconds', 'Wire 8_time_seconds', 'Wire 9_time_seconds', 'heat_finish_seconds', 'h
eat_1_finish_seconds', 'heat_2_start_seconds', 'heat_2_finish_seconds', 'heat_3_start_seconds', 'heat_3_finish_seconds', 'heat_4_star
t_seconds', 'heat_4_finish_seconds', 'heat_5_start_seconds', 'heat_5_finish_seconds', 'heat_6_start_seconds', 'heat_6_finish_second
s', 'heat_7_start_seconds', 'heat_7_finish_seconds', 'heat_8_start_seconds', 'heat_8_finish_seconds', 'heat_9_start_seconds', 'heat_9
_finish_seconds', 'heat_10_start_seconds', 'heat_10_finish_seconds', 'heat_11_start_seconds', 'heat_11_finish_seconds', 'heat_12_star
t_seconds', 'heat_12_finish_seconds', 'heat_13_start_seconds', 'heat_13_finish_seconds', 'heat_14_start_seconds', 'heat_14_finish_sec
onds', 'heat_15_start_seconds', 'heat_15_finish_seconds', 'prediction']
```

In [161]:
```
phik_mx
```

Out[161]:

	first_temperature	Bulk 1	Bulk 2	Bulk 3	Bulk 4	Bulk 5	Bulk 6	Bulk 7	Bulk 9	Bulk 10	...	heat_11_finish_seconds	heat_12_s
first_temperature	1.000000	0.000000	0.227738	0.0	0.174106	0.289226	0.000000	0.181606	0.000000	0.000000	...	0.000000	
Bulk 1	0.000000	1.000000	0.442517	0.0	0.149401	0.244812	0.000000	0.905982	0.000000	0.166056	...	0.632638	
Bulk 2	0.227738	0.442517	1.000000	0.0	0.278041	0.939734	0.000000	0.306977	0.000000	0.000000	...	0.000000	
Bulk 3	0.000000	0.000000	0.000000	1.0	0.000000	0.501175	0.337043	0.000000	0.215257	0.000000	...	0.000000	
Bulk 4	0.174106	0.149401	0.278041	0.0	1.000000	0.000000	0.000000	0.136119	0.000000	0.193303	...	0.000000	
...	...	...	...	...	...	...	...	...	...	...	...	...	
heat_14_start_seconds	0.000000	0.000000	0.000000	0.0	0.000000	0.000000	0.722314	0.000000	0.000000	0.000000	...	1.000000	
heat_14_finish_seconds	0.000000	0.000000	0.000000	0.0	0.000000	0.000000	0.722314	0.000000	0.000000	0.000000	...	1.000000	
heat_15_start_seconds	0.000000	0.000000	0.000000	0.0	0.000000	0.000000	0.722314	0.000000	0.000000	0.000000	...	1.000000	
heat_15_finish_seconds	0.000000	0.000000	0.000000	0.0	0.000000	0.000000	0.722314	0.000000	0.000000	0.000000	...	1.000000	
prediction	0.737505	0.289630	0.000000	0.0	0.000000	0.000000	0.312351	0.365095	0.000000	0.000000	...	0.401718	

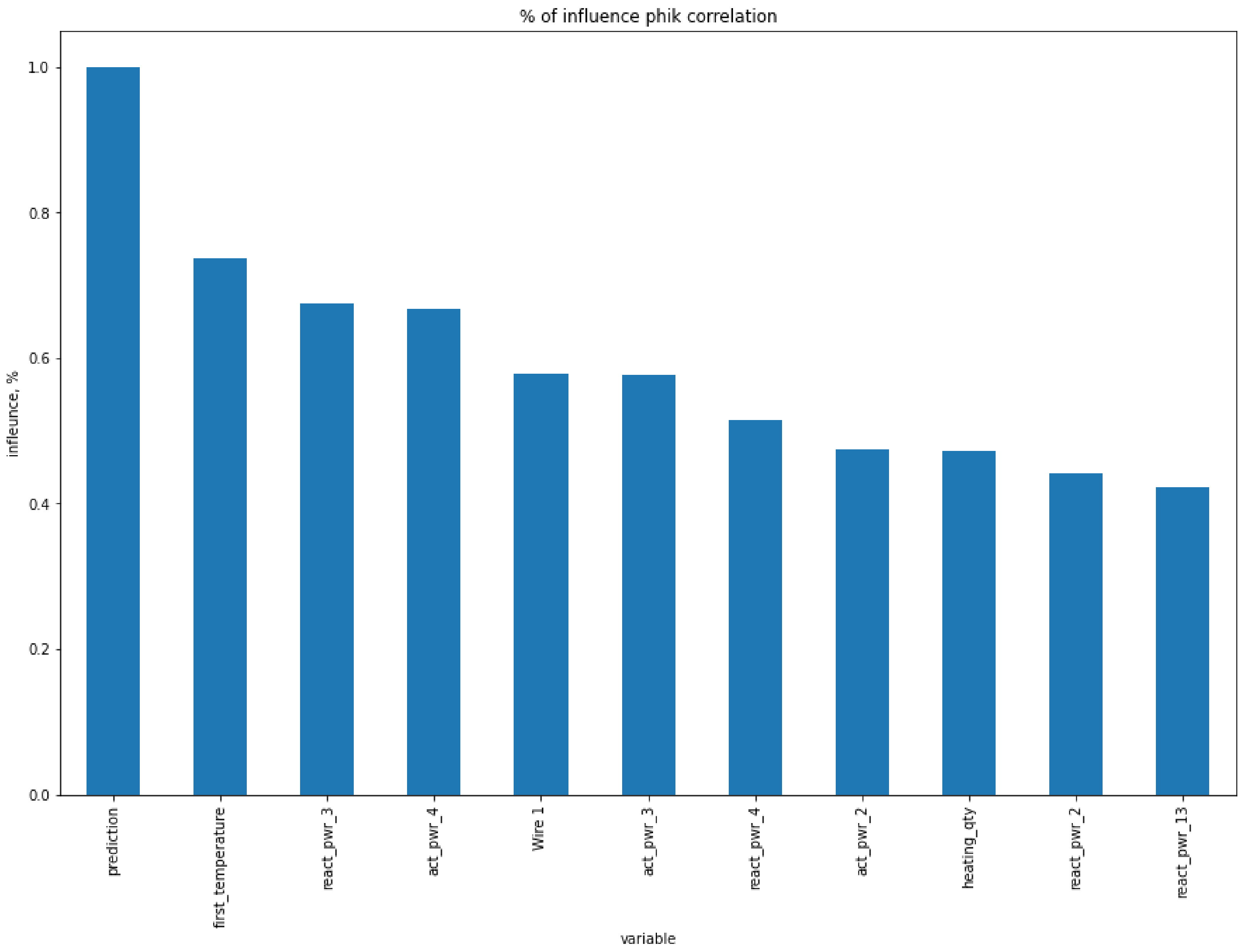
110 rows × 110 columns

In [162]:
```
# selection of features with highest affect
phik_mx[phik_mx['prediction'] != 0 ]['prediction'].sort_values(ascending = False).head(11)
```

Out[162]:
```
prediction           1.000000
first_temperature    0.737505
react_pwr_3          0.674816
act_pwr_4            0.668048
Wire 1               0.578748
act_pwr_3            0.576382
react_pwr_4          0.515441
act_pwr_2            0.475136
heating_qty          0.472720
react_pwr_2          0.441378
react_pwr_13         0.423095
Name: prediction, dtype: float64
```

In [163]:
```python
# plotting the histograms for features with highest affect
plt.figure(figsize=(15,10))
phik_mx[phik_mx['prediction'] != 0 ]['prediction'].sort_values(ascending = False).head(11).plot(kind = 'bar',
                                title = '% of influence phik correlation', xlabel = 'variable', ylabel = 'infleunce, %')
```

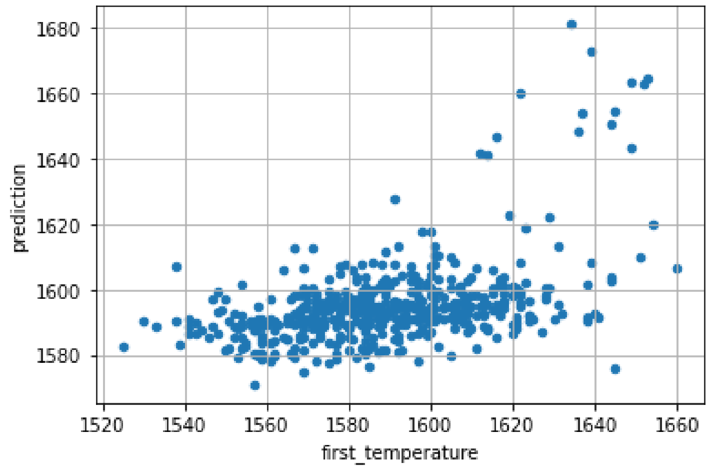
Out[163]:
```
<AxesSubplot:title={'center':'% of influence phik correlation'}, xlabel='variable', ylabel='infleunce, %'>
```

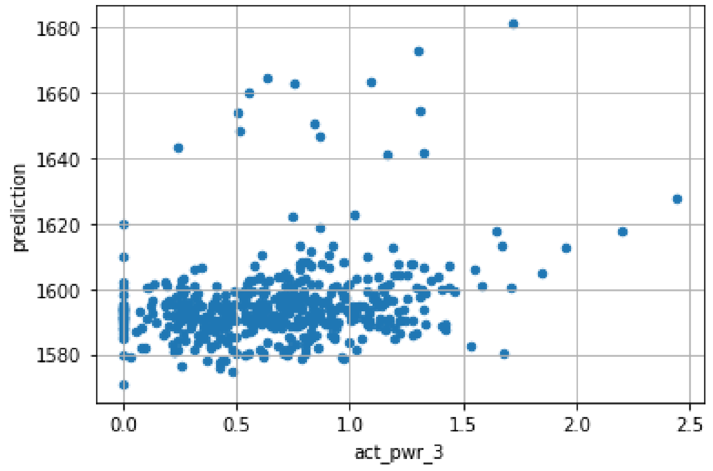

% of influence phik correlation
infleunce, %
1.0
0.8
0.6
0.4
0.2
0.0
prediction
first_temperature
react_pwr_3
act_pwr_4
Wire 1
act_pwr_3
react_pwr_4
act_pwr_2
heating_qty
react_pwr_2
react_pwr_13
variable

Conclusion

The highest affect on temperature has: - first temperature measurement and third reactive power

In [164]:
```
for i in ['prediction']:
    for j in ['first_temperature','act_pwr_3']:
        influence_factors_df.plot(y=i, x = j, kind = 'scatter', grid=True)
```





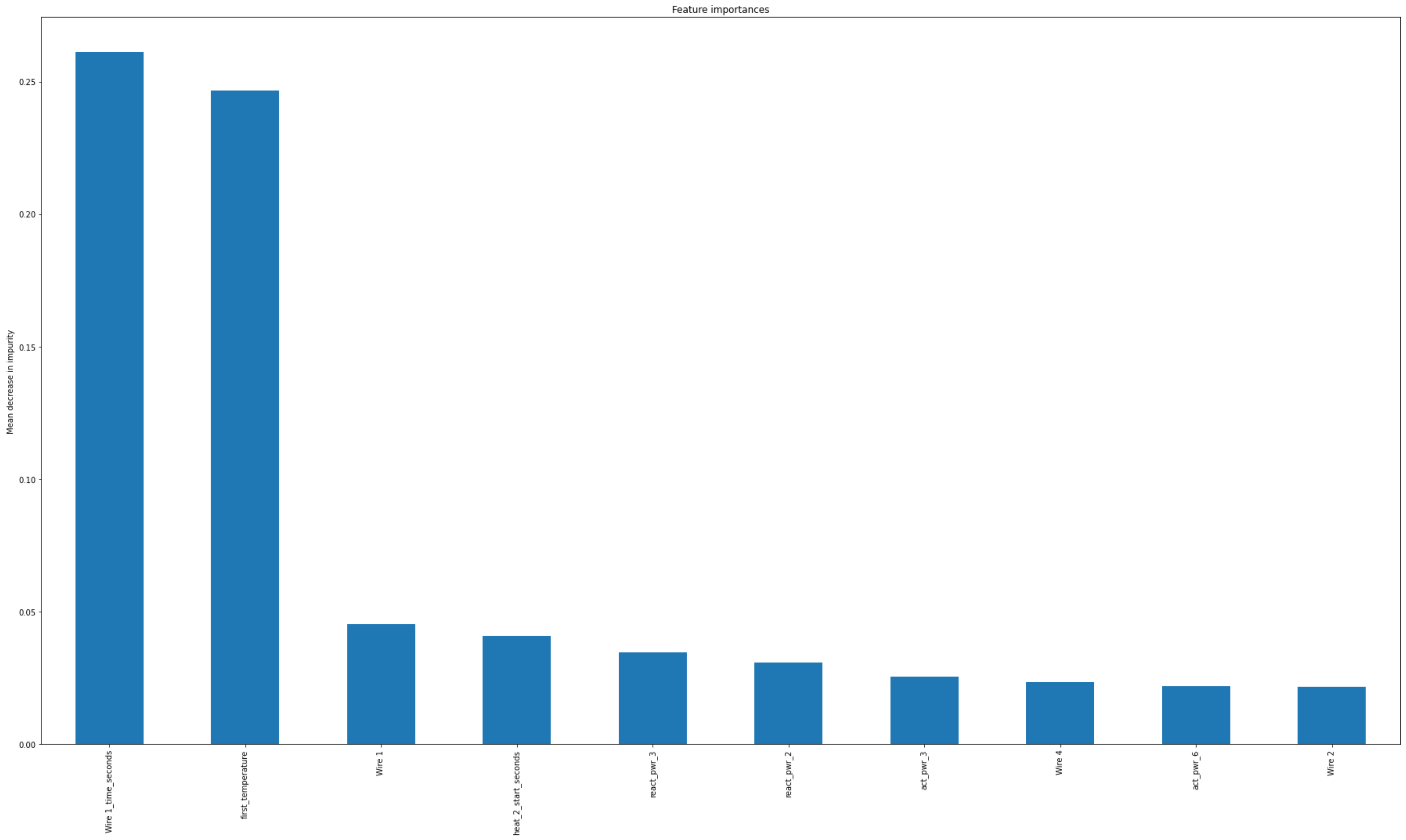
```
In [165]:  importances = dt_model.feature_importances_
```

```
In [166]:  model_importances = pd.Series(importances, index=features.columns)
```

```
In [167]:  model_importances = model_importances.sort_values(ascending=False).head(10)
```

```
In [168]:  std = np.std([dt_model.feature_importances_ for tree in str(1000)], axis=0)
```

In [169]:
```
fig, ax = plt.subplots(figsize=(25,15))
model_importances.plot.bar(yerr=std[0:10], ax=ax)
ax.set_title("Feature importances")
ax.set_ylabel("Mean decrease in impurity")
fig.tight_layout()
```



5 General Conclusions

During the project realization the following tasks were completed:

- Performed Exploratory data analysis;
- Data preparation, data cleaning, unification of formats;
- Three models were trined - with the best score MAE - 5,95, required score (MAE < 6) achieved;
- Best model was tested - MAE score is 5,95 on test sample;
- The features that affected the most are - reactive power and quantity of temperature measurement.