

Stack Data Model

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Background

H2Fly requested a data driven model for the PowerCell P-Stack

The input data are derived from Test Nr. TV500873

The Configuration of the stack was a PowerCell P-stack, 455 cells

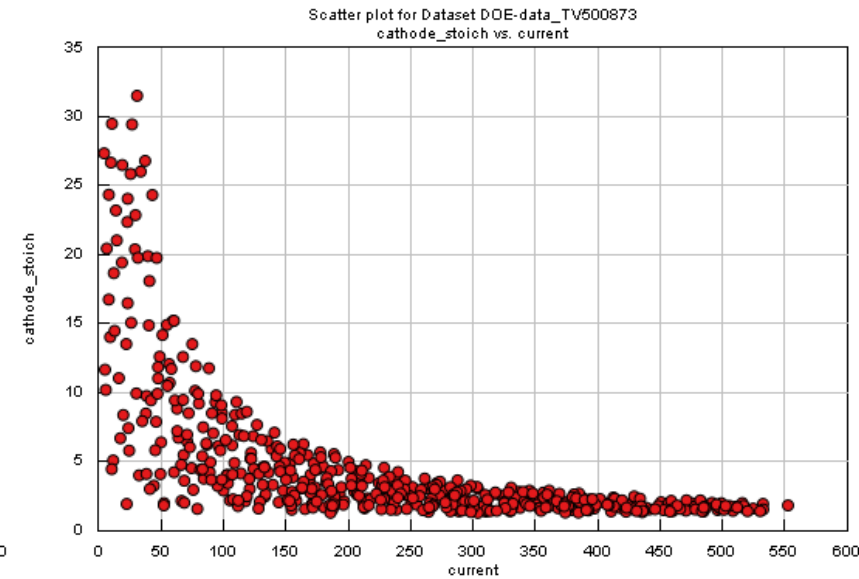
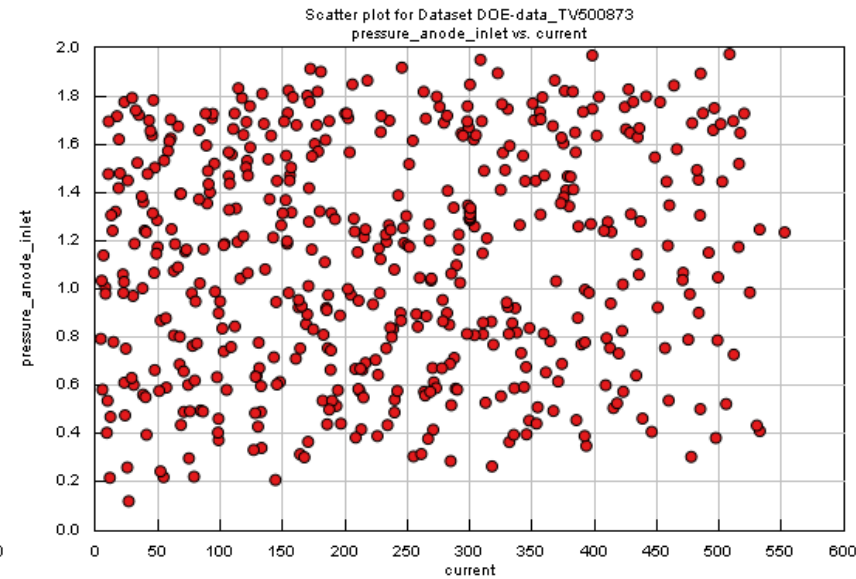
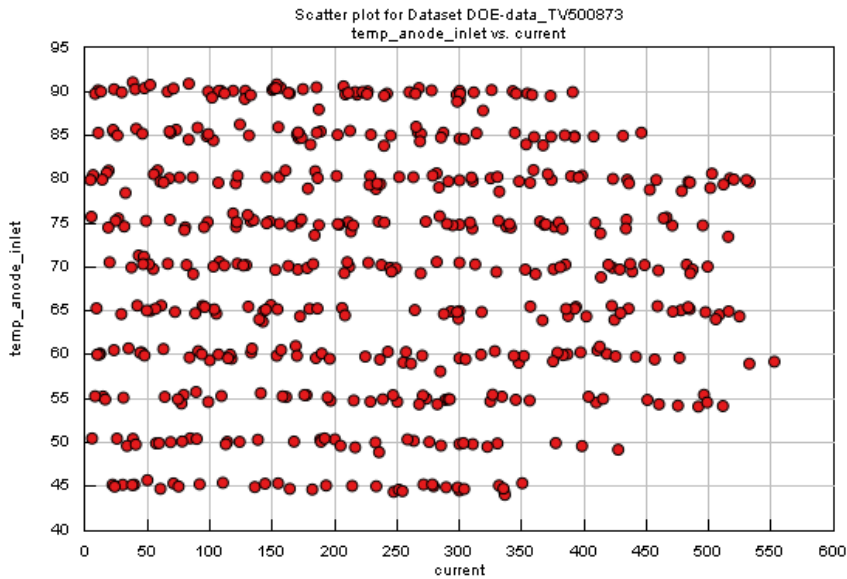
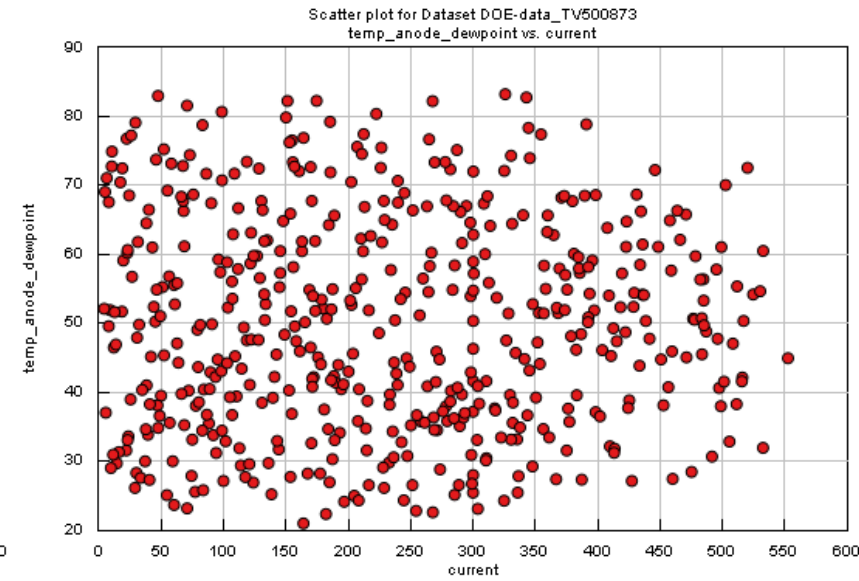
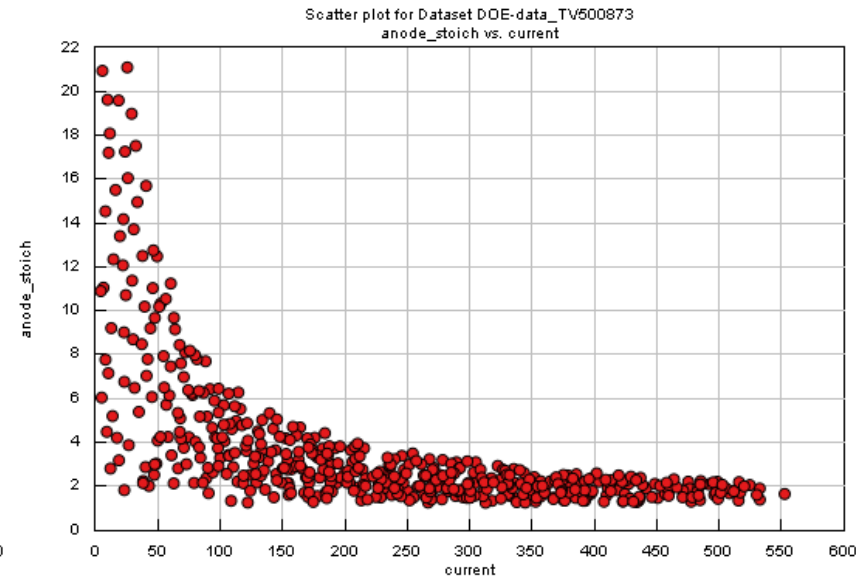
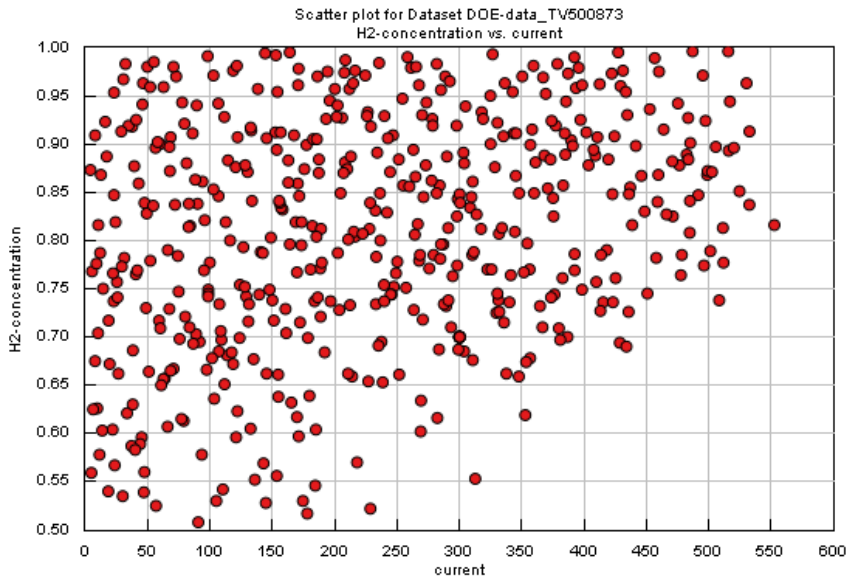
The operating range was from 0 – 550 A

The following parameters have been varied:

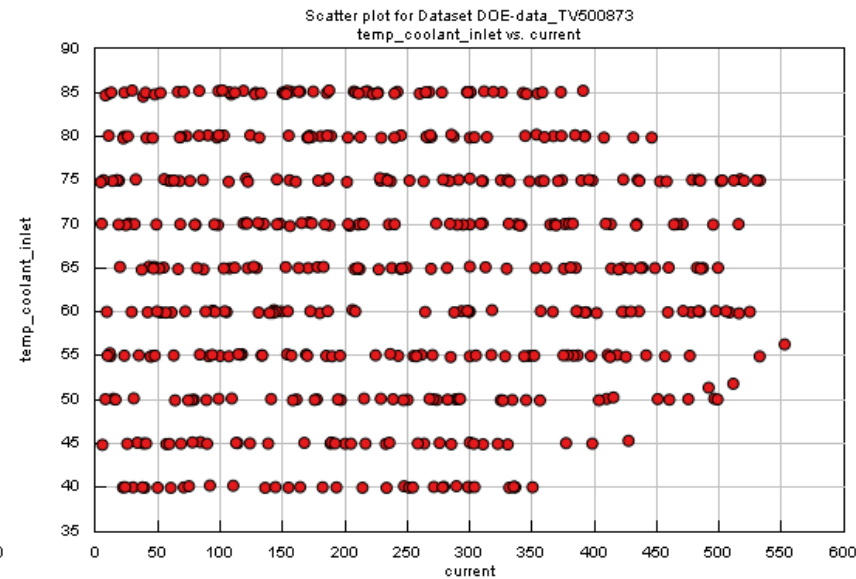
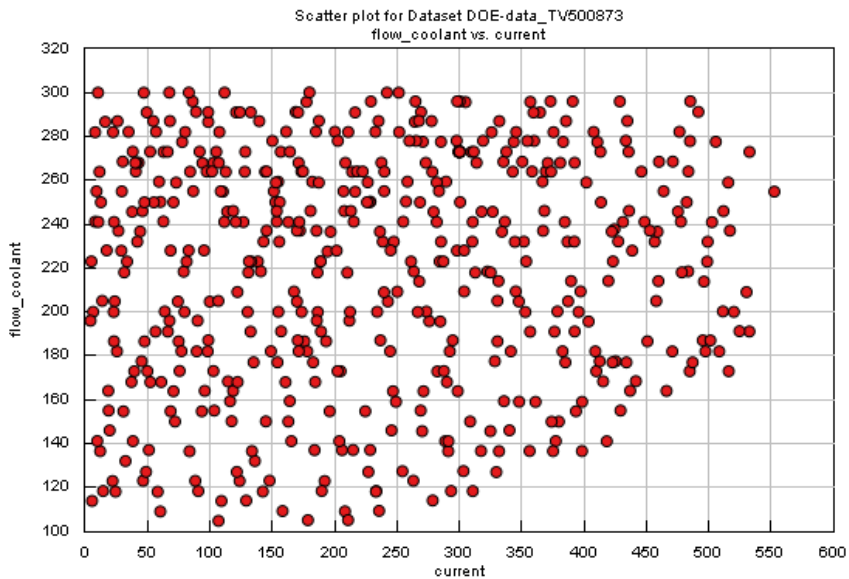
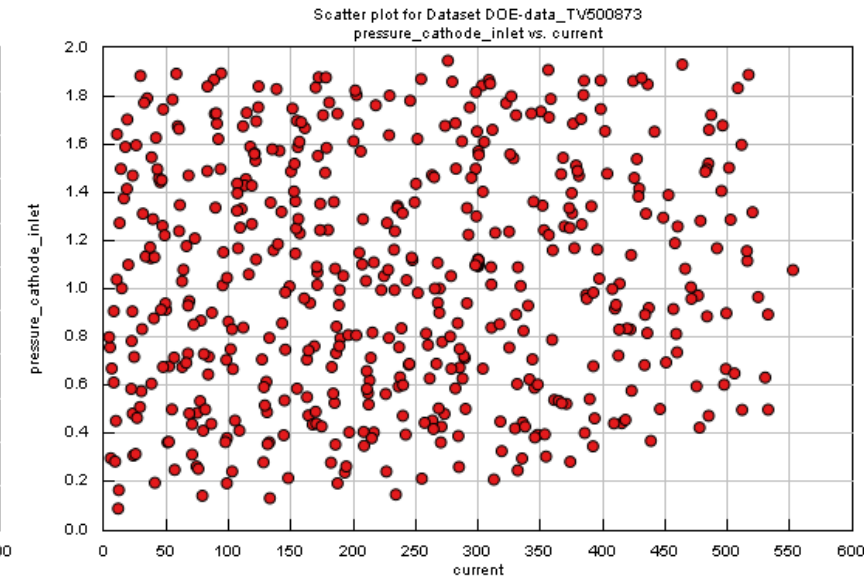
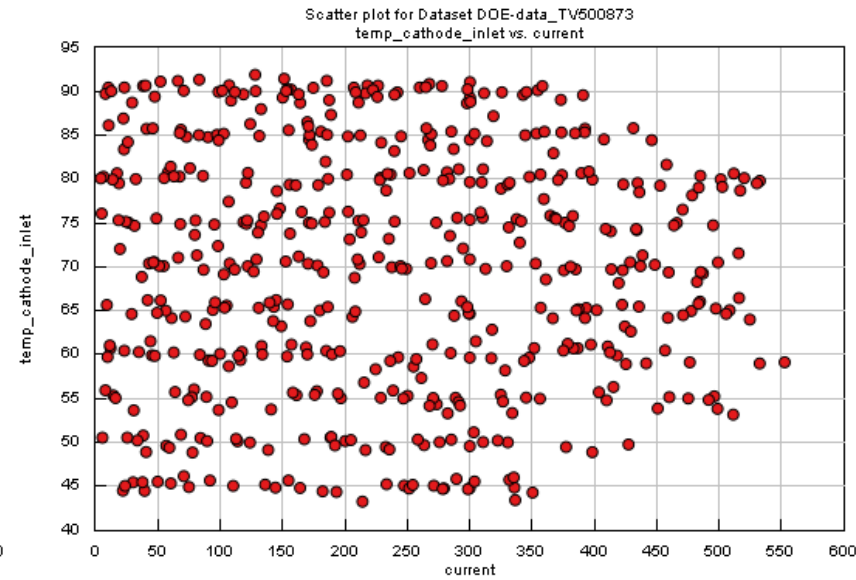
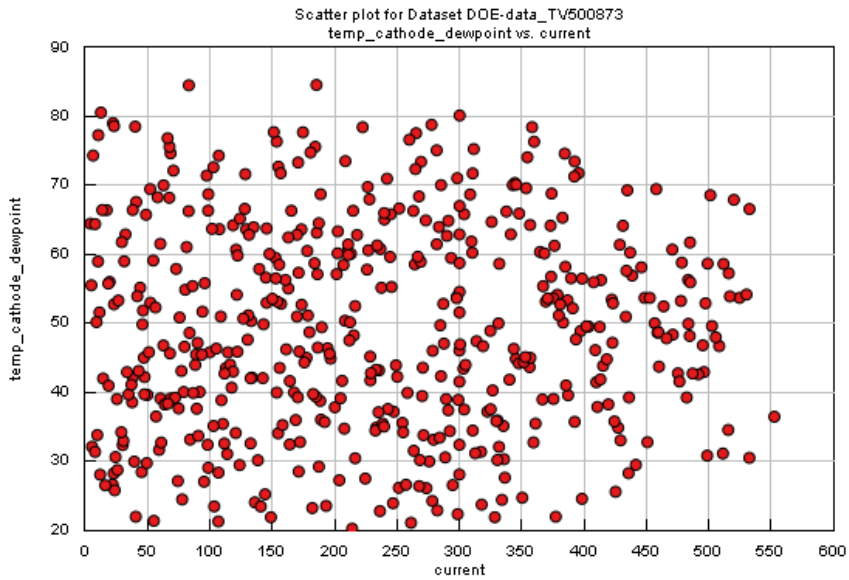
- H2 concentration(0.5 – 1)
- Anode Stoichiometry (lowest value: 1.2)
- Anode Dewpoint Temperature (20 °C – 85 °C)
- Anode Inlet Temperature (45 °C – 90 °C)
- Anode Inlet Pressure (0.2 barg – 2 barg)
- Cathode Stoichiometry (lowest value: 1.2)
- Cathode Dewpoint Temperature (20 °C – 85 °C)
- Cathode Inlet Temperature (45 °C – 90 °C)
- Cathode Inlet Pressure (0.14 barg – 1.9 barg)
- Coolant Inlet flow
(100 l/min – 300 l/min or 0.22 – 0.66 l/min/cell)
- Coolant Inlet Temperature (40 °C – 85 °C)



Variation of Input parameters:



Variation of Input parameters:



Modelling approach

The models have been created with the GT-DoE data processing module within the GT-Suite Multi-physics simulations software from Gamma Technologies

The type of the models are response surfaces which have been generated based on a Gauss / Kriging process

All options have been set to default values, all input parameters have been used without any weighting of sensitivity

The following response models have been created:

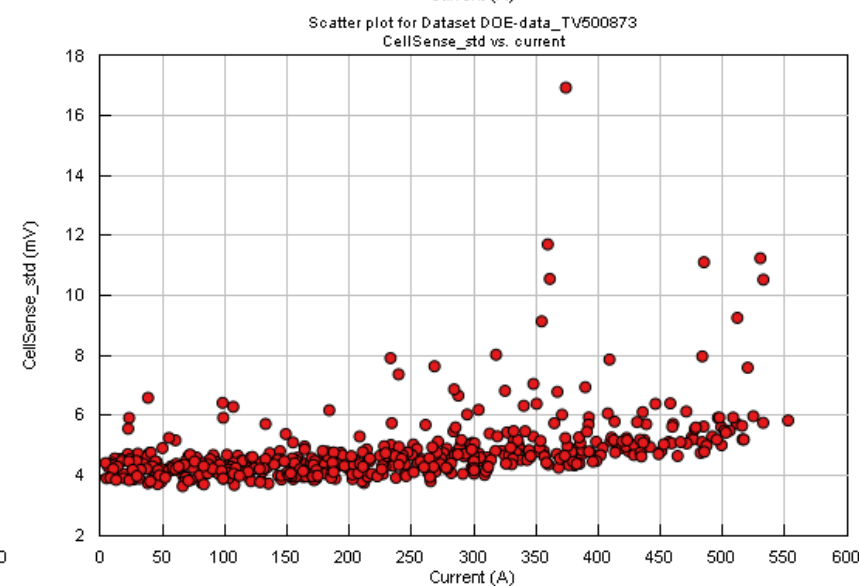
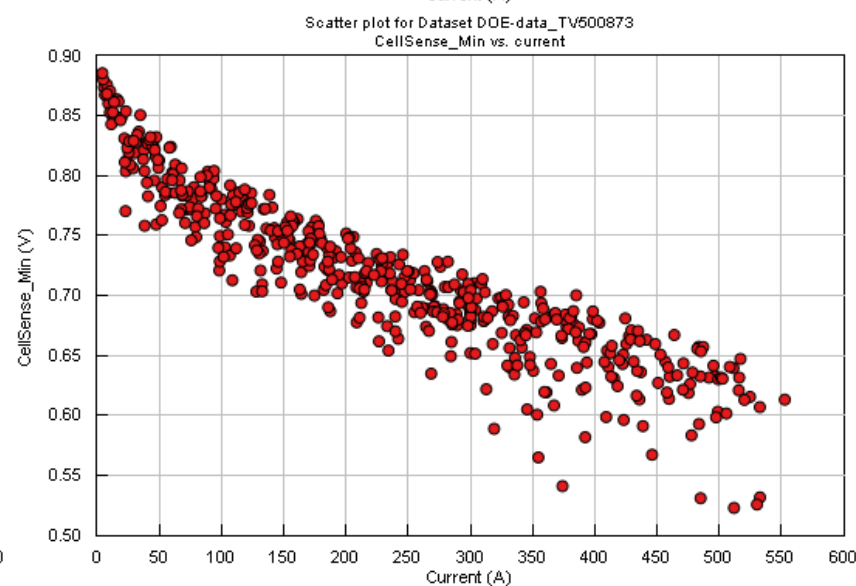
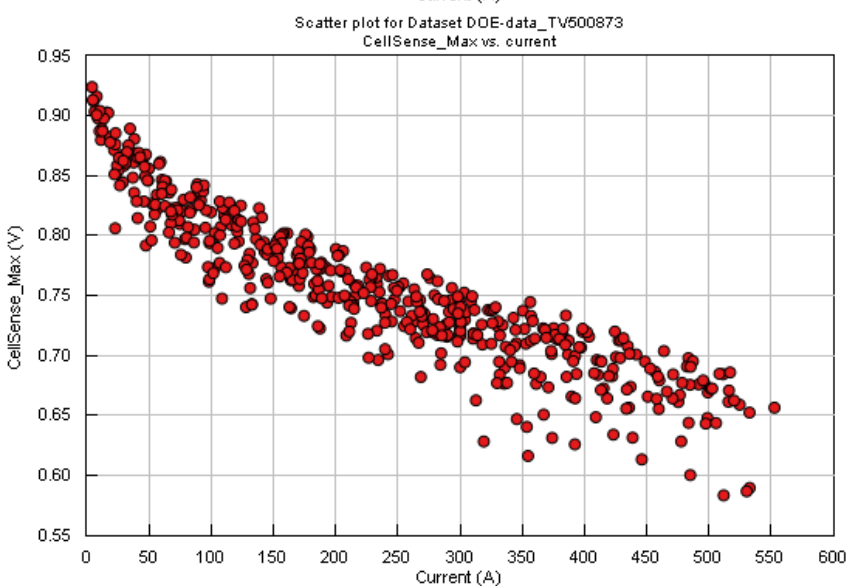
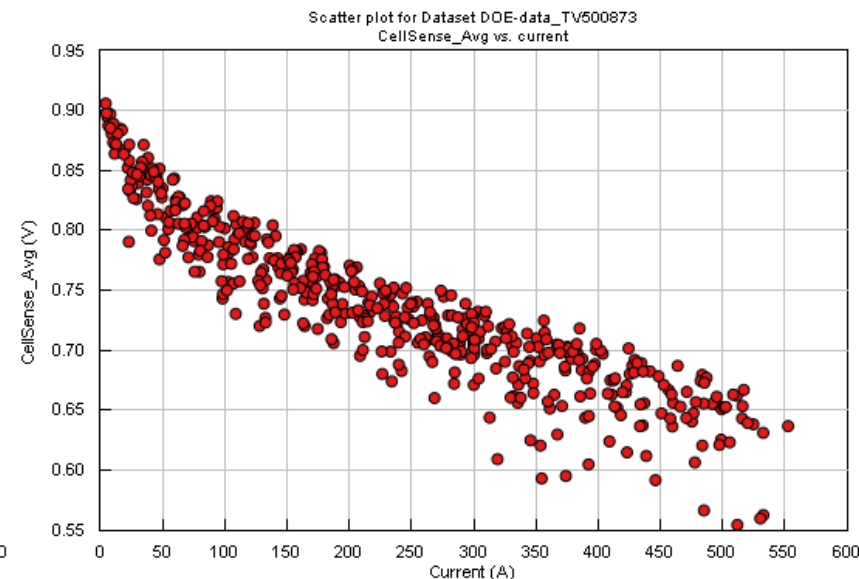
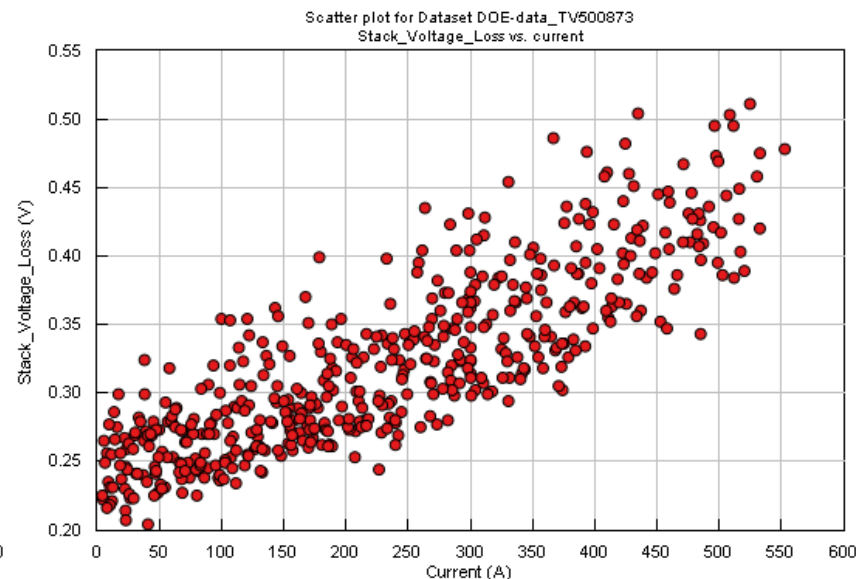
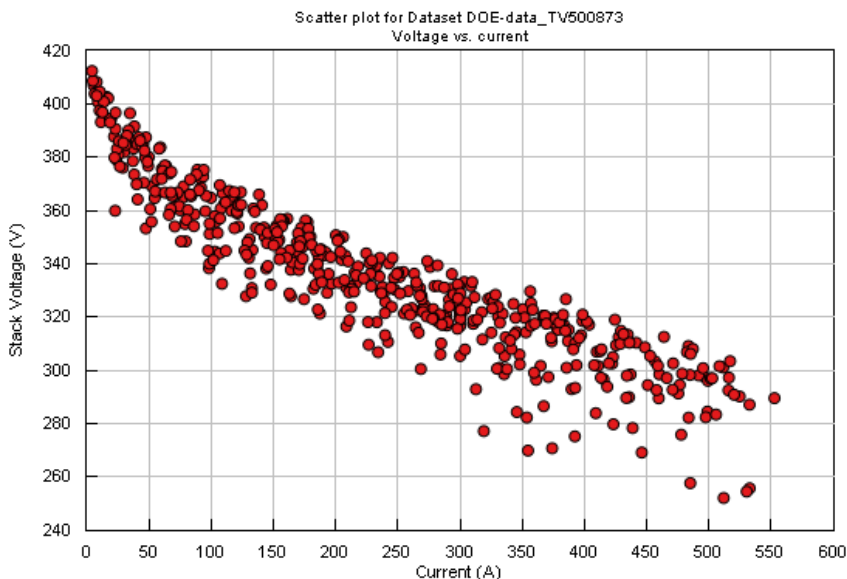
- Stack Voltage (V)
- Stack Voltage loss ($U_{\text{cell package}} - U_{\text{stack terminals}}$) (V)
- Average Cell Voltage (V)
- Max. Cell Voltage (V)
- Min Cell Voltage (V)
- Cell Voltage Standard Deviation (mV)
- Anode Pressure Drop (mbar)
- Cathode Pressure Drop (mbar)
- Coolant Pressure Drop (mbar)
- Anode Delta-T (° C)
- Cathode Delta-T (° C)
- Coolant Delta-T (° C)

IMPORTANT:

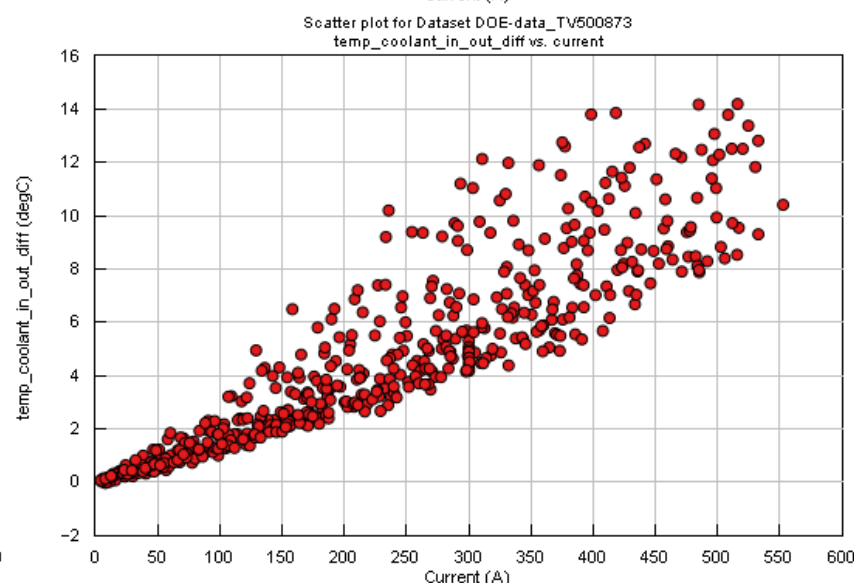
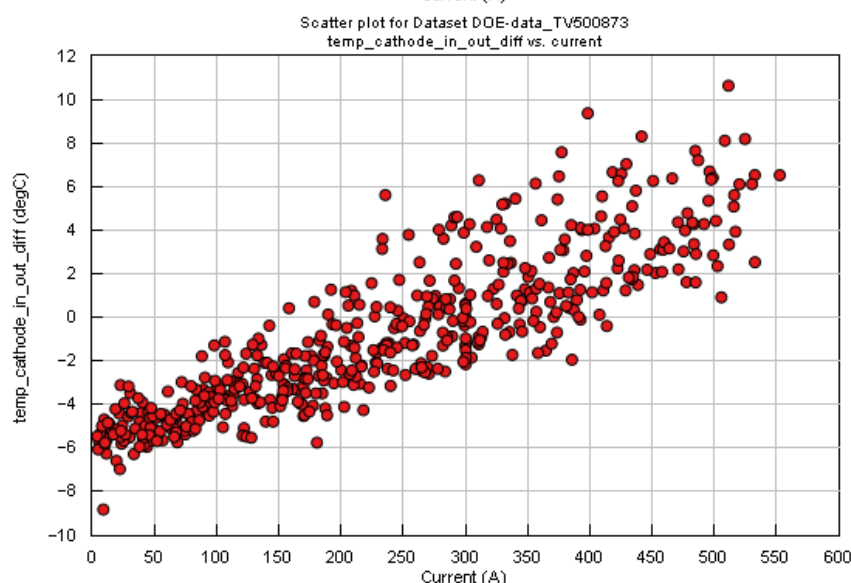
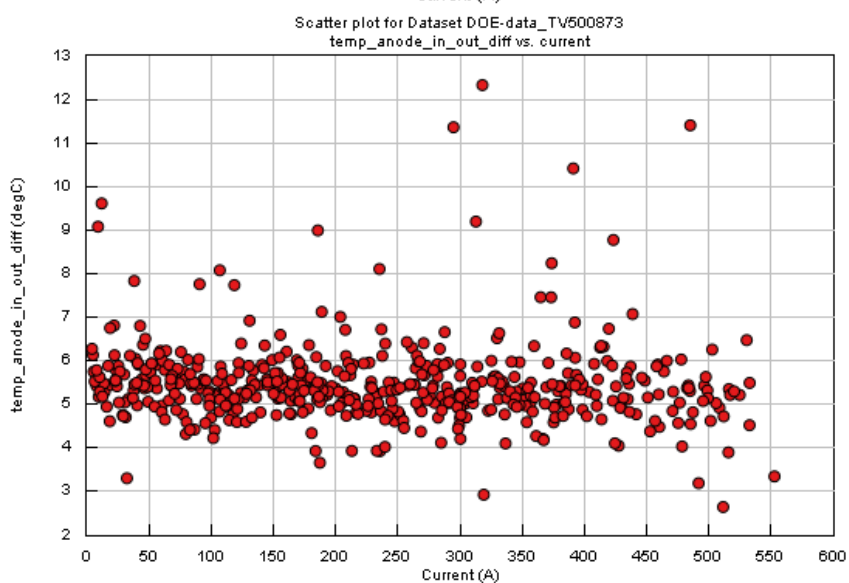
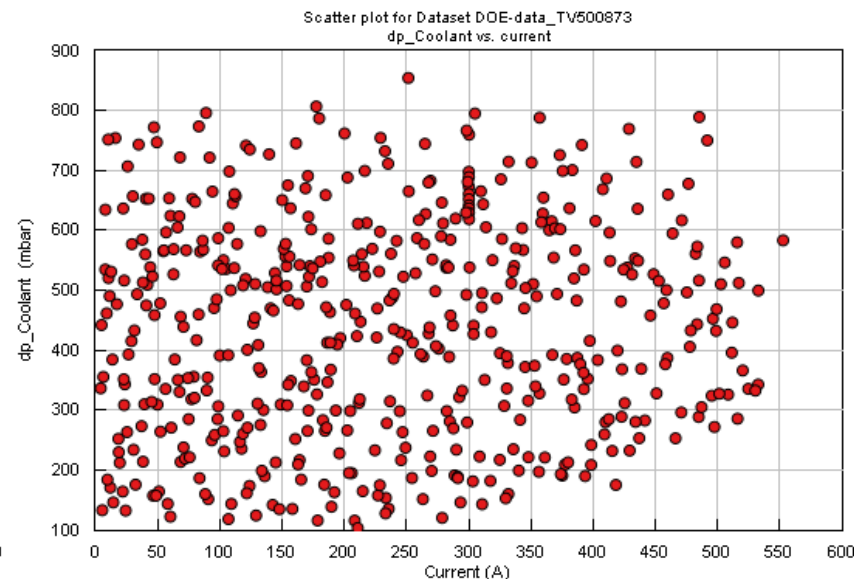
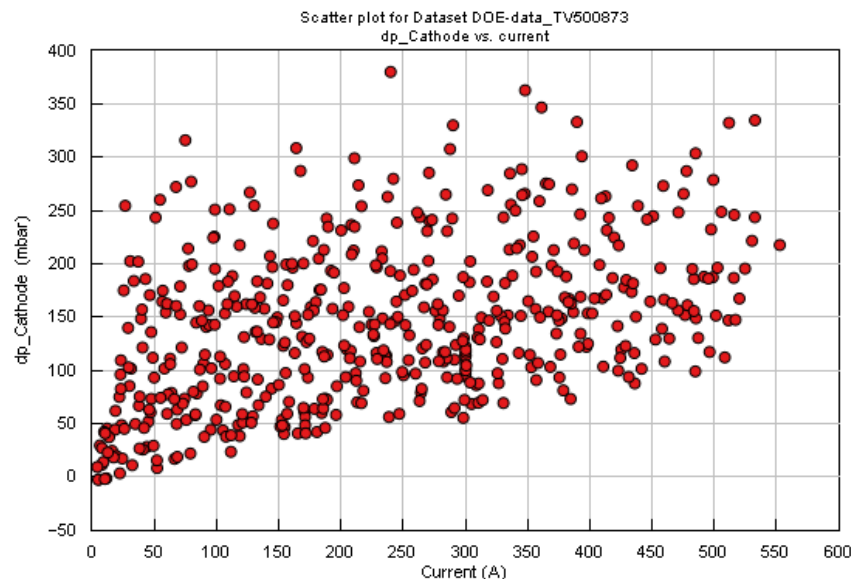
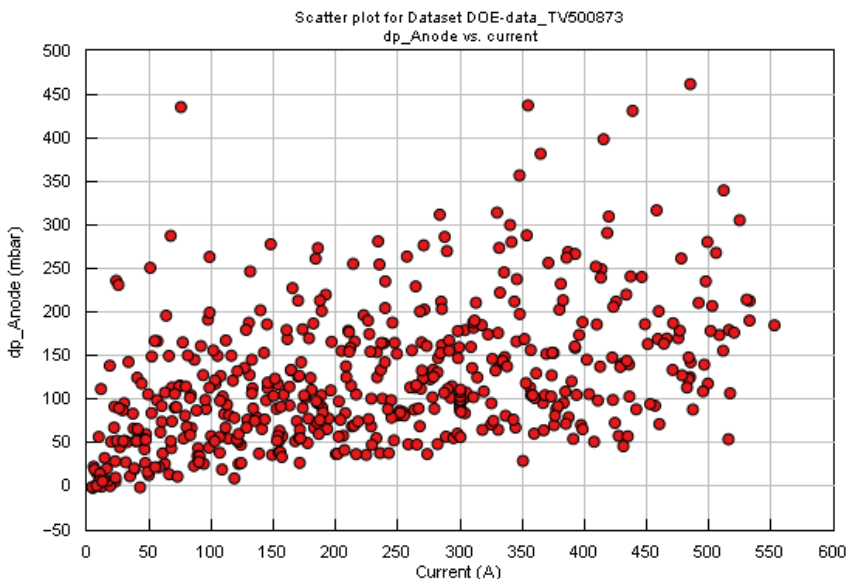
The model is only valid within the range of the tested data. Predictive results outside the tested area may be misleading!



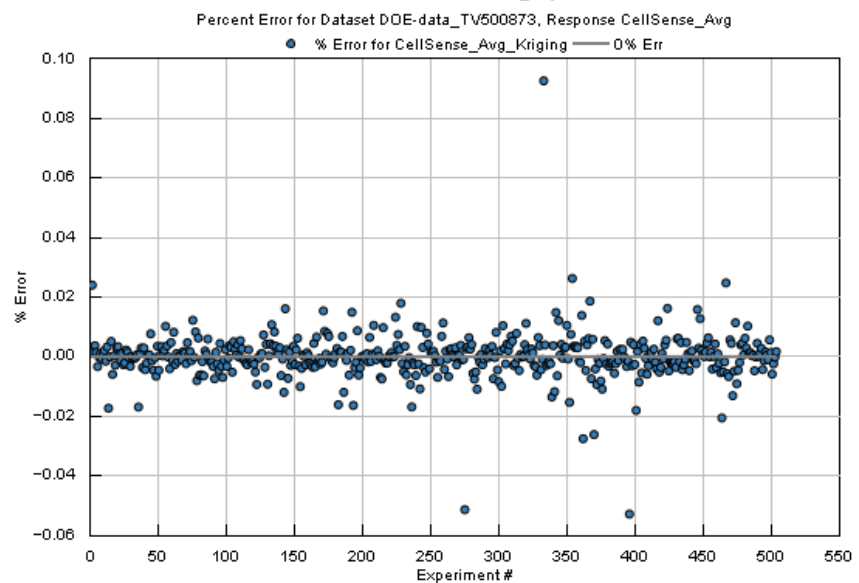
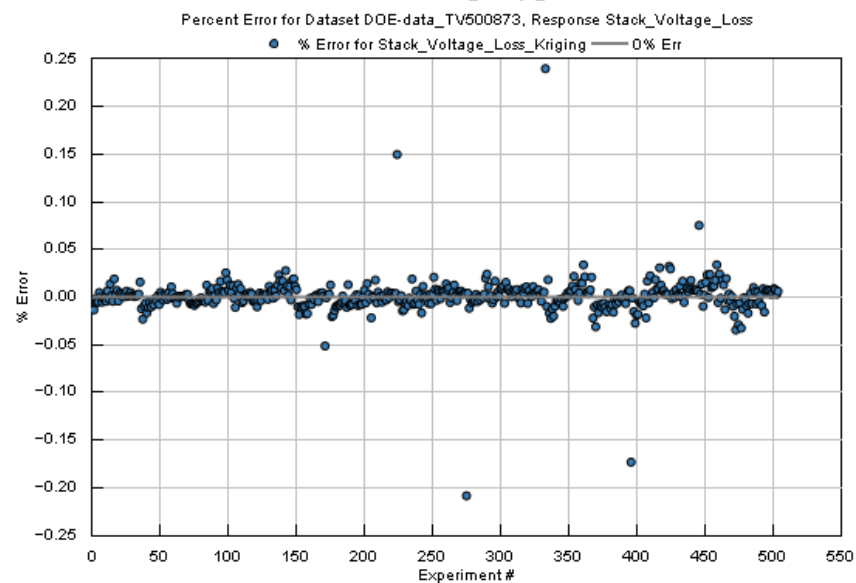
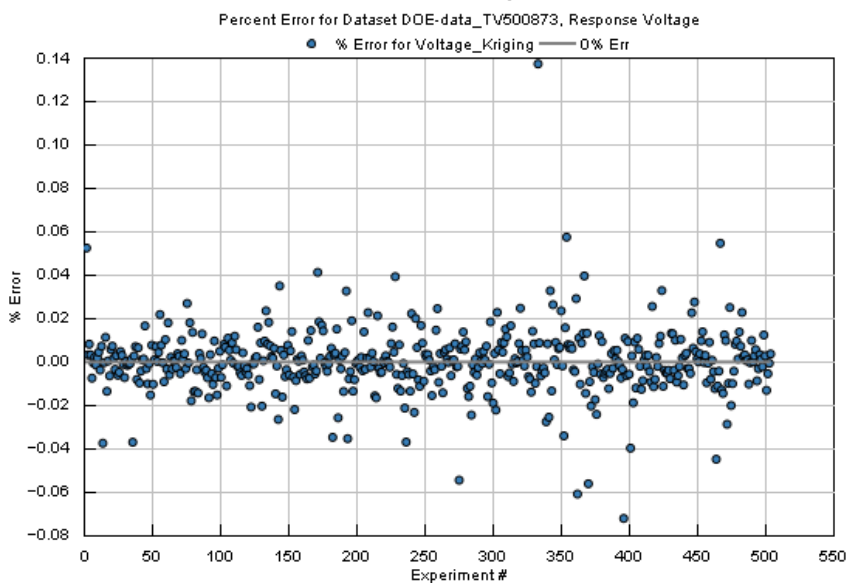
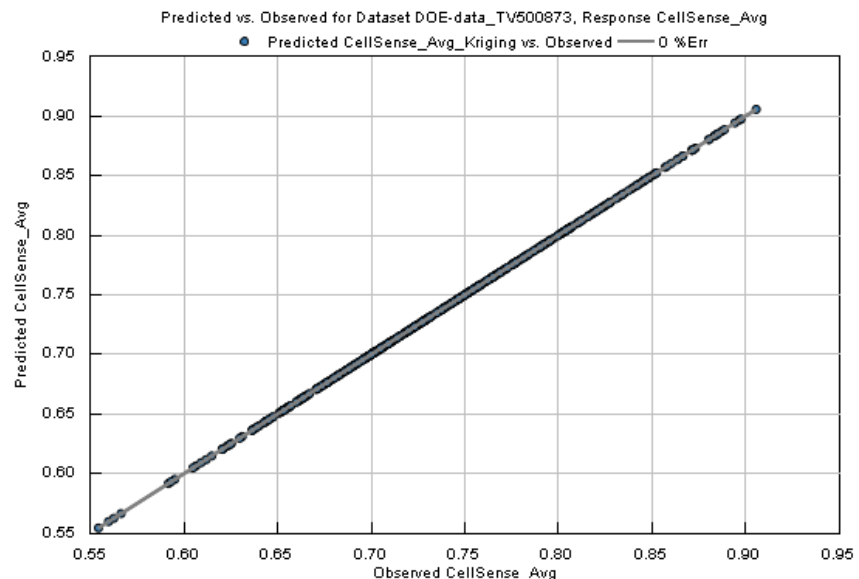
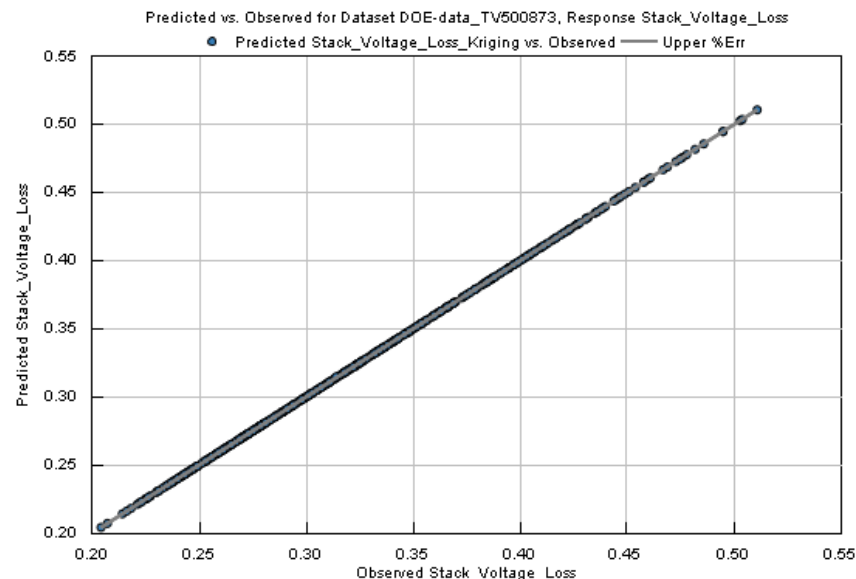
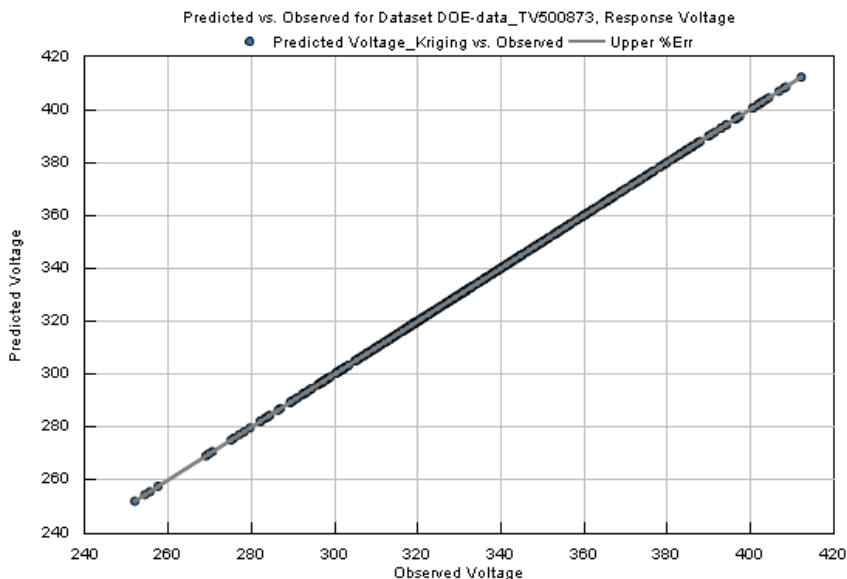
Test Data for Model validation



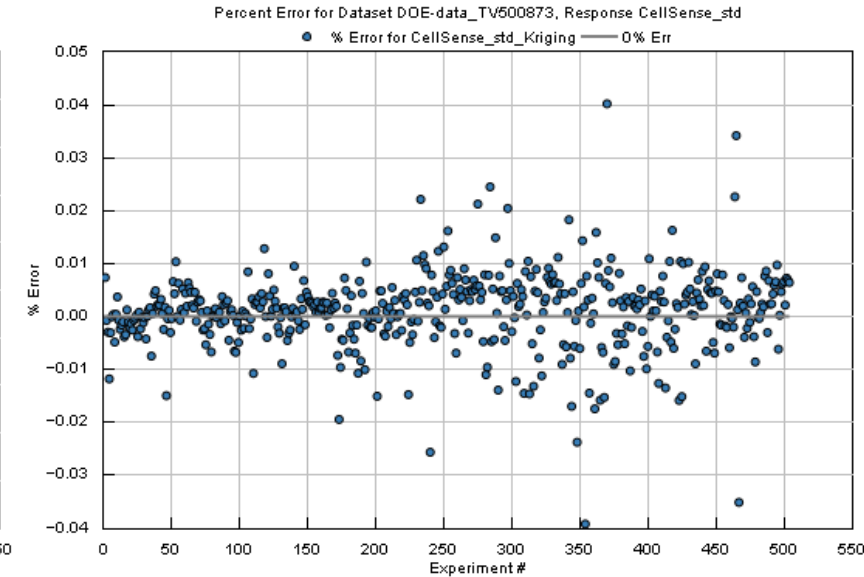
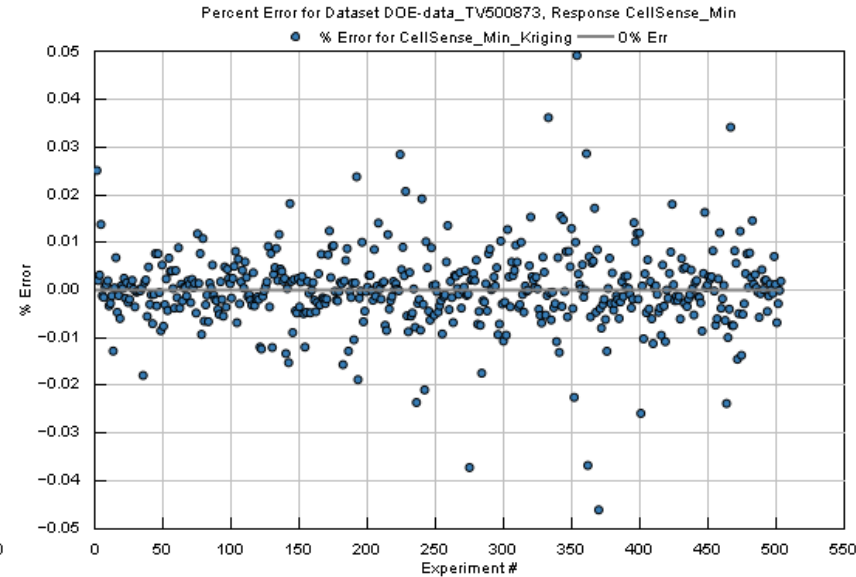
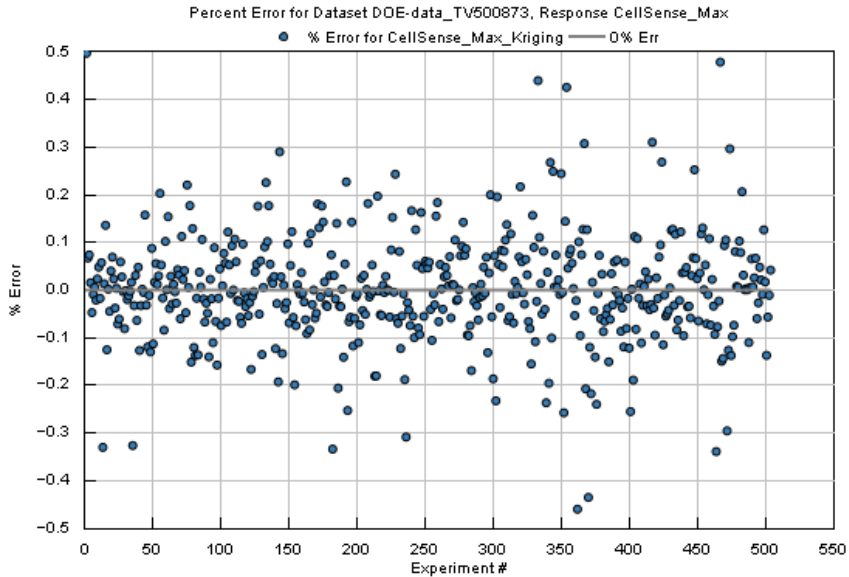
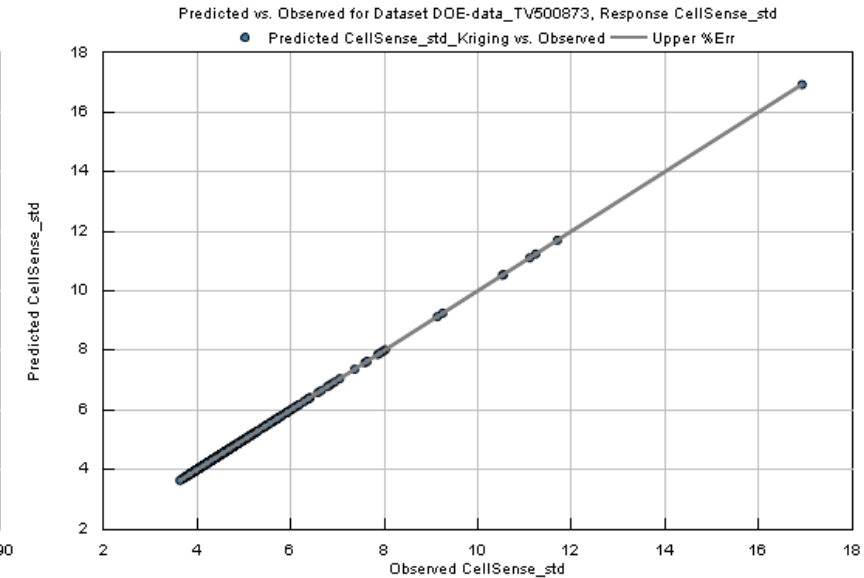
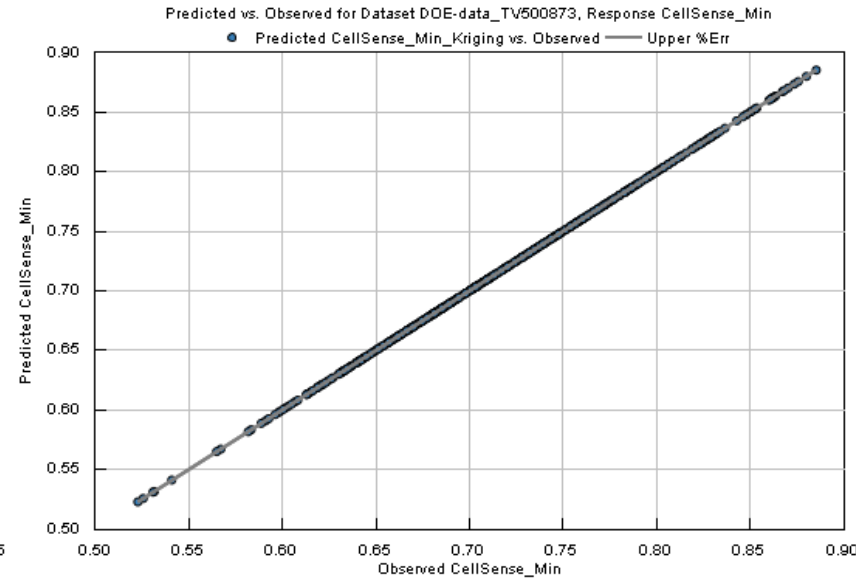
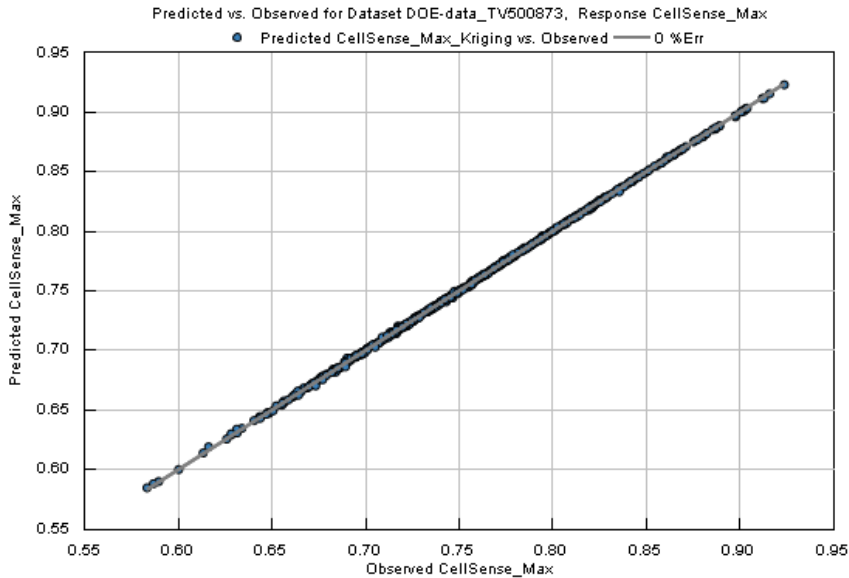
Test Data for Model validation



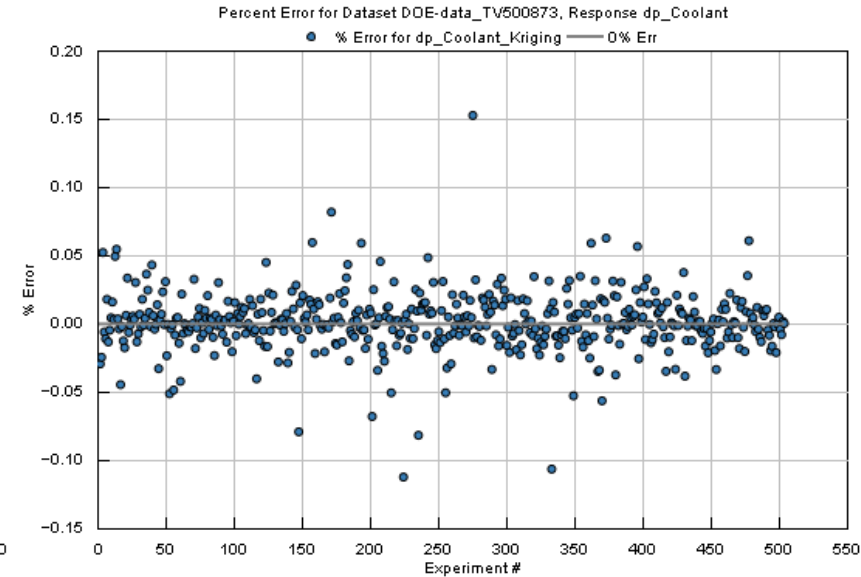
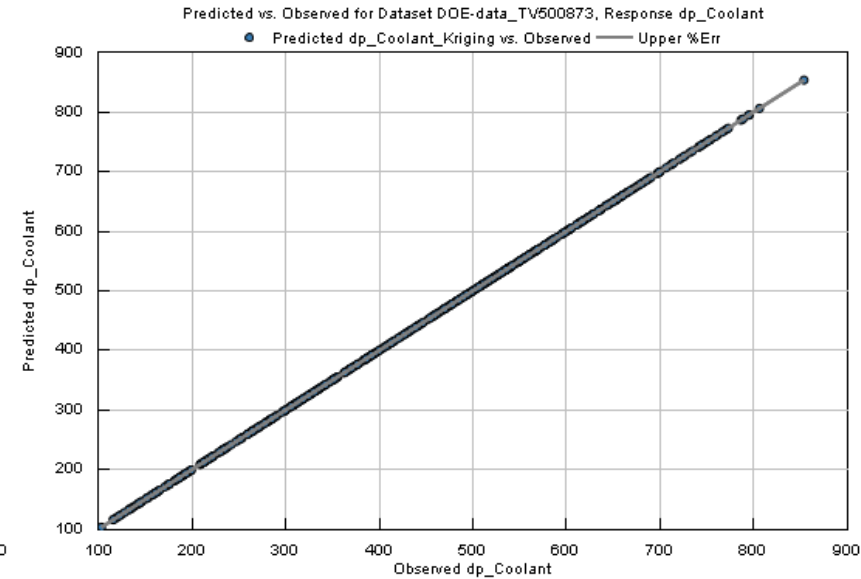
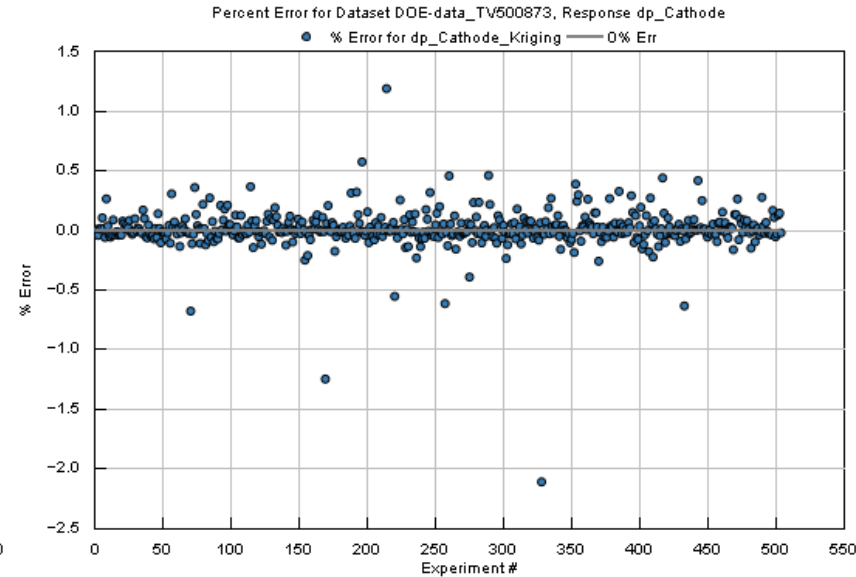
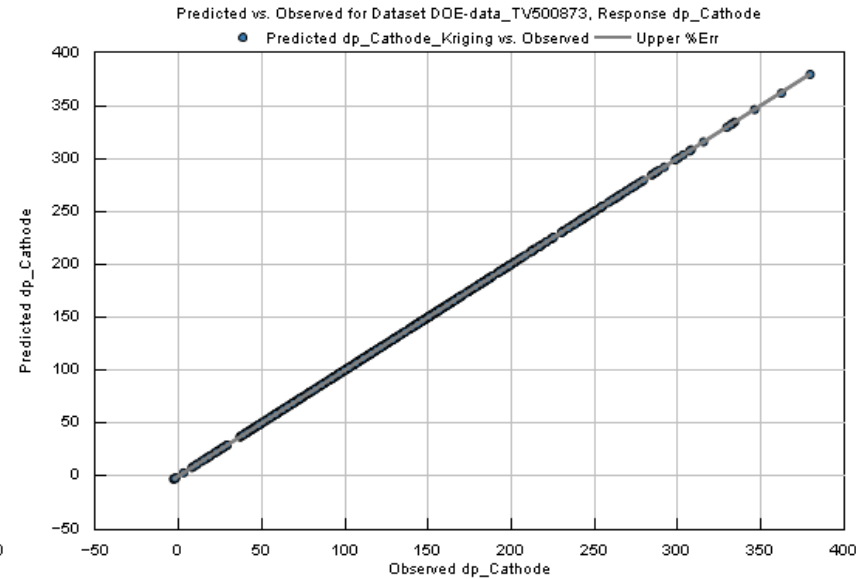
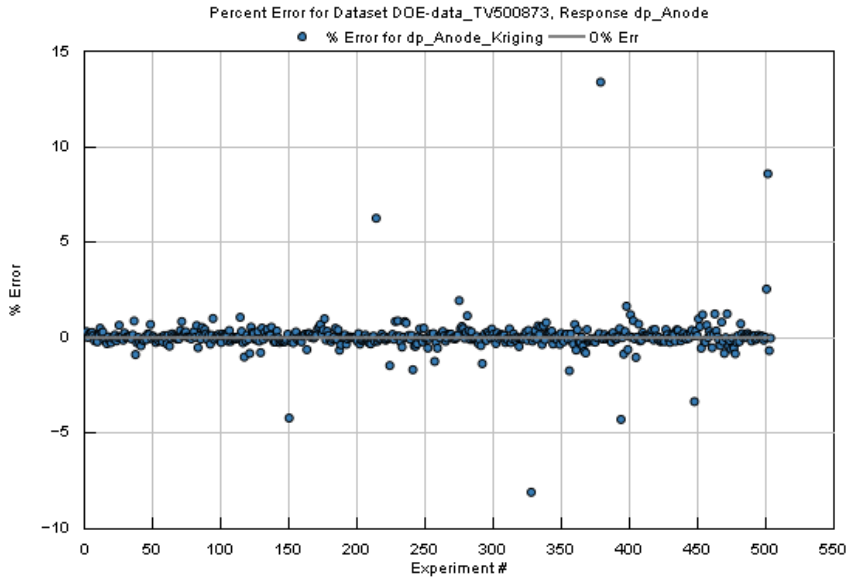
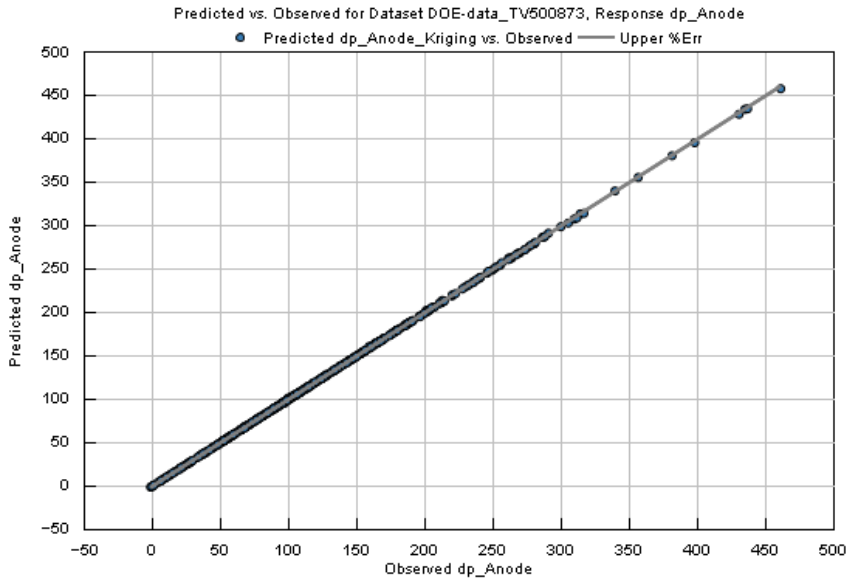
Model Analysis:



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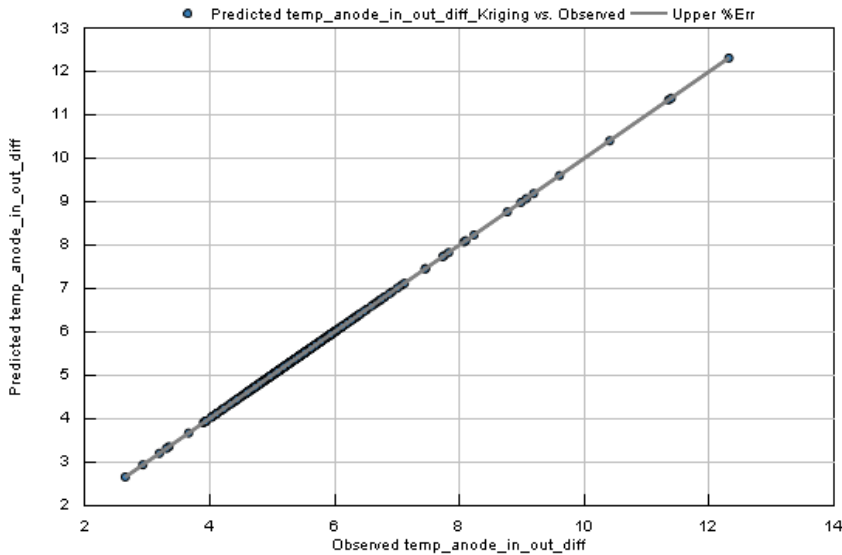


Model Analysis:

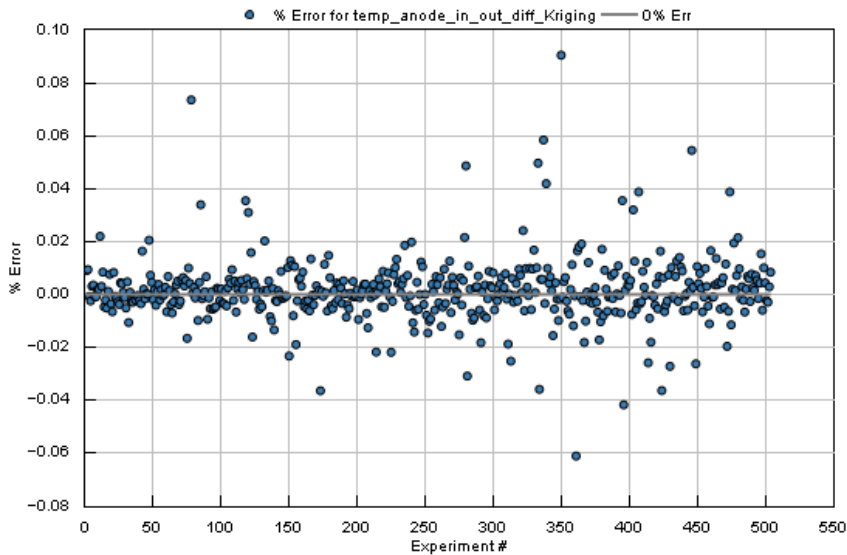


Model Analysis:

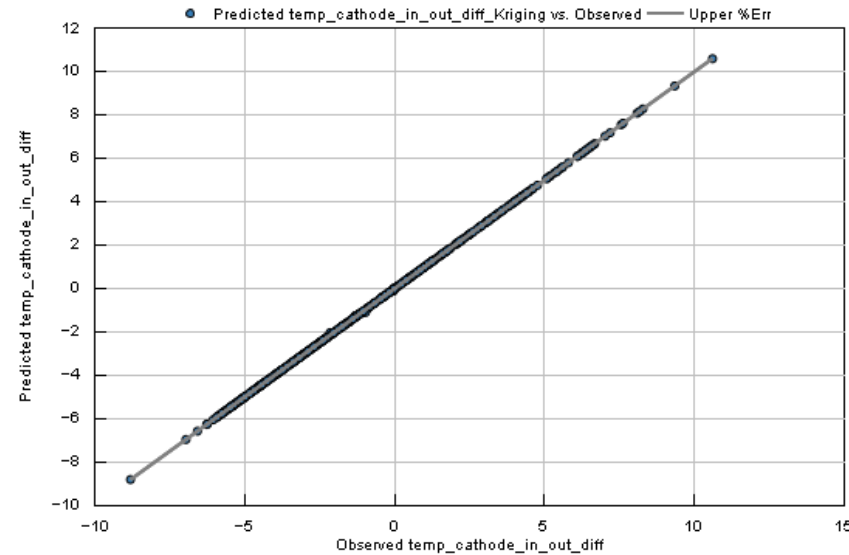
Predicted vs. Observed for Dataset DOE-data_TV500873, Response temp_anode_in_out_diff



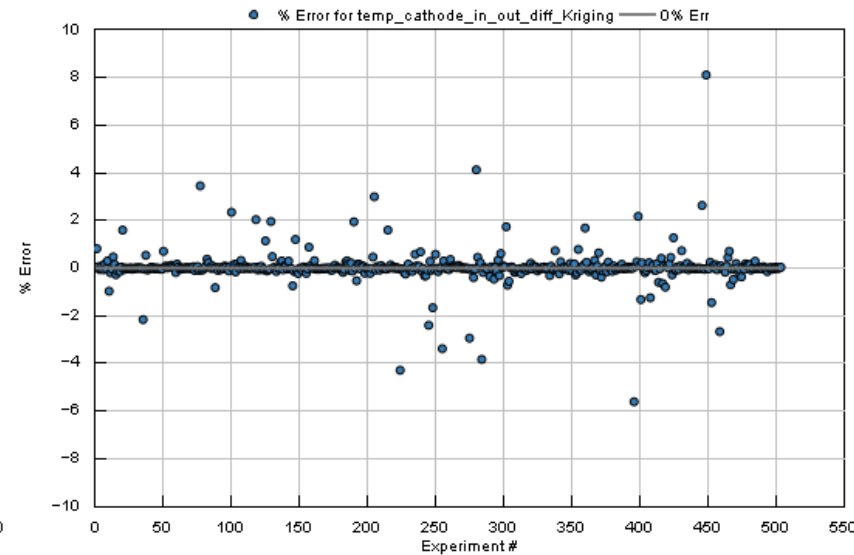
Percent Error for Dataset DOE-data_TV500873, Response temp_anode_in_out_diff



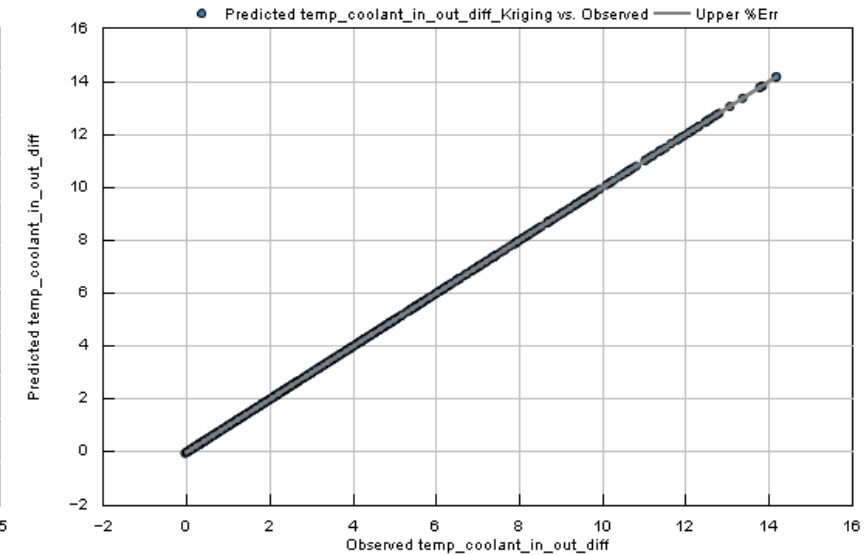
Predicted vs. Observed for Dataset DOE-data_TV500873, Response temp_cathode_in_out_diff



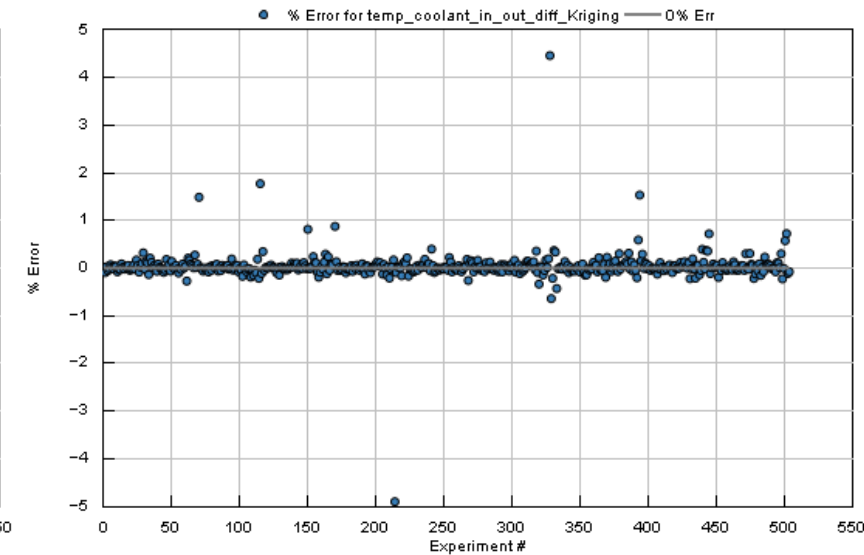
Percent Error for Dataset DOE-data_TV500873, Response temp_cathode_in_out_diff



Predicted vs. Observed for Dataset DOE-data_TV500873, Response temp_coolant_in_out_diff



Percent Error for Dataset DOE-data_TV500873, Response temp_coolant_in_out_diff



C-Code generation and export

The models are directly exported into C-Code and set up for usage in the GT-Suite simulation package

The structure of the code has not been analysed. Changes might be necessary for usage with other software

The code requests two external libraries:

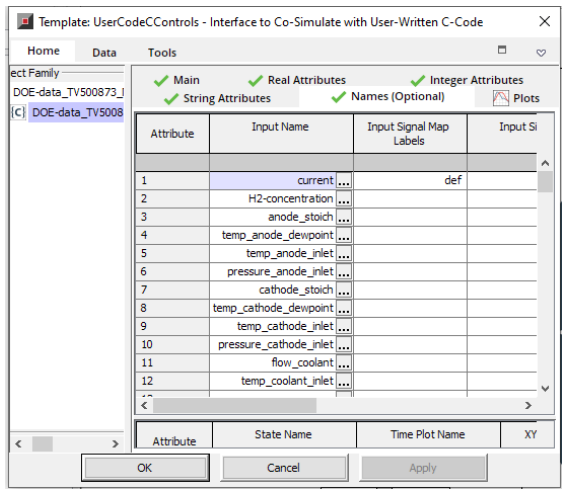
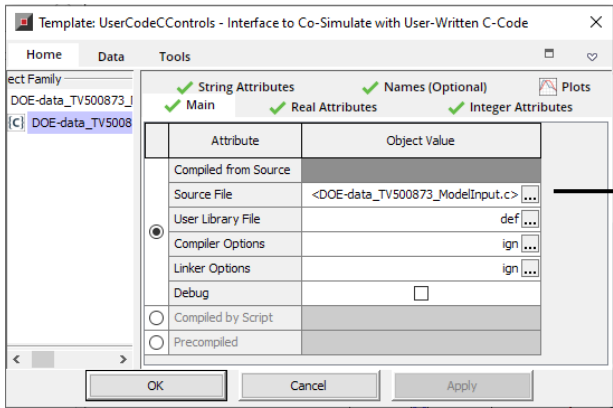
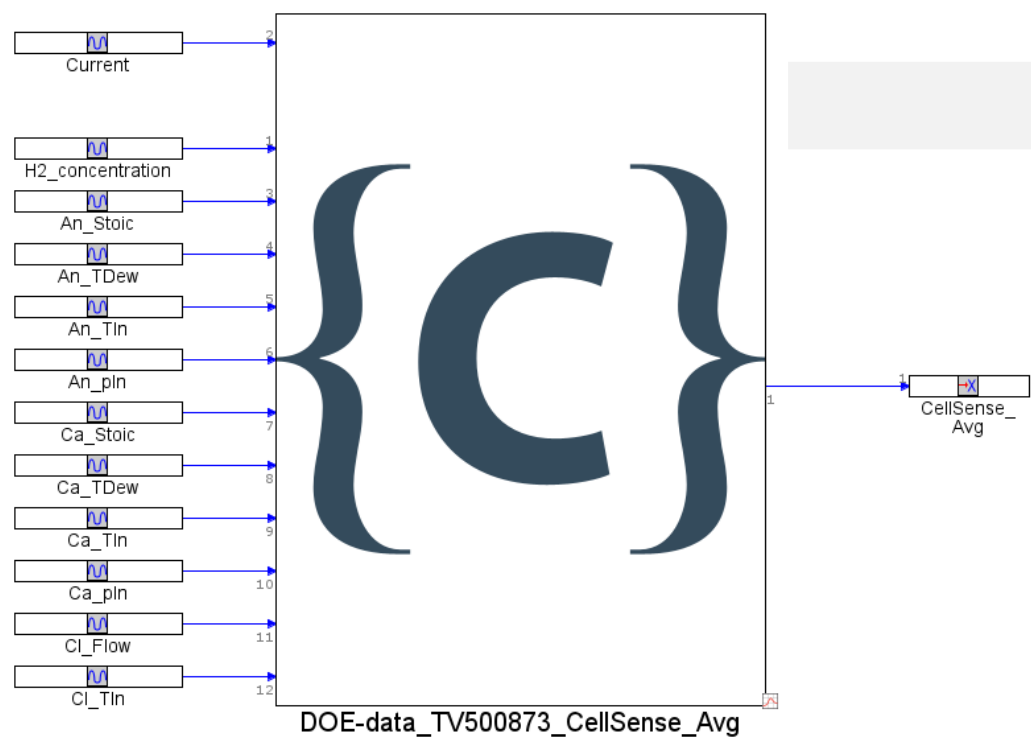
- math.h → supplied by the compiler
- uccontrols.h → supplied by GT-Suite, but not needed when used with other software tools

The order of the input data is the following:

Unit	Custom Label
A	current
	H2-concentration
	anode_stoich
C	temp_anode_dewpoint
C	temp_anode_inlet
bar	pressure_anode_inlet
	cathode_stoich
C	temp_cathode_dewpoint
C	temp_cathode_inlet
bar	pressure_cathode_inlet
L/min	flow_coolant
C	temp_coolant_inlet



Example for Integration in GT-Suite



Example for standalone usage

In order to run the c files standalone w/o GT-Suit some small modifications have to be done to the C-files. The function **get_response()** can then be called. One response is generated by C-file. The name of the C-file defines what the response is. See the example below:

```
#include "DOE-data_TV500873_ModelInput_Default_Voltage_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_temp_coolant_in_out_diff_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_temp_cathode_in_out_diff_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_temp_anode_in_out_diff_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_Stack_Voltage_Loss_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_dp_Coolant_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_dp_Cathode_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_dp_Anode_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_CellSense_std_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_CellSense_Min_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_CellSense_Max_Kriging_Casel_standalone.c"
//#include "DOE-data_TV500873_ModelInput_Default_CellSense_Avg_Kriging_Casel_standalone.c"

#include <stdio.h>
#include <stdlib.h>

double response;

/* Input order in factors vector
{"current", "H2-concentration", "anode_stoich", "temp_anode_dewpoint", "temp_anode_inlet",
"pressure_anode_inlet", "cathode_stoich", "temp_cathode_dewpoint", "temp_cathode_inlet", "pressure_cathode_inlet",
"flow_coolant", "temp_coolant_inlet"}
*/
double factors[12] = {450, 0.7, 1.5, 50, 61, 1, 2, 50, 70, 1.4, 250, 70};

int main()
{
    FILE *fptr;
    fptr = fopen("response", "w");
    if(fptr == NULL)
    {
        printf("Error!");
        exit(1);
    }

    get_response(factors, &response);
    fprintf(fptr, "%f\n", response);

    fclose(fptr);
}
```



Delivery

- 12x C-files that can be used standalone w/o GT-Suit
- **main.c**: An example file that is using the standalone files

