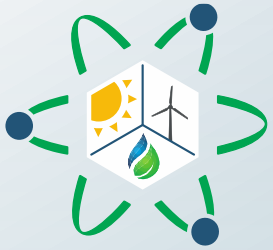


IES
Integrated Energy Systems

Training on Feasible Actuator Range Modifier (FARM)

IES Tools Virtual Workshop:
Capability Overview and Training

March 18, 2022

Haoyu Wang, Roberto Ponciroli, Richard Vilim

Argonne National Laboratory

haoyuwang@anl.gov

Table of Content

- FARM capability overview
- Software installation
- Input creation and running the code
- Output analysis
- Future Directions

1. FARM capability overview

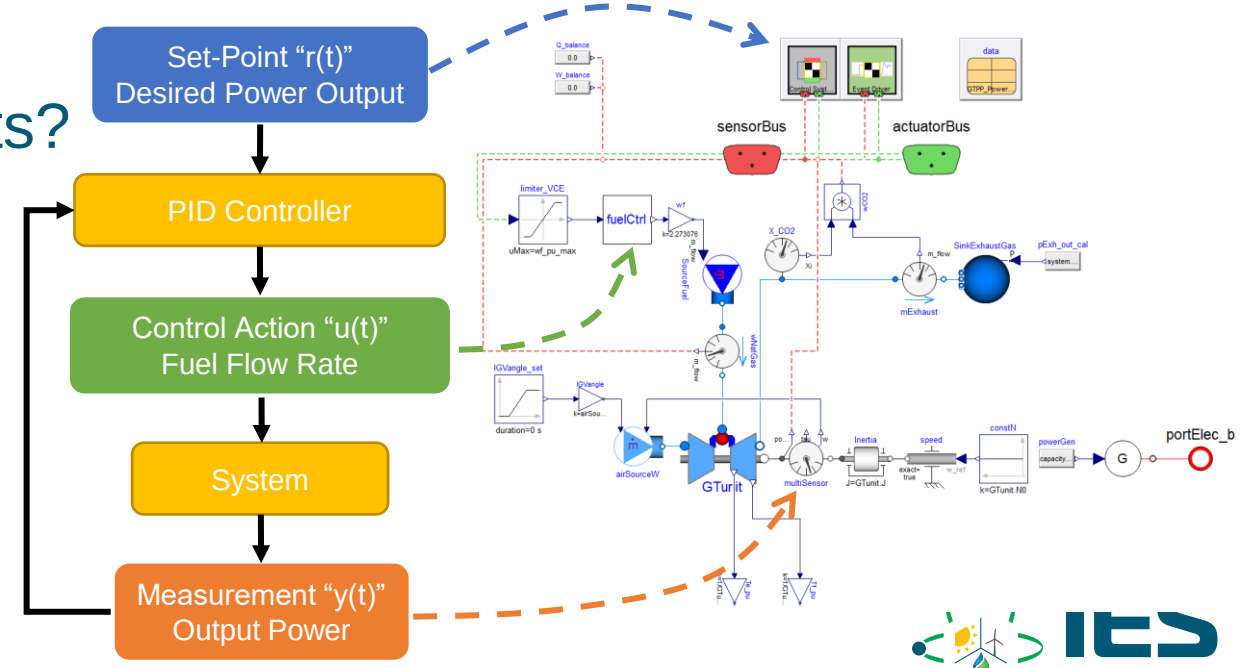
- FARM: Feasible Actuator Range Modifier
  - FARM is a RAVEN plugin to meet the supervisory control needs.
  - FARM helps validate the issued actuator value, to meet both
    - Explicit constraints, and
    - Implicit constraints.

- Q1: What are these constraints?

  Let's use a Gas Turbine to explain:

  Explicit constraints:
  - Power output to grid;
  - Power ramp rate, etc.

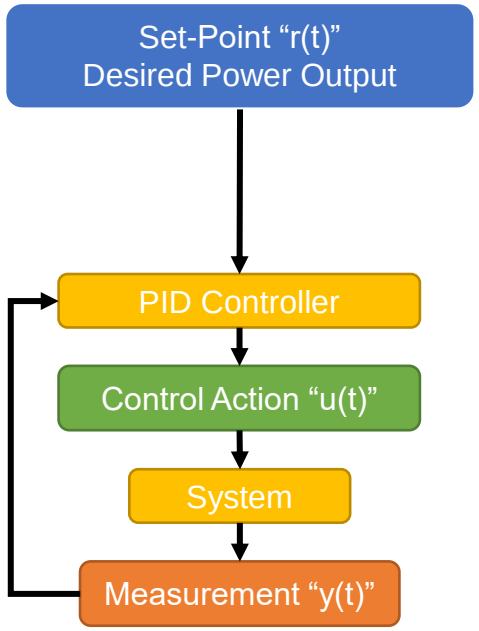
  Implicit constraints:
  - Firing Temperature, etc.



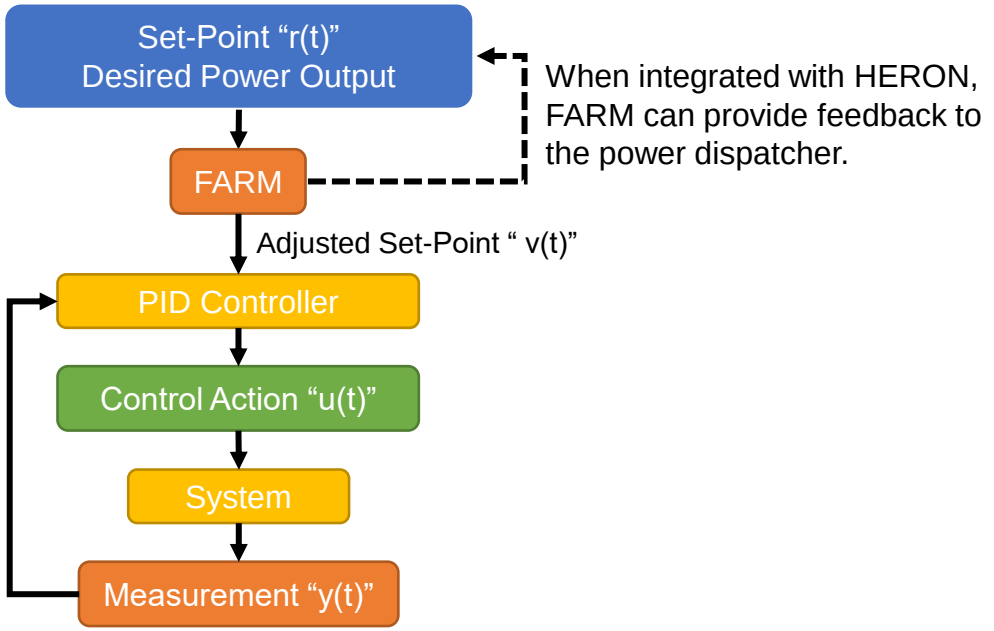
Integrated Energy Systems

1. FARM capability overview

- FARM: Feasible Actuator Range Modifier
  - Q2: Where is FARM in the feedback loop control?



Without FARM

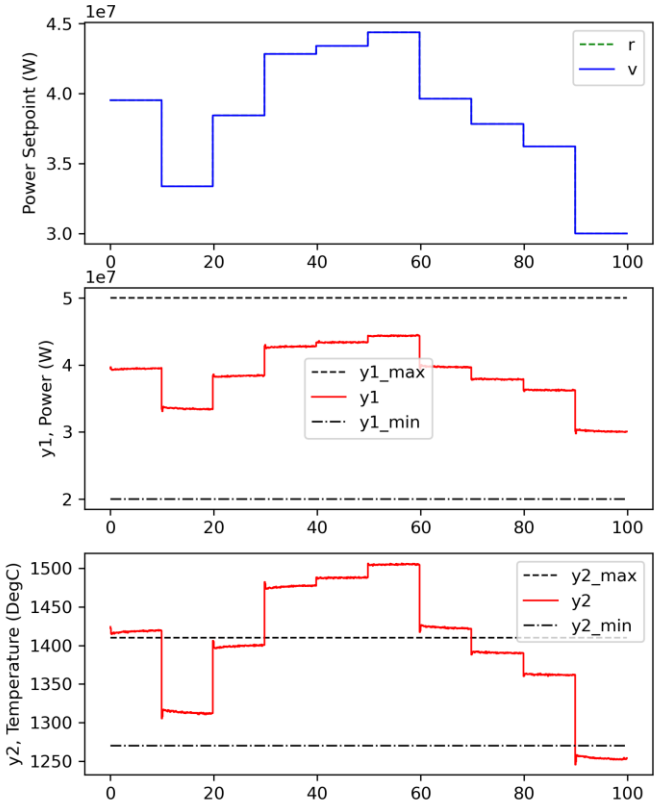


With FARM

IES
Integrated Energy Systems

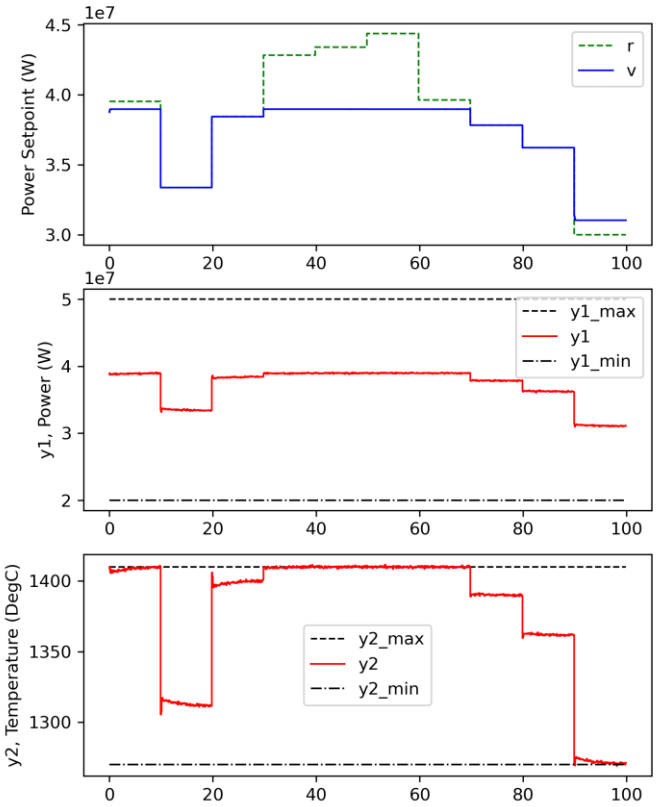
1. FARM capability overview

- FARM: Feasible Actuator Range Modifier
  - Q3: What's the effects of FARM?



Without FARM:
- System run on original power setpoint
- Implicit constraints were violated (Firing temperature)

With FARM:
- Power setpoint was adjusted
- Implicit constraints were met (Firing temperature)



Integrated Energy Systems

2. Software installation

- FARM is an open-source software
  - https://github.com/Argonne-National-Laboratory/FARM
  - In order to run FARM, RAVEN is a pre-requisite.
- FARM installation consists of 2 steps:
  - Step 1: Download FARM source code using git

```
haoyuwang@p075722 MINGW64 /d/GitProjects/training
$ git clone https://github.com/Argonne-National-Laboratory/FARM.git
```

  - Step 2: Register FARM plugin in RAVEN

```
haoyuwang@p075722 MINGW64 /d/GitProjects/training/raven (devel)
$ ./scripts/install_plugins.py -s /d/GitProjects/training/FARM/
```

IES
Integrated Energy Systems

3. Input creation and running the code

- FARM uses XML file as input
  - One example is in

    FARM / training031822 / FARM_para_SES.xml
  - We will focus on some key entries.

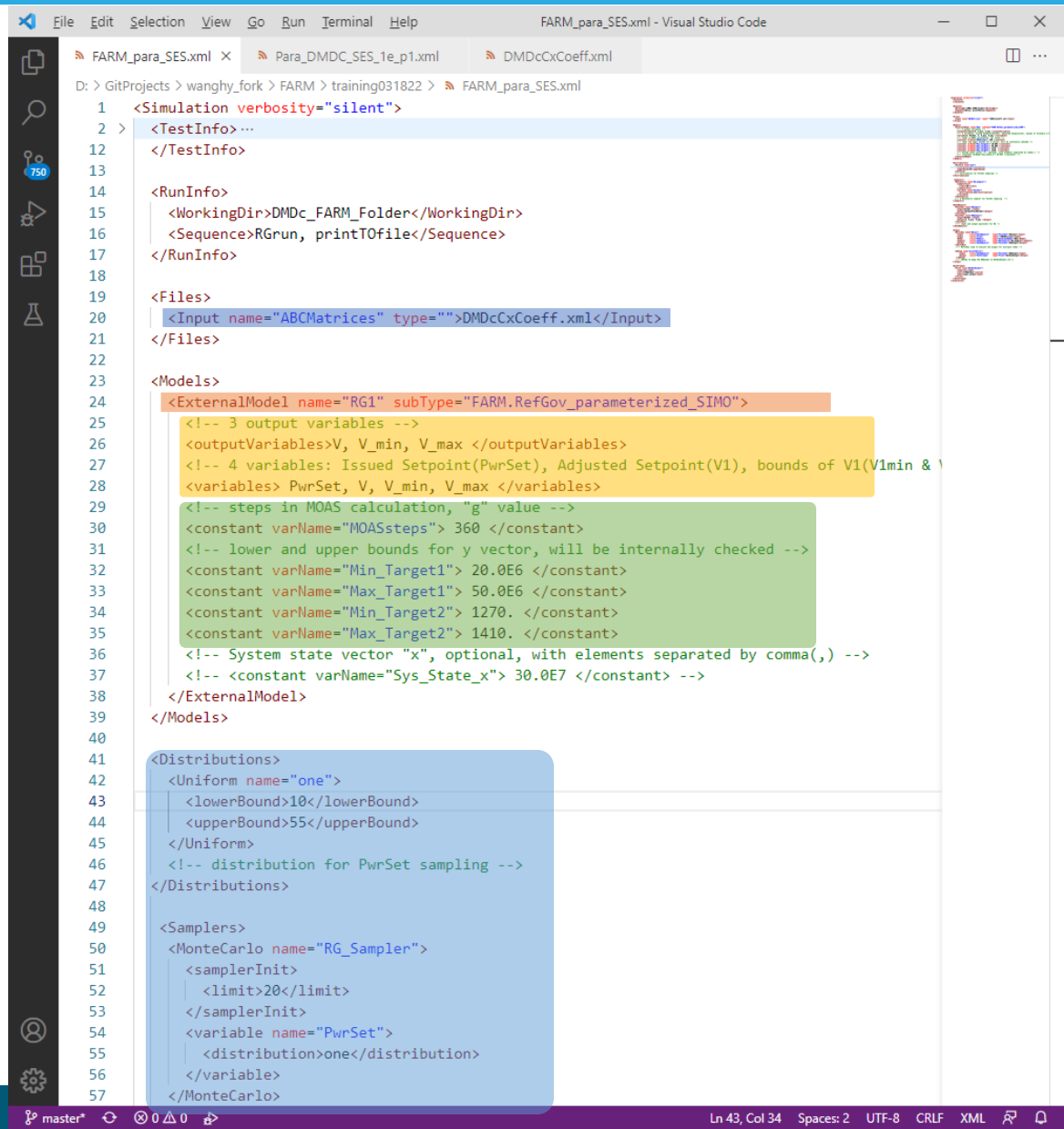
3.1. An XML file containing the state-space representation matrices;

3.2. FARM external model name;

3.3. Input and output variables for FARM;

3.4. Prediction time horizon, and operational constraints;

3.5. Random number generator for input variables creation



3. Input creation and running the code

- 3.1. An XML file containing the state-space representation matrices
  - A state-space matrix set [A,B,C,D] is required to describe the system.
  - Can be generated through RAVEN DMDc*.
  - One example is available at

    FARM / training031822 / Para_DMDC_SES_1e_p1.xml

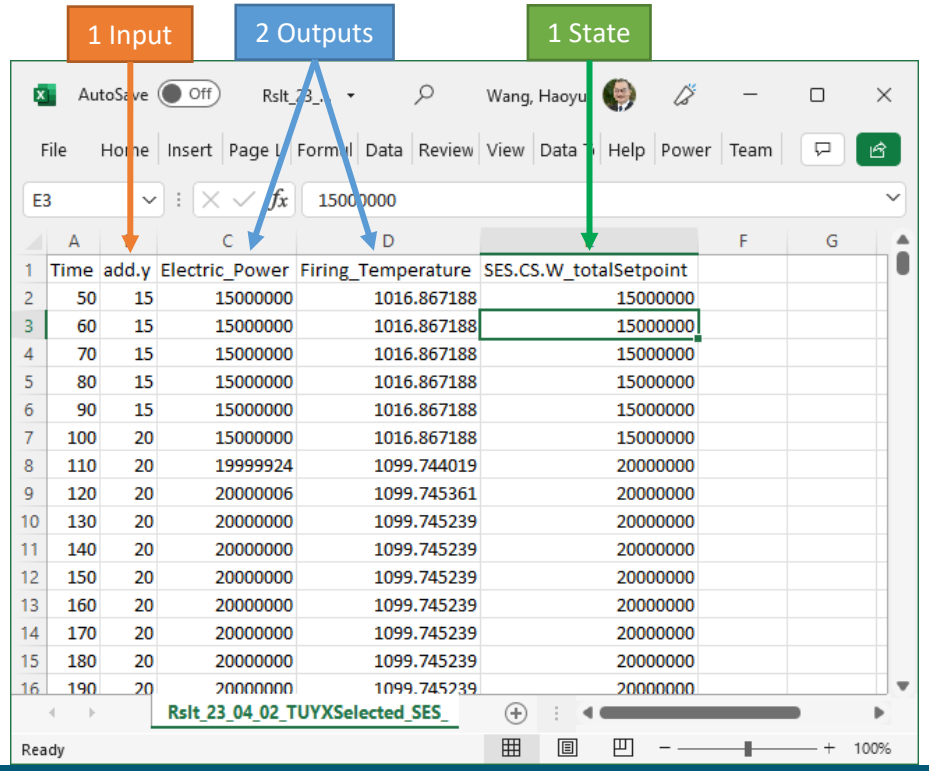
Input $v \in \mathbb{R}^m$

State-space model

$$x(k+1) = Ax(k) + Bv(k)$$
$$y(k) = Cx(k) + Dv(k)$$

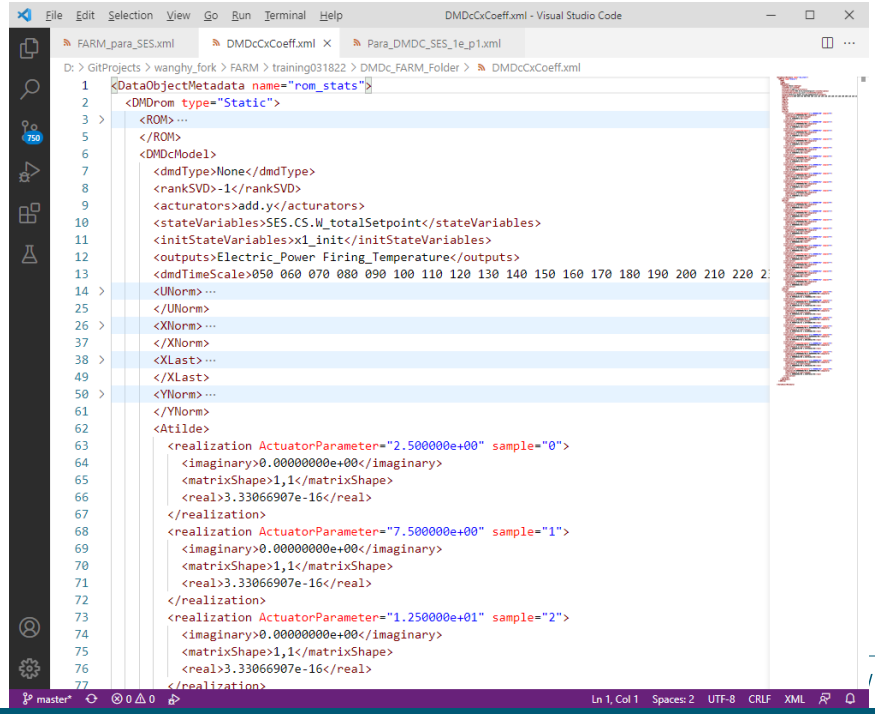
Output $y \in \mathbb{R}^p$

State $x \in \mathbb{R}^n$



	A	C	D	F	G
1	Time	add.y	Electric_Power	Firing_Temperature	SES.CS.W_totalSetpoint
2	50	15	15000000	1016.867188	15000000
3	60	15	15000000	1016.867188	15000000
4	70	15	15000000	1016.867188	15000000
5	80	15	15000000	1016.867188	15000000
6	90	15	15000000	1016.867188	15000000
7	100	20	15000000	1016.867188	15000000
8	110	20	19999924	1099.744019	20000000
9	120	20	20000006	1099.745361	20000000
10	130	20	20000000	1099.745239	20000000
11	140	20	20000000	1099.745239	20000000
12	150	20	20000000	1099.745239	20000000
13	160	20	20000000	1099.745239	20000000
14	170	20	20000000	1099.745239	20000000
15	180	20	20000000	1099.745239	20000000
16	190	20	20000000	1099.745239	20000000

RAVEN DMDc



*For more details, please refer to RAVEN user manual Section 15.3.11, DMDc

3. Input creation and running the code

- 3.2. FARM external model name;
  - To use FARM, “FARM.RefGov_parameterized_SIMO” need to be specified as the external model.
  - Source code* is available at

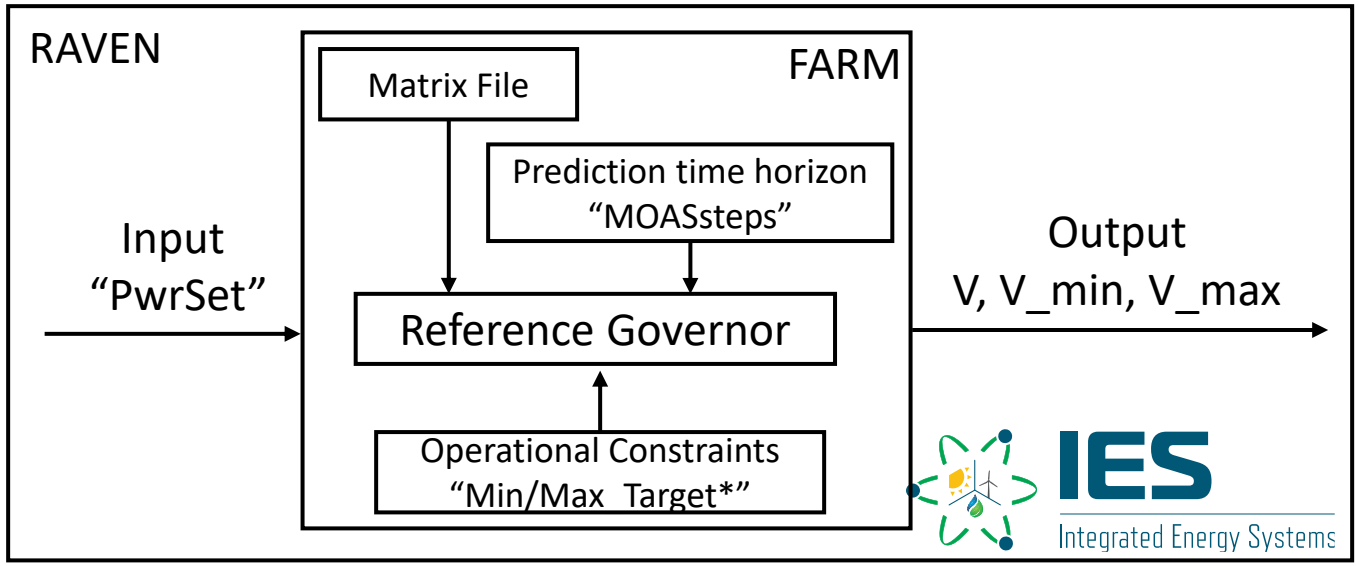
    FARM / src / RefGov_parameterized_SIMO.py
- 3.3. Input and output variables for FARM;
  - Input: “PwrSet”, the power setpoint before any adjustment;
    - “PwrSet” should share the same unit as the actuator signal in DMDc training data;
  - Output: “V”, adjusted power setpoint; “V_min” and “V_max”, the min & max allowed V value.
- 3.4. “MOASsteps” for the prediction time horizon;
  - $\text{MOASsteps} = \frac{\text{Time Horizon}}{\text{Matrices interval}}$
  - Example:
    - To predict the response for 1 hour;
    - Matrices are in 10s interval
    - MOASsteps = 3600s / 10s = 360.

IES Integrated Energy Systems

*For more details, please refer to FARM user manual Section 1.1

3. Input creation and running the code

- 3.4. “Min/Max_Target*” for the operational constraints;
  - “Min_Target_i” and “Max_Target_i” defines the bounds for the i^{th} system output y_i.
  - Example:
  - In training data, y_1 is Electric Power (W), y_2 is Firing Temperature (℃)
  - Then in the FARM input file,
    - Min_Target_1=20.0E6, Max_Target_1=50.0E6 → 20.0MW < Electric Power < 50.0MW
    - Min_Target_2=1270.0, Max_Target_2=1410.0 → 1270℃ < Firing Temperature < 1410℃
  - Mind the units.
- The structure of entire FARM Plugin:



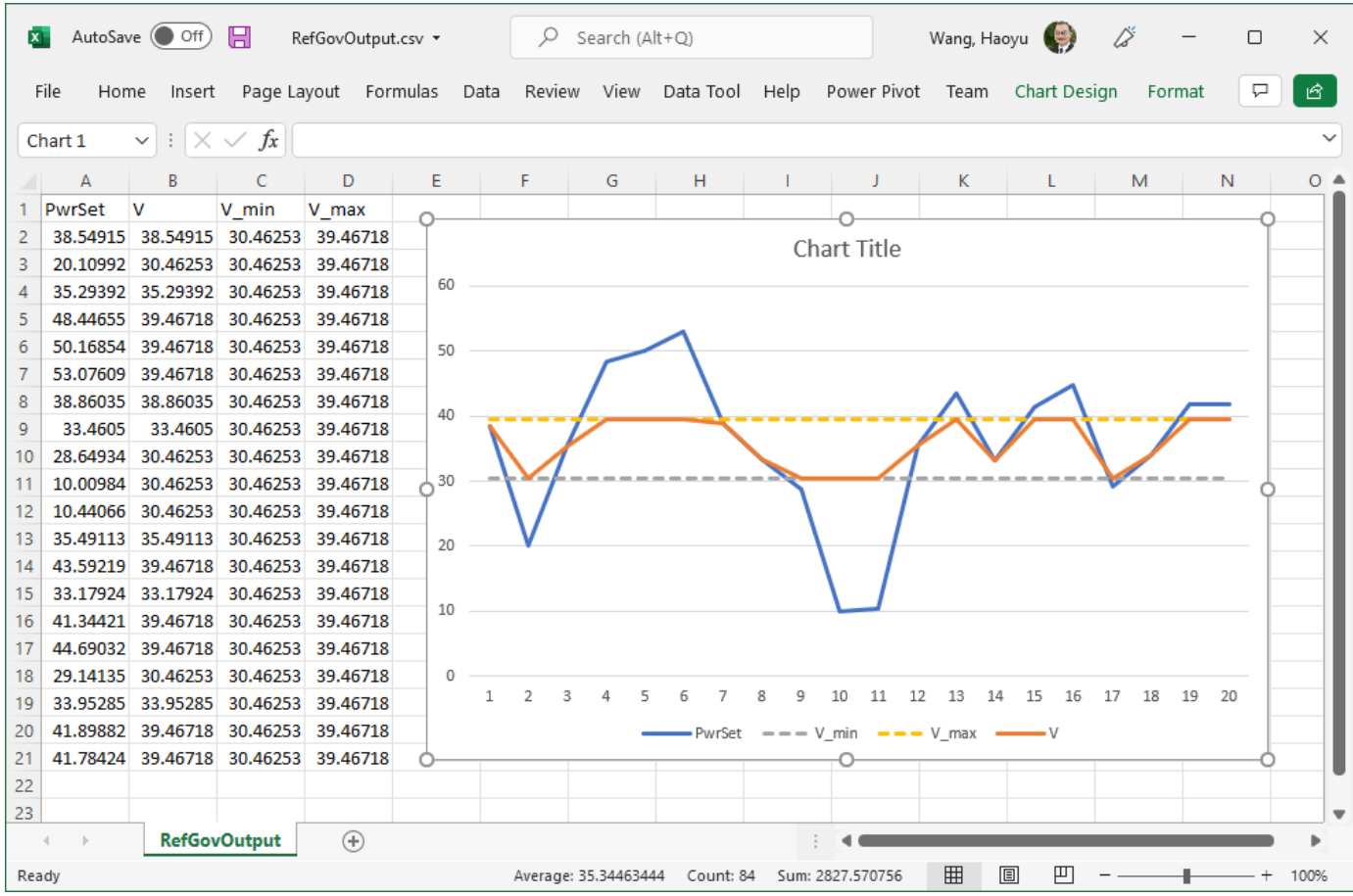
3. Input creation and running the code

- The FARM input file can be executed like other RAVEN input files:

```
haoyuwang@p075722 MINGW64 /d/GitProjects/training/FARM (master)
$ ../raven/raven_framework training031822/FARM_para_SES.xml
```

4. Output analysis

- The FARM output can be found in:
  - FARM / training031822 / DMDc_FARM_Folder / RefGovOutput.csv
    - 20 entries, with 4 column in each entry
      - Issued power setpoint “PwrSet”;
      - Adjusted power setpoint “V”;
      - Minimum allowed value “V_min”;
      - Maximum allowed value “V_max”;
    - The “PwrSet” are regulated to “V”, to meet both explicit and implicit constraints.



	A	B	C	D
1	PwrSet	V	V_min	V_max
2	38.54915	38.54915	30.46253	39.46718
3	20.10992	30.46253	30.46253	39.46718
4	35.29392	35.29392	30.46253	39.46718
5	48.44655	39.46718	30.46253	39.46718
6	50.16854	39.46718	30.46253	39.46718
7	53.07609	39.46718	30.46253	39.46718
8	38.86035	38.86035	30.46253	39.46718
9	33.4605	33.4605	30.46253	39.46718
10	28.64934	30.46253	30.46253	39.46718
11	10.00984	30.46253	30.46253	39.46718
12	10.44066	30.46253	30.46253	39.46718
13	35.49113	35.49113	30.46253	39.46718
14	43.59219	39.46718	30.46253	39.46718
15	33.17924	33.17924	30.46253	39.46718
16	41.34421	39.46718	30.46253	39.46718
17	44.69032	39.46718	30.46253	39.46718
18	29.14135	30.46253	30.46253	39.46718
19	33.95285	33.95285	30.46253	39.46718
20	41.89882	39.46718	30.46253	39.46718
21	41.78424	39.46718	30.46253	39.46718
22				
23				

5. Future Directions

- FARM is being implemented into HERON to help with power dispatch problem. [1]
- Online system identification and matrices update (ETA: April 2022)
  - User do not need to generate matrices off-line;
  - Online data-driven derivation and update of A,B,C,D matrices;
  - Better supports the physics-based high-fidelity model.

References

[1] Wang, Haoyu, Roberto Ponciroli, and Richard B. Vilim. Automation of FARM from Alpha Phase to Beta Phase. No. ANL/NSE-22/6. Argonne National Lab.(ANL), Argonne, IL (United States), 2022.

IES

Integrated Energy Systems

Thank you!

Haoyu Wang

Argonne National Laboratory

haoyuwang@anl.gov