MODEL RANDOM FOREST DENGAN BAYESIAN OPTIMIZATION HYPERPARAMETER TUNING (BO-RF) UNTUK ANALISIS PERGERAKAN DAN PREDIKSI HARGA SAHAM

IMPORT LIBRARY

In [55]:
```
# Install Library yang dibutuhkan
#%pip install TA-Lib
#%pip install bayesian-optimization
```

In [56]:
```
# Library
import pandas as pd
import numpy as np
from warnings import filterwarnings

# Grafik dan Visualisasi
import matplotlib.pyplot as plt
import seaborn as sns

# Indikator Teknikal Saham
import talib

# Machine Learning
from sklearn.ensemble import RandomForestRegressor
from bayes_opt import BayesianOptimization
from sklearn.model_selection import TimeSeriesSplit, cross_val_score
from sklearn.metrics import mean_absolute_error, mean_absolute_percentage_error, root_mean_squared_error, r2_score

filterwarnings('ignore')
plt.rcParams['font.size'] = 14
```

DATA COLLECTION

In [57]:
```
def data_collection(path_data):
    print('--- Proses Data Collection ---')
    # Memasukkan data olahan harga saham harian
    try:
        df = pd.read_excel(path_data, parse_dates=['Date'], index_col='Date')
        print(f'Data berhasil dikoleksi dari {path_data}')
    except Exception as e:
        print(f'Error dalam koleksi data: {e}')
        return None

    # Inspeksi data awal
    print('Ukuran data:', df.shape)
    print('Lima data teratas:')
    display(df.head(5))
    print('Informasi umum data:')
    df.info()

    return df
```

DATA PREPARATION

In [58]:
```
def data_augmentation(df):
    return df

def feature_engineering(df_awal):
    df_fitur = pd.DataFrame(index=df_awal.index)

    df_fitur['Intraday_Range'] = df_awal['High'] - df_awal['Low']
    df_fitur['Intraday_Change'] = df_awal['Close'] - df_awal['Open']
    df_fitur['MA_5'] = talib.MA(df_awal['Close'], timeperiod=5)
    df_fitur['MA_10'] = talib.MA(df_awal['Close'], timeperiod=10)
    df_fitur['RSI_7'] = talib.RSI(df_awal['Close'], timeperiod=7)
    df_fitur['RSI_14'] = talib.RSI(df_awal['Close'], timeperiod=14)
    df_fitur['MOM_10'] = talib.MOM(df_awal['Close'], timeperiod=10)
    df_fitur['ROC_10'] = talib.ROC(df_awal['Close'], timeperiod=10)
    df_fitur['ATR_14'] = talib.ATR(df_awal['High'], df_awal['Low'], df_awal['Close'], timeperiod=14)
    df_fitur['Volatility_10'] = df_awal['Close_Diff'].rolling(window=10).std()

    df_fitur['Open_t-1'] = df_awal['Open'].shift(1)
    df_fitur['High_t-1'] = df_awal['High'].shift(1)
    df_fitur['Low_t-1'] = df_awal['Low'].shift(1)
```

```
    df_fitur['Close_t-1'] = df_awal['Close'].shift(1)

    if 'Volume_Log' in df_awal.columns:
        df_fitur['Volume_Log_t-1'] = df_awal['Volume_Log'].shift(1)

    df_fitur['Close_Diff_t-1'] = df_awal['Close_Diff'].shift(1)

    df_fitur['Intraday_Range_t-1'] = df_fitur['Intraday_Range'].shift(1)
    df_fitur['Intraday_Change_t-1'] = df_fitur['Intraday_Change'].shift(1)
    df_fitur['MA_5_t-1'] = df_fitur['MA_5'].shift(1)
    df_fitur['MA_10_t-1'] = df_fitur['MA_10'].shift(1)
    df_fitur['RSI_7_t-1'] = df_fitur['RSI_7'].shift(1)
    df_fitur['RSI_14_t-1'] = df_fitur['RSI_14'].shift(1)
    df_fitur['MOM_10_t-1'] = df_fitur['MOM_10'].shift(1)
    df_fitur['ROC_10_t-1'] = df_fitur['ROC_10'].shift(1)
    df_fitur['ATR_14_t-1'] = df_fitur['ATR_14'].shift(1)
    df_fitur['Volatility_10_t-1'] = df_fitur['Volatility_10'].shift(1)

    df_fitur['Year'] = df_fitur.index.year
    df_fitur['Month'] = df_fitur.index.month
    df_fitur['Week'] = df_fitur.index.isocalendar().week.astype(float)
    df_fitur['DayOfWeek'] = df_fitur.index.dayofweek
    df_fitur['DayOfMonth'] = df_fitur.index.day
    df_fitur['DayOfYear'] = df_fitur.index.dayofyear
    df_fitur['Quarter'] = df_fitur.index.quarter
    df_fitur['IsMonthStart'] = df_fitur.index.is_month_start.astype(int)
    df_fitur['IsMonthEnd'] = df_fitur.index.is_month_end.astype(int)

    df_fitur.dropna(inplace=True)
    return df_fitur

def data_preparation(df):
    print('--- Proses Data Preparation ---')
    df_prep = df.copy()

    # Data Cleaning & Data Transformation
    if 'Volume' in df_prep.columns:
        df_prep['Volume'] = df_prep['Volume'].ffill().fillna(0)
        df_prep['Volume_Log'] = np.log1p(df_prep['Volume'])
        df_prep = df_prep.drop('Volume', axis=1)

    df_prep['Close_Diff'] = df_prep['Close'].diff()

    # Feature Engineering
    df_fitur = feature_engineering(df_prep)

    # Data Augmentation
    df_keseluruhan = pd.concat([df_prep, df_fitur], axis=1)
    df_keseluruhan.dropna(inplace=True)
    df_keseluruhan = data_augmentation(df_keseluruhan)

    # Feature Selection & Data Splitting
    variabel_input = [col for col in df_keseluruhan.columns if col not in['Open', 'High', 'Low', 'Volume_Log', 'Close', 'Close_Diff',
                                                                           'Intraday_Range', 'Intraday_Change', 'MA_5', 'MA_10', 'RSI_7',
                                                                           'RSI_14', 'MOM_10', 'ROC_10', 'ATR_14', 'Volatility_10',
                                                                           'Open_t-1', 'High_t-1', 'Low_t-1', 'RSI_14_t-1', 'MA_10_t-1',
                                                                           'ROC_10_t-1']]

    X = df_keseluruhan[variabel_input]
    y = df_keseluruhan['Close_Diff']

    train_size = int(len(df_keseluruhan) * 0.8)
    X_train = X.iloc[:train_size]
    X_test = X.iloc[train_size:]
    y_train = y.iloc[:train_size]
    y_test = y.iloc[train_size:]

    print(f'Dimensi X_train: {X_train.shape}')
    print(f'Dimensi X_test: {X_test.shape}')
    print(f'Dimensi y_train: {y_train.shape}')
    print(f'Dimensi y_test: {y_test.shape}')

    return X_train, y_train, X_test, y_test, df_keseluruhan, variabel_input
```

MODEL DEVELOPMENT

In [59]:

```
def model_development(X_train, y_train):
    print('--- Proses Model Development ---')

    pbounds = {'n_estimators': (200, 1000),
               'max_depth': (5, 50),
               'min_samples_leaf': (1, 15),
               'min_samples_split': (2, 20),
```

```
            'max_features': (0.1, 1.0)}

    def rf_cv_score(n_estimators, max_depth, min_samples_leaf, max_features, min_samples_split):
        try:
            n_estimators = int(n_estimators)
            max_depth = int(max_depth)
            min_samples_leaf = int(min_samples_leaf)
            min_samples_split = int(min_samples_split)

            model = RandomForestRegressor(n_estimators=n_estimators,
                                          max_depth=max_depth,
                                          min_samples_leaf=min_samples_leaf,
                                          max_features=max_features,
                                          min_samples_split=min_samples_split,
                                          random_state=42,
                                          n_jobs=1)

            tscv = TimeSeriesSplit(n_splits=5)
            scores = cross_val_score(model, X_train, y_train, cv=tscv, scoring='neg_root_mean_squared_error', n_jobs=1)
            return np.mean(scores)

        except Exception as e:
            print(f"Error: {e}")
            return -1e9

    optimizer = BayesianOptimization(f=rf_cv_score, pbounds=pbounds, random_state=42, verbose=2)
    optimizer.maximize(init_points=5, n_iter=50)

    best_params = optimizer.max['params']
    best_params_formatted = {'n_estimators': int(best_params['n_estimators']),
                             'max_depth': int(best_params['max_depth']),
                             'min_samples_leaf': int(best_params['min_samples_leaf']),
                             'min_samples_split': int(best_params['min_samples_split']),
                             'max_features': best_params['max_features']}

    print(f'Best Hyperparameters: {best_params_formatted}')

    best_rf_model = RandomForestRegressor(**best_params_formatted, random_state=42, n_jobs=1)
    best_rf_model.fit(X_train, y_train)

    return best_rf_model
```

MODEL EVALUATION

In [60]:
```
def model_evaluation(model, X_test, y_test):
    print('--- Proses Model Evaluation ---')

    y_pred_arr = model.predict(X_test)
    y_pred = pd.Series(y_pred_arr, index=X_test.index, name='Pred_Close_Diff')

    rmse = root_mean_squared_error(y_test, y_pred)
    mae = mean_absolute_error(y_test, y_pred)
    r2 = r2_score(y_test, y_pred)

    print('RMSE:', rmse)
    print('MAE:', mae)
    print('R-squared:', r2)

    plt.figure(figsize=(12, 8))
    plt.plot(y_test.index, y_test, label='Close_Diff Aktual', color='blue')
    plt.plot(y_test.index, y_pred, label='Hasil Prediksi Close_Diff (BO-RF)', color='red', linestyle='--')
    plt.xlabel('Date')
    plt.ylabel('Close_Diff')
    plt.legend()
    plt.show()

    # Feature Importance dalam Model BO-RF
    importances = pd.Series(model.feature_importances_, index=variabel_input)
    importances_sorted = importances.sort_values(ascending=False)

    plt.figure(figsize=(10, 10))
    ax = sns.barplot(x=importances_sorted.values, y=importances_sorted.index, palette="viridis")
    for i, v in enumerate(importances_sorted.values):
        ax.text(v + 0.001, i, f"{v:.4f}", color='black', va='center')
    plt.title("Feature Importance")
    plt.show()

    return y_pred
```

MODEL POSTPROCESSING

In [61]:
```python
def model_postprocessing(model, X_test, y_pred, df_keseluruhan, variabel_input):
    print('--- Proses Model Post-Processing ---')

    # Inversi ke skala harga penutupan 'Close'
    close_t_minus_1_test = df_keseluruhan.loc[X_test.index, 'Close_t-1']
    close_actual_test = df_keseluruhan.loc[X_test.index, 'Close']
    pred_close = close_t_minus_1_test + y_pred

    hasil_df = pd.DataFrame({'Close': close_actual_test,
                             'Close_t-1': close_t_minus_1_test,
                             'Pred_Close_Diff': y_pred,
                             'Pred_Close': pred_close},
                            index=X_test.index)

    # Metrik Evaluasi terhadap data terinversi
    rmse_new = root_mean_squared_error(hasil_df['Close'], hasil_df['Pred_Close'])
    mae_new = mean_absolute_error(hasil_df['Close'], hasil_df['Pred_Close'])
    mape_new = mean_absolute_percentage_error(hasil_df['Close'], hasil_df['Pred_Close'])
    r_squared_new = r2_score(hasil_df['Close'], hasil_df['Pred_Close'])

    print('RMSE (Terinversi):', rmse_new)
    print('MAE (Terinversi):', mae_new)
    print('MAPE (Terinversi):', mape_new)
    print('R-squared (Terinversi):', r_squared_new)

    # Visualisasi data aktual dan data terinversi
    plt.figure(figsize=(12, 8))
    plt.plot(hasil_df.index, hasil_df['Close'], label='Actual Close', color='blue')
    plt.plot(hasil_df.index, hasil_df['Pred_Close'], label='Predicted Close (BO-RF)', color='red', linestyle='--')
    plt.title("Actual vs Predicted Close Price")
    plt.xlabel('Date')
    plt.ylabel('Close Price')
    plt.legend()
    plt.show()

    display(hasil_df.head(10))
    return hasil_df
```

MAIN FLOW

In [62]:
```python
# Lokasi penyimpanan file data harga saham harian
path_data = r"D:\file\[KULIAHAN]\SKRIPSI\Resources\Data Olahan\BBCA_01102019_01102025.xlsx"

# Data Collection
df_awal = data_collection(path_data)

if df_awal is not None:
    # Data Preparation
    X_train, y_train, X_test, y_test, df_keseluruhan, variabel_input = data_preparation(df_awal)

    # Model Development
    best_model = model_development(X_train, y_train)

    # Model Evaluation
    y_pred_diff = model_evaluation(best_model, X_test, y_test)

    # Model Postprocessing
    df_results = model_postprocessing(best_model, X_test, y_pred_diff, df_keseluruhan, variabel_input)
```

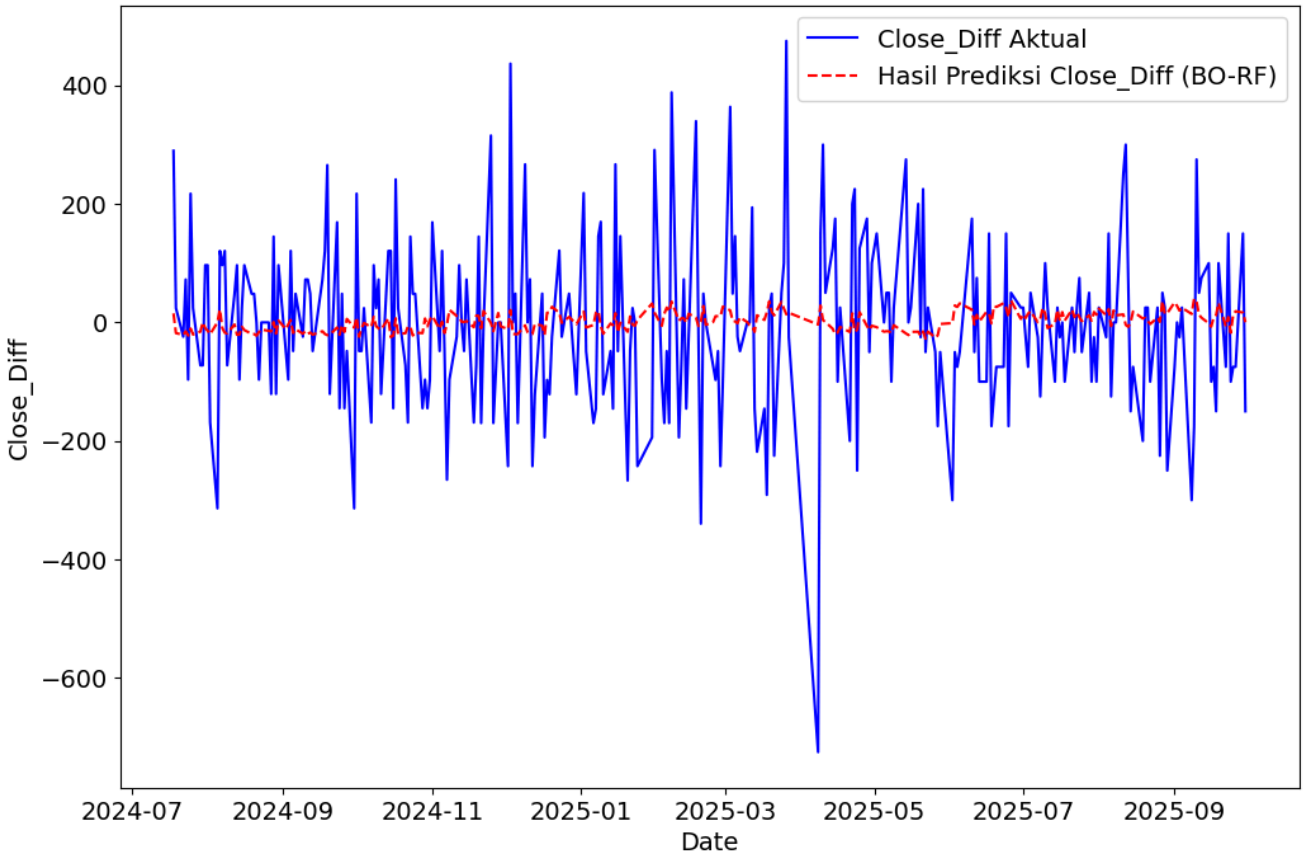
```
--- Proses Data Collection ---
Data berhasil dikoleksi dari D:\file\[KULIAHAN]\SKRIPSI\Resources\Data Olahan\BBCA_01102019_01102025.xlsx
Ukuran data: (1447, 5)
Lima data teratas:
```

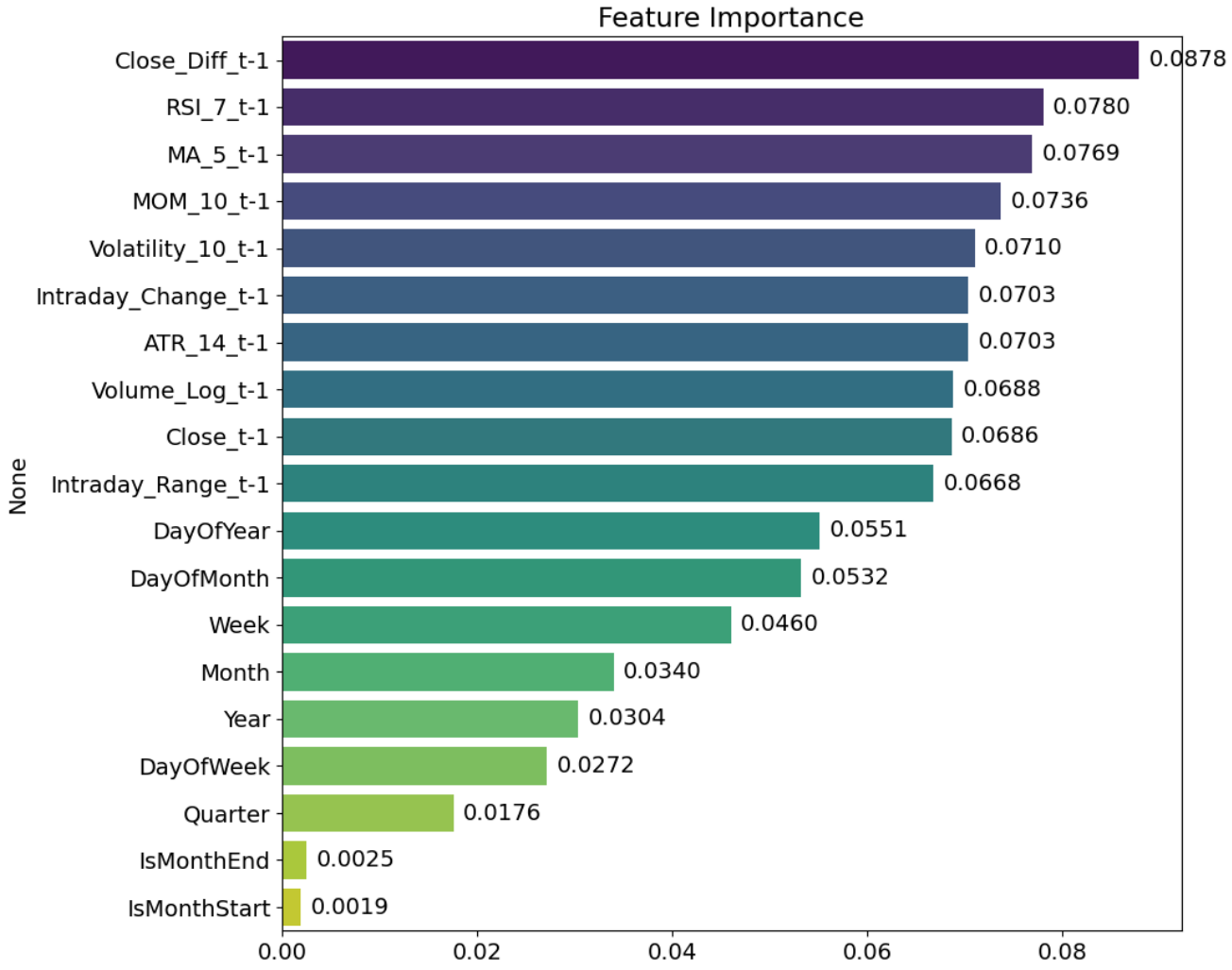
Date	Open	High	Low	Close	Volume
2019-10-01	5212.767129	5260.471321	5212.767129	5238.787598	40057000.0
2019-10-02	5212.767466	5264.808406	5212.767466	5247.461426	52376500.0
2019-10-03	5212.767129	5243.124342	5160.726193	5238.787598	50269000.0
2019-10-04	5186.746829	5260.471491	5186.746829	5243.124512	56890500.0
2019-10-07	5264.808105	5273.481595	5247.461127	5264.808105	56705500.0

```
Informasi umum data:
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1447 entries, 2019-10-01 to 2025-09-30
Data columns (total 5 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Open    1447 non-null   float64
 1   High    1447 non-null   float64
 2   Low     1447 non-null   float64
 3   Close   1447 non-null   float64
 4   Volume  1445 non-null   float64
dtypes: float64(5)
memory usage: 67.8 KB
--- Proses Data Preparation ---
Dimensi X_train: (1145, 19)
Dimensi X_test: (287, 19)
Dimensi y_train: (1145,)
Dimensi y_test: (287,)
--- Proses Model Development ---
```

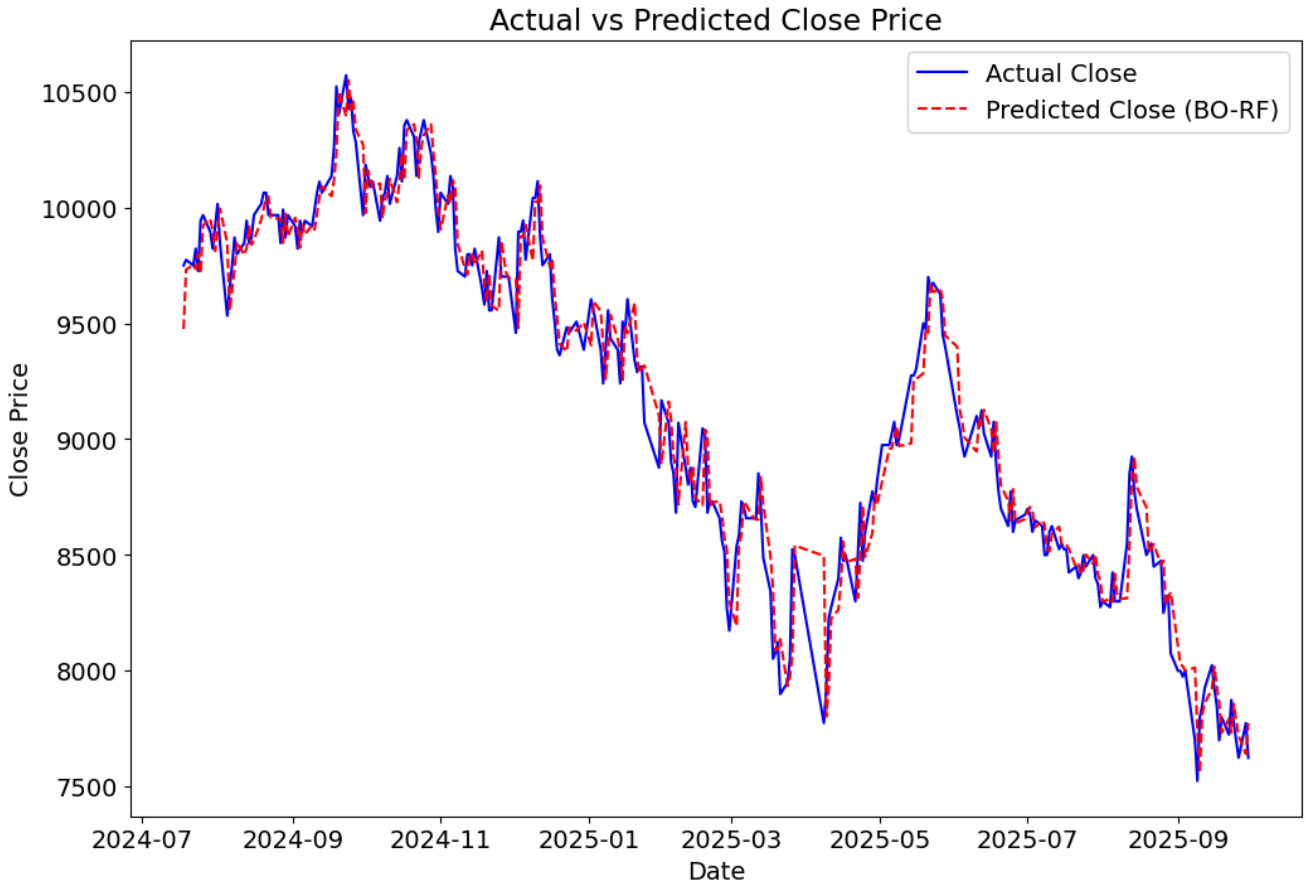
iter	target	n_esti...	max_depth	min_sa...	min_sa...	max_fe...
1	-100.6624	499.63209	47.782143	11.247915	12.775852	0.2404167
2	-101.3908	324.79561	7.6137625	13.126466	12.820070	0.7372653
3	-100.9022	216.46759	48.645943	12.654196	5.8221039	0.2636424
4	-101.2157	346.72360	18.690900	8.3465900	9.7750103	0.3621062
5	-102.0053	689.48231	11.277223	5.0900250	8.5945131	0.5104629
6	-100.9085	452.83363	5.0	1.0	2.0	0.1
7	-101.2998	999.80739	47.761236	12.242372	3.4141416	0.7625173
8	-100.5066	500.39724	47.268124	11.238309	13.415831	0.1749395
9	-101.2358	503.66888	44.781790	9.4724373	14.115756	0.4603522
10	-100.2009	500.21498	47.683939	12.997755	15.338085	0.1
11	-100.2311	502.59011	49.794547	14.252361	15.112529	0.1
12	-100.2009	500.99942	50.0	12.490750	19.219193	0.1
13	-100.2497	501.24672	45.876776	15.0	20.0	0.1
14	-100.2432	495.55783	48.644388	15.0	20.0	0.1
15	-100.2483	494.63064	41.567014	15.0	20.0	0.1
16	-100.4400	494.47593	45.162985	8.9101143	20.0	0.1
17	-100.2475	487.31118	44.547395	15.0	20.0	0.1
18	-100.2294	487.36616	36.564551	14.242714	20.0	0.1
19	-100.2467	488.28180	39.837666	15.0	13.246054	0.1
20	-101.9661	482.73708	40.294607	9.3524672	16.726662	1.0
21	-100.2452	492.64473	34.677911	15.0	15.981540	0.1
22	-100.2467	488.95963	28.839631	15.0	20.0	0.1
23	-100.2475	487.80857	29.687762	15.0	11.516746	0.1
24	-100.2463	491.74340	35.441221	15.0	6.6369616	0.1
25	-100.2432	495.66416	27.263956	15.0	9.5926519	0.1
26	-100.2450	490.22018	27.160449	15.0	2.7133012	0.1
27	-100.3767	492.12689	28.492361	7.8328708	6.8928195	0.1
28	-100.2293	489.57651	20.657549	14.972715	9.8689209	0.1
29	-101.8276	493.31706	22.830070	10.298293	16.139224	1.0
30	-100.2491	483.75493	22.909848	15.0	6.0061848	0.1
31	-100.2450	490.77660	18.620186	15.0	2.7671888	0.1
32	-100.2505	498.49057	24.703404	15.0	2.2941429	0.1
33	-100.2508	499.33774	32.550449	15.0	4.0292367	0.1
34	-100.2494	484.41342	13.952176	15.0	7.3608782	0.1
35	-100.3750	485.22767	18.388584	7.7882737	2.7615254	0.1
36	-100.2504	479.14199	19.182905	15.0	13.219875	0.1
37	-101.5842	475.56289	16.561657	15.0	5.0811592	1.0
38	-100.2506	480.68599	25.768688	15.0	17.810605	0.1
39	-100.2421	491.79343	10.342795	15.0	6.9040303	0.1
40	-100.2420	484.81623	11.699148	15.0	15.334086	0.1
41	-100.2494	478.93121	16.496900	15.0	20.0	0.1
42	-100.3196	486.74199	7.7107610	8.4253850	9.3870030	0.1
43	-100.3291	493.08711	11.459425	7.3542061	2.0	0.1
44	-100.2497	500.23201	13.983275	15.0	2.0	0.1
45	-101.1741	498.35414	5.0	13.800489	2.0	1.0
46	-100.3860	497.76049	19.318093	8.1516890	2.0	0.1
47	-100.2482	506.64450	19.907749	15.0	3.5318753	0.1
48	-100.2493	505.86379	27.677025	15.0	7.7262197	0.1
49	-100.3920	505.61901	27.354712	8.5242727	2.0	0.1
50	-100.4441	479.81132	12.054666	7.2905780	17.372466	0.1
51	-101.5403	514.12127	26.005687	15.0	3.0597750	1.0
52	-100.2497	501.08267	19.068082	15.0	7.7011937	0.1
53	-100.2531	472.28379	22.664510	15.0	20.0	0.1
54	-100.4868	476.19616	21.859706	7.6830686	20.0	0.1
55	-100.2491	483.17619	32.688887	15.0	3.2554498	0.1

```
==========================================================================================
Best Hyperparameters: {'n_estimators': 500, 'max_depth': 47, 'min_samples_leaf': 12, 'min_samples_split': 15, 'max_features': 0.1}
--- Proses Model Evaluation ---
RMSE: 145.3246447220812
MAE: 111.37879057104509
R-squared: 0.012606542350644623
```


Close_Diff Aktual
Hasil Prediksi Close_Diff (BO-RF)
Close_Diff
Date
400
200
0
−200
−400
−600
2024-07
2024-09
2024-11
2025-01
2025-03
2025-05
2025-07
2025-09


Feature Importance
None
Close_Diff_t-1 0.0878
RSI_7_t-1 0.0780
MA_5_t-1 0.0769
MOM_10_t-1 0.0736
Volatility_10_t-1 0.0710
Intraday_Change_t-1 0.0703
ATR_14_t-1 0.0703
Volume_Log_t-1 0.0688
Close_t-1 0.0686
Intraday_Range_t-1 0.0668
DayOfYear 0.0551
DayOfMonth 0.0532
Week 0.0460
Month 0.0340
Year 0.0304
DayOfWeek 0.0272
Quarter 0.0176
IsMonthEnd 0.0025
IsMonthStart 0.0019
0.00
0.02
0.04
0.06
0.08

```
--- Proses Model Post-Processing ---
RMSE (Terinversi): 145.32464472208116
MAE (Terinversi): 111.37879057104506
MAPE (Terinversi): 0.01230504613385758
R-squared (Terinversi): 0.9633985860557127
```



Date	Close	Close_t-1	Pred_Close_Diff	Pred_Close
2024-07-18	9749.879883	9460.279297	15.181230	9475.460527
2024-07-19	9774.013672	9749.879883	-18.090978	9731.788905
2024-07-22	9749.879883	9774.013672	-20.884219	9753.129453
2024-07-23	9822.280273	9749.879883	-15.104390	9734.775493
2024-07-24	9725.746094	9822.280273	-22.214779	9800.065494
2024-07-25	9942.946289	9725.746094	-10.442897	9715.303197
2024-07-26	9967.080078	9942.946289	-20.506522	9922.439767
2024-07-29	9894.679688	9967.080078	-15.591789	9951.488289
2024-07-30	9822.280273	9894.679688	0.124386	9894.804073
2024-07-31	9918.812500	9822.280273	-9.732546	9812.547728