BIOND 4.0 – Offline demonstrator Architecture / Platform for Digital Twin

Mika Karaila, mika.karaila@valmet.com

Valmet – Research Director

Aalto – Professor of Practise

Agenda

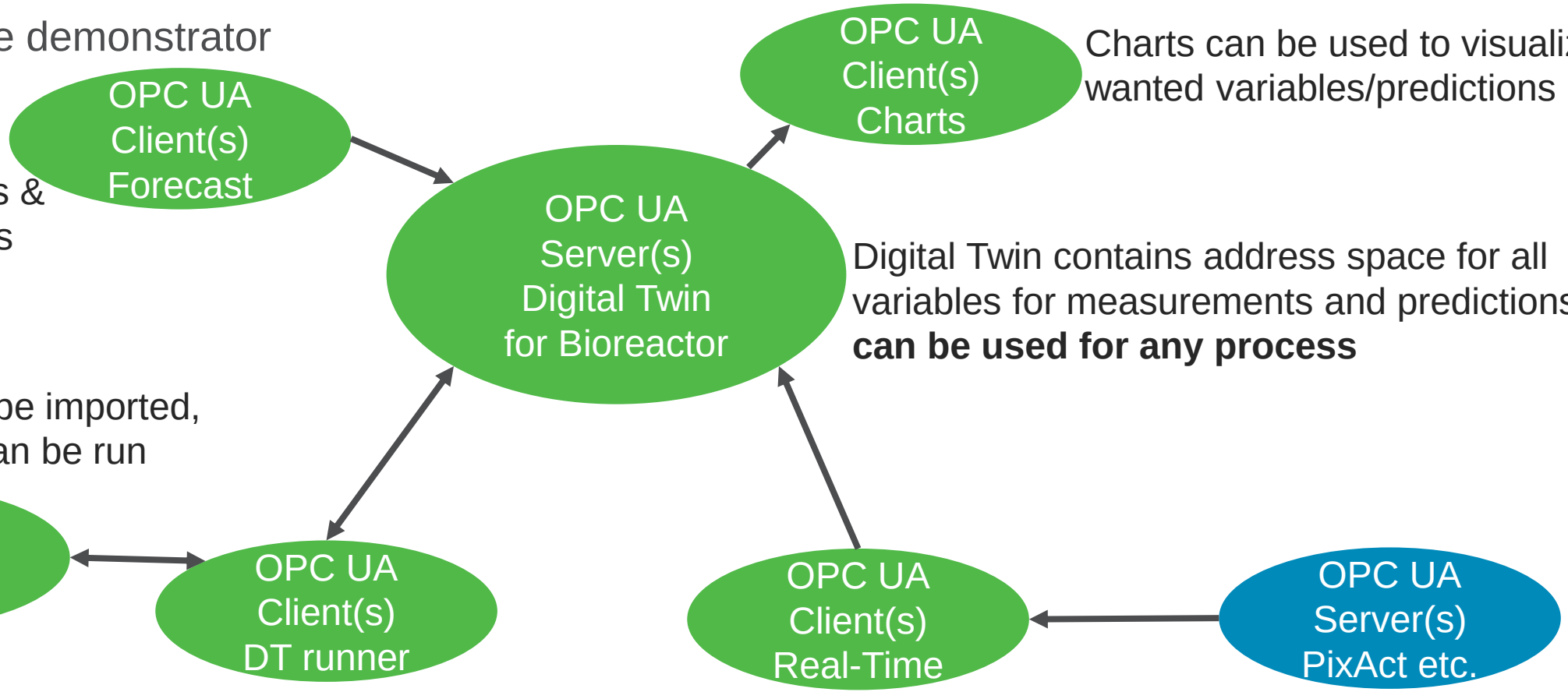
- Architecture
- Implemented OPC UA Servers and OPC UA Clients
  - Current status: tested with UaExpert (screenshots)
- Next actions:
  - FMU model needed or some other to make predictions (Aalto researcher tests on-going)
  - OPC UA Client to connect FMU Server (or other model) and Bioreactor Digital Twin server
- Latest version changes:
  - Added error checking/handling/messages/return codes
  - Certificate: 

  - Better functionality, no hard coded variables: add/delete vendor(s) & variables, save / load address space

Architecture – modular and scalable

Offline / online demonstrator

Forecast client can read historical values & write predictions



Charts can be used to visualize wanted variables/predictions

Digital Twin contains address space for all variables for measurements and predictions, **can be used for any process**

FMU model can be imported, and simulation can be run

DT runner client will read measurements from the Digital Twin server and call model simulation and write predictions back to Digital Twin server

OPC UA Client can read actual measurement from the vendor OPC UA Server like PixAct and write them to Digital Twin OPC UA Server

OPC UA Server for Bioreactor measurements

OPC UA Server FMI and Digital Twin client

- User can import FMU file, instantiate model and run simulation
  - Digital Twin client can call methods: import, instantiate and run.
  - It will synchronize needed variables from the Bioreactor DT server for simulation inputs and read model outputs and write them back to the Bioreactor DT server as predictions

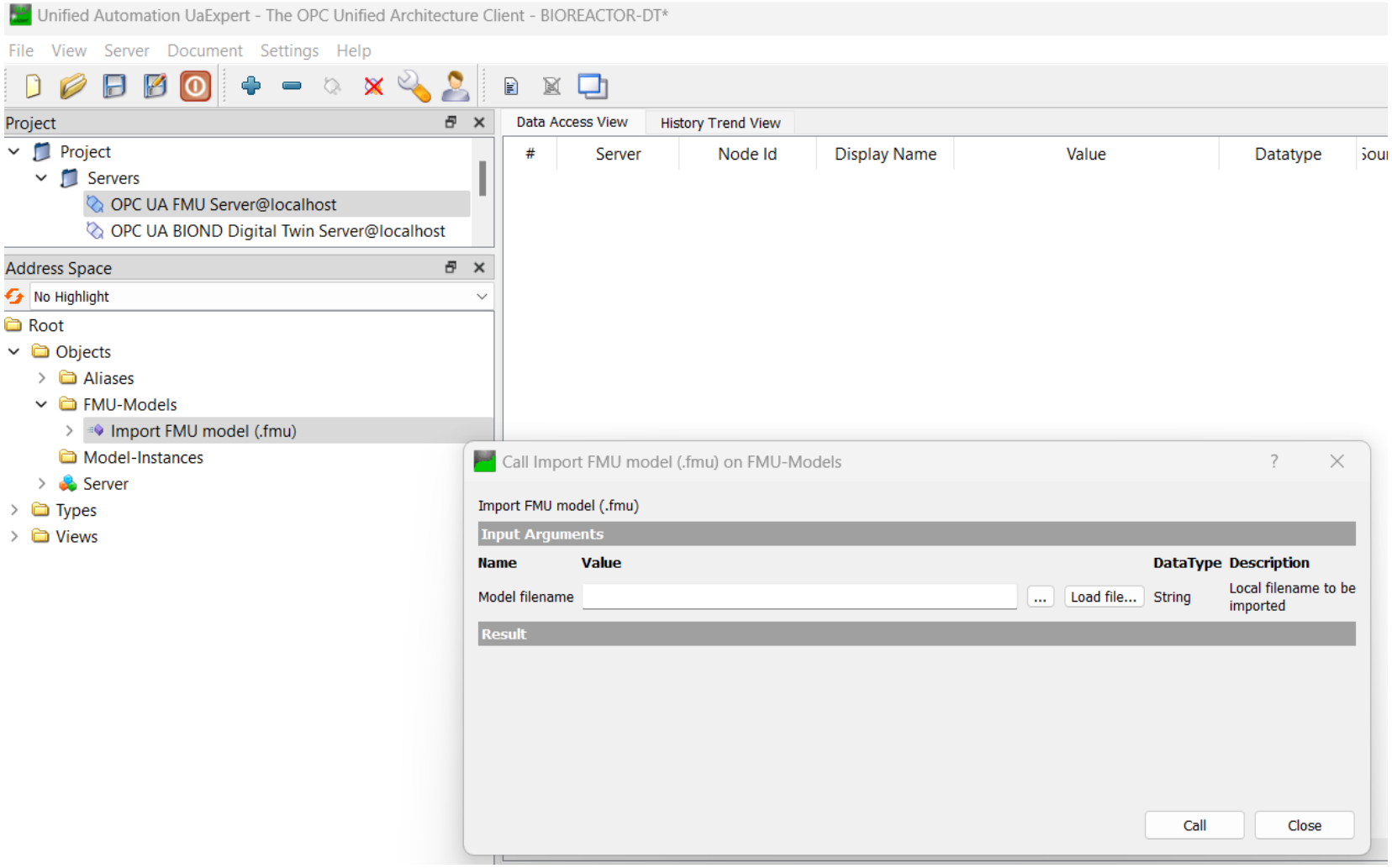
- As model can be run and fine tuned with the actual measured values so that predictions will match this will need some additional parameters inside FMU model for this purpose

OPC UA Server for Bioreactor as Digital Twin

- User can import excel file that will create all variables into the address space
  - Additional own namespace variables are created at the same time for predictions
- Replay will write values from the Pandas data frame into the server
  - Uses current time and writes all values into the future historical values (time delta can be modified to run faster)
    - Start time can be given as parameter for the replay
    - Interval can be given as parameter for the replay (faster or slower than recorded)
  - This will enable that simulation can read offline values as “real-time” and execute model and server will predict values
    - Model can also use historical values and re-fit model and new prediction with new model (validate and check error before using new prediction values)

Screenshots from the FMU OPC UA Server

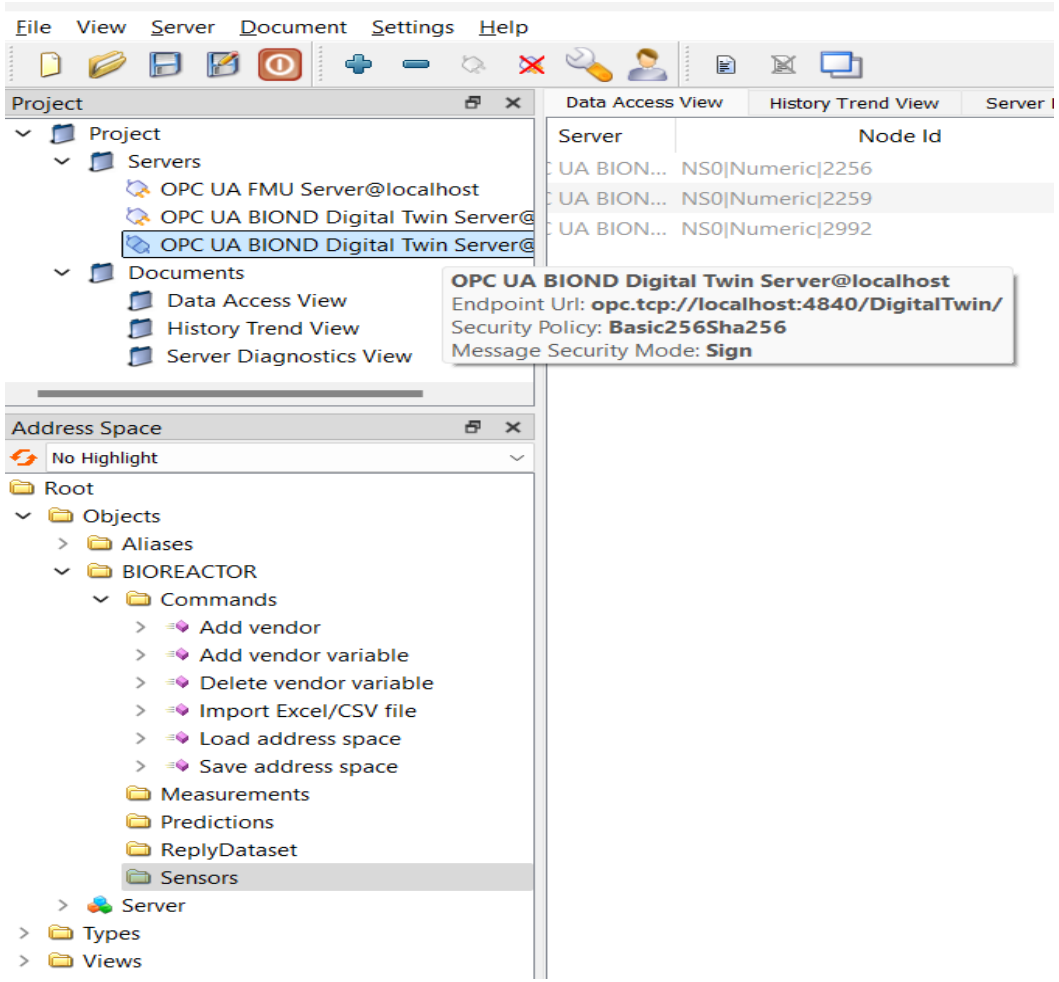
Bioreactor FMU model can be imported and then instantiate, and simulation could be run



Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server started – Import recorded data (Excel file format)

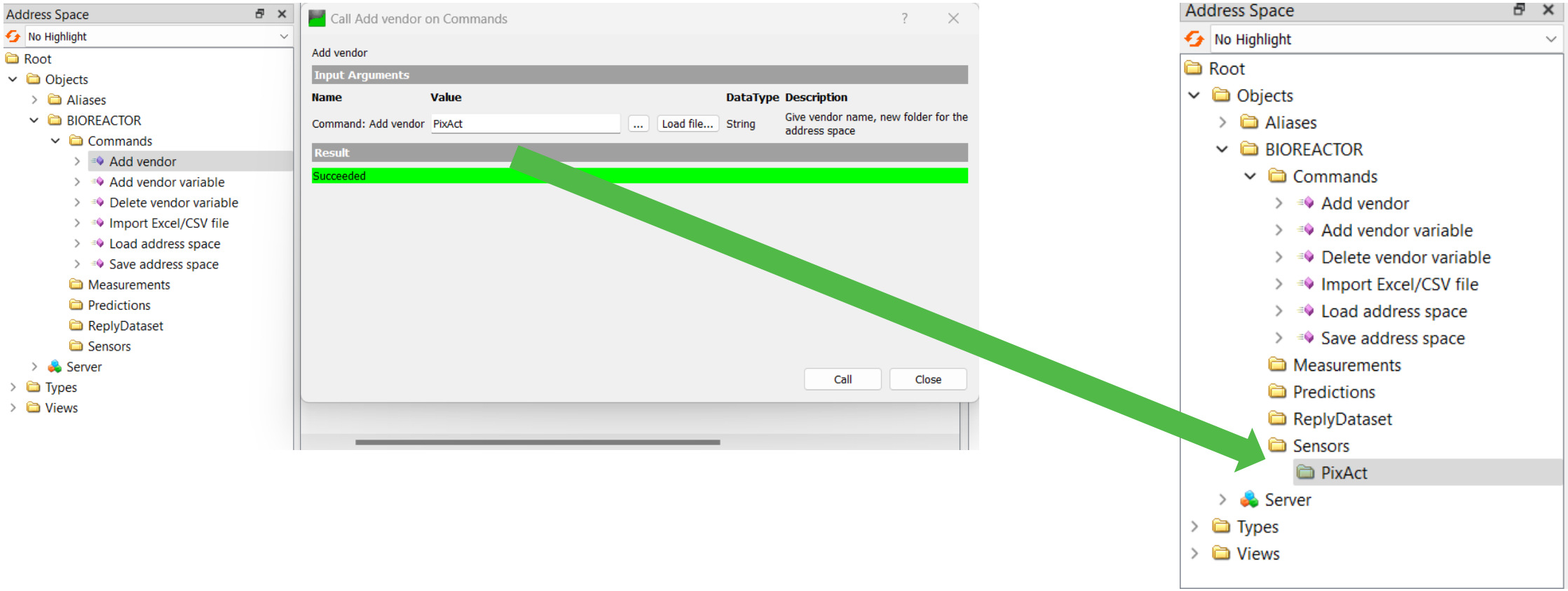
- Server supports now username & password (Sign)
- Certificates are under certificates folder (Encrypt)
- All methods are under Commands folder
- Add vendor will create folder under Sensors
- Add vendor variable will add variable under just created Sensors/*VendorName* folder
- Delete vendor variable can be used to remove vendor variable
- Import Excel/CSV file will read dataset from the file
- Load address space will read XML format file
- Save address space will write XML format file



Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Add vendor

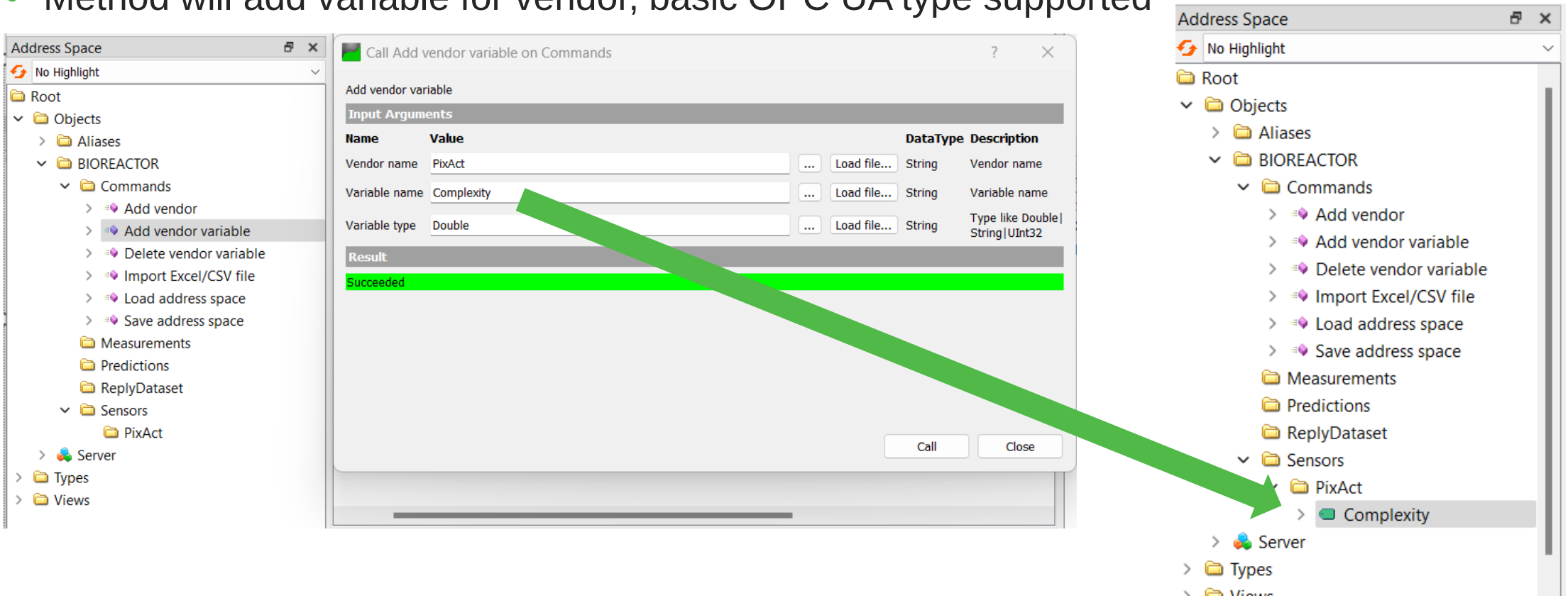
- Method will add folder under Sensors folder (easier to see vendor specific measurements)



Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Add vendor variable

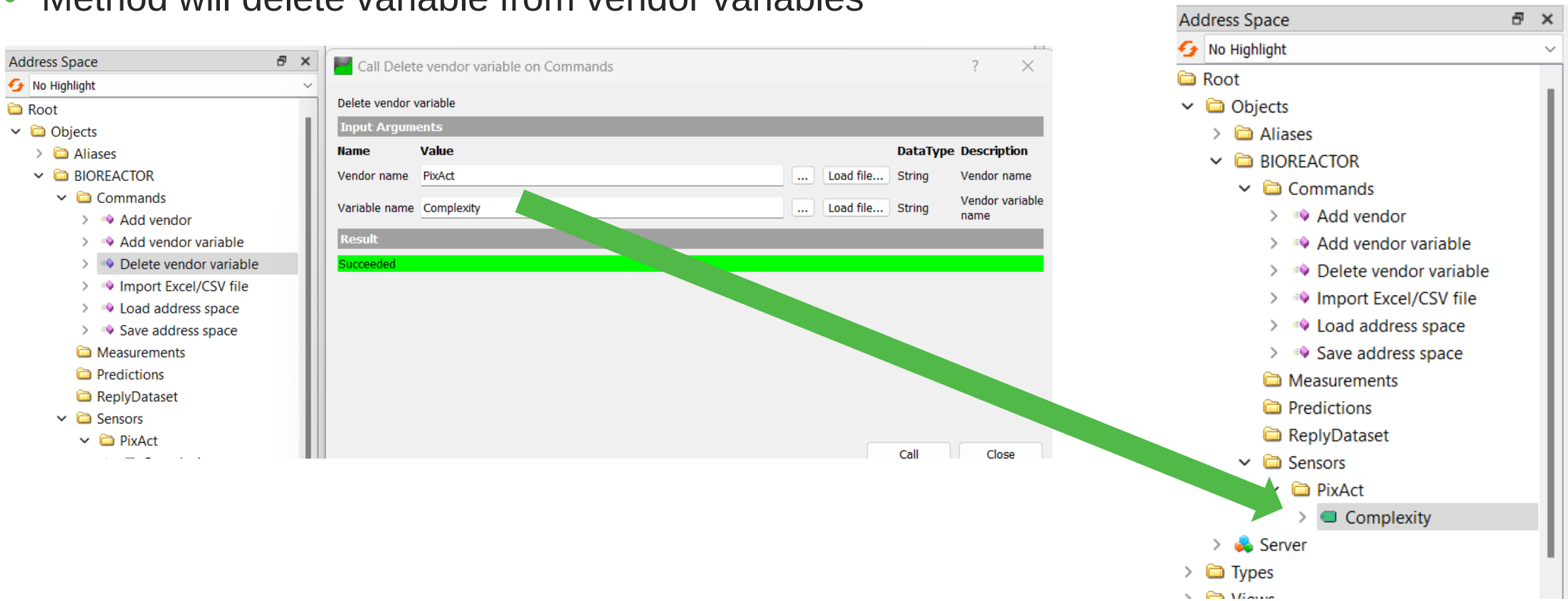
- Method will add variable for vendor, basic OPC UA type supported



Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Delete vendor variable

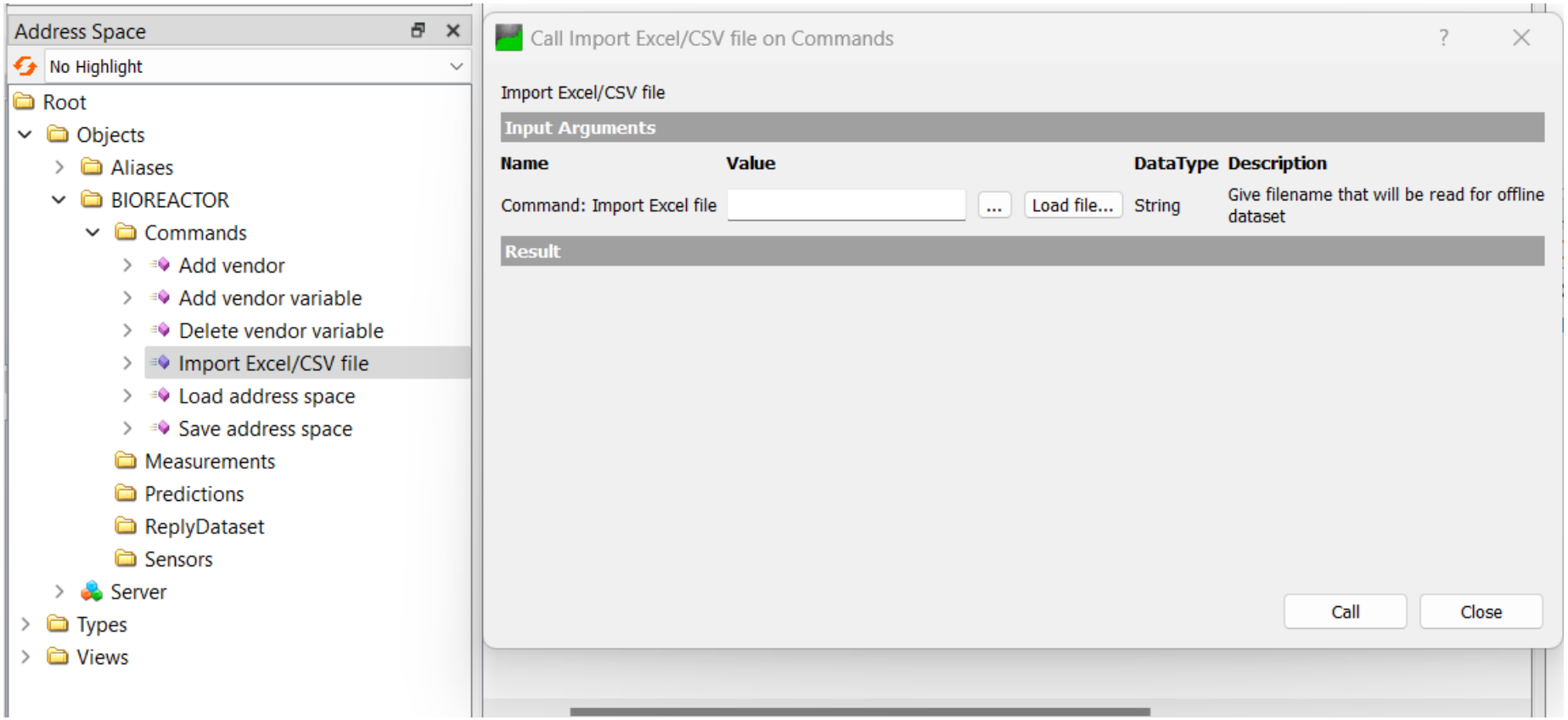
- Method will delete variable from vendor variables



Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Import Excel file

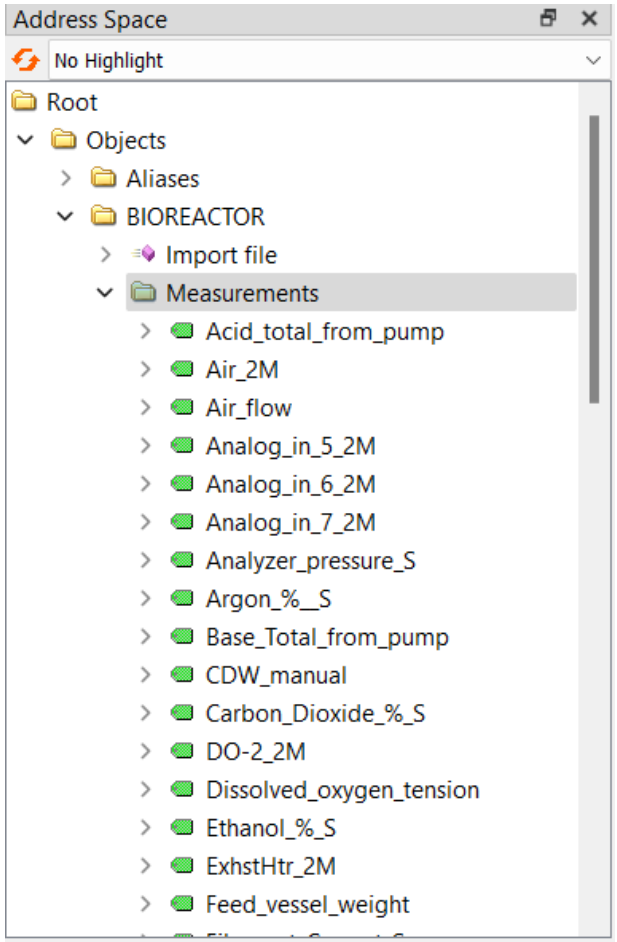
- Method will read file and store dataset (Pandas) into the server memory for the Replay

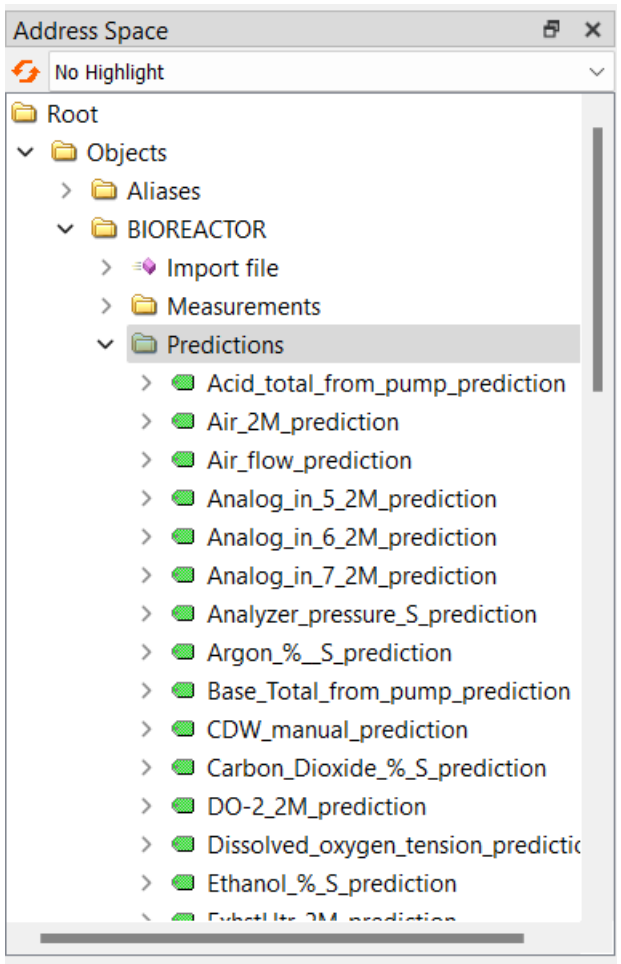


Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Measurements & predictions variables created into the address space

- As Excel file is read all needed variables are created under Measurements & Predictions folders
- Variables are historized into the history.sql (delete file to clear history)

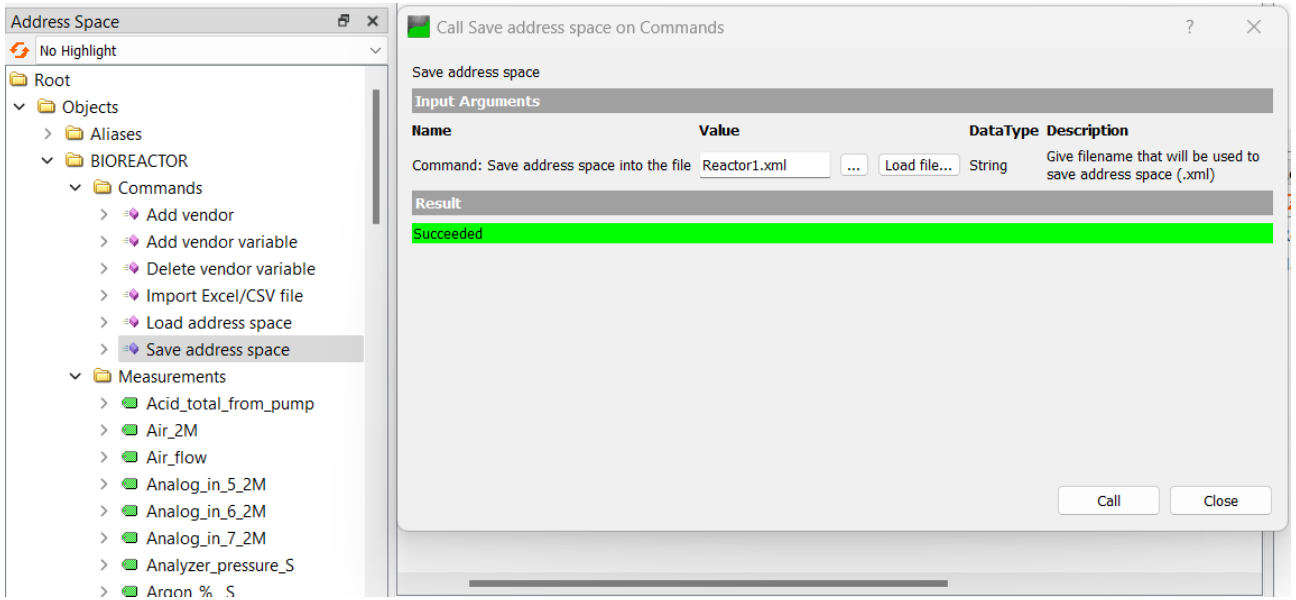




Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Save address space (into the file)

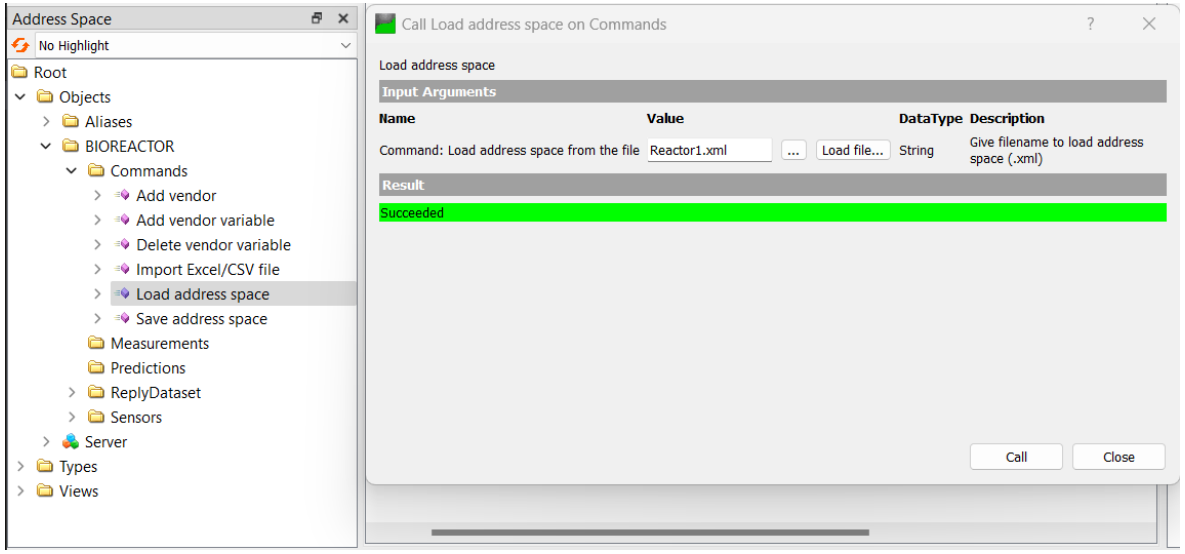
- Import Excel to get all needed Measurements into the address space
- Then add vendors and vendor variables for the specific Reactor
- Save address space to use it later again
- Use case: Different Reactors with same Sensors (reuse address space)



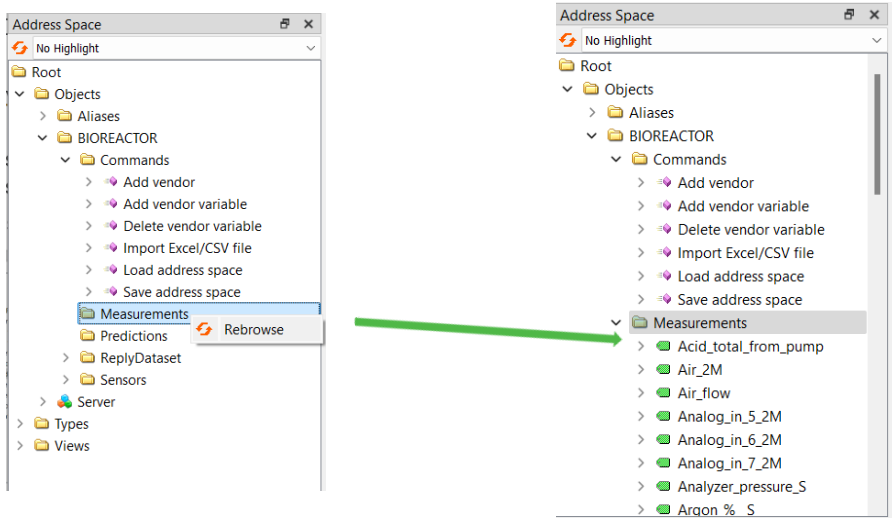
Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Load address space (from the file)

- You must start server and then load needed file (XML format)
- This will load for example all Measurements, Predictions and vendors under Sensors folder with vendor specific variables into the address space (no need to Import Excel / Add vendor variables)
- Use case: Different Reactors with same Sensors (reuse address space)



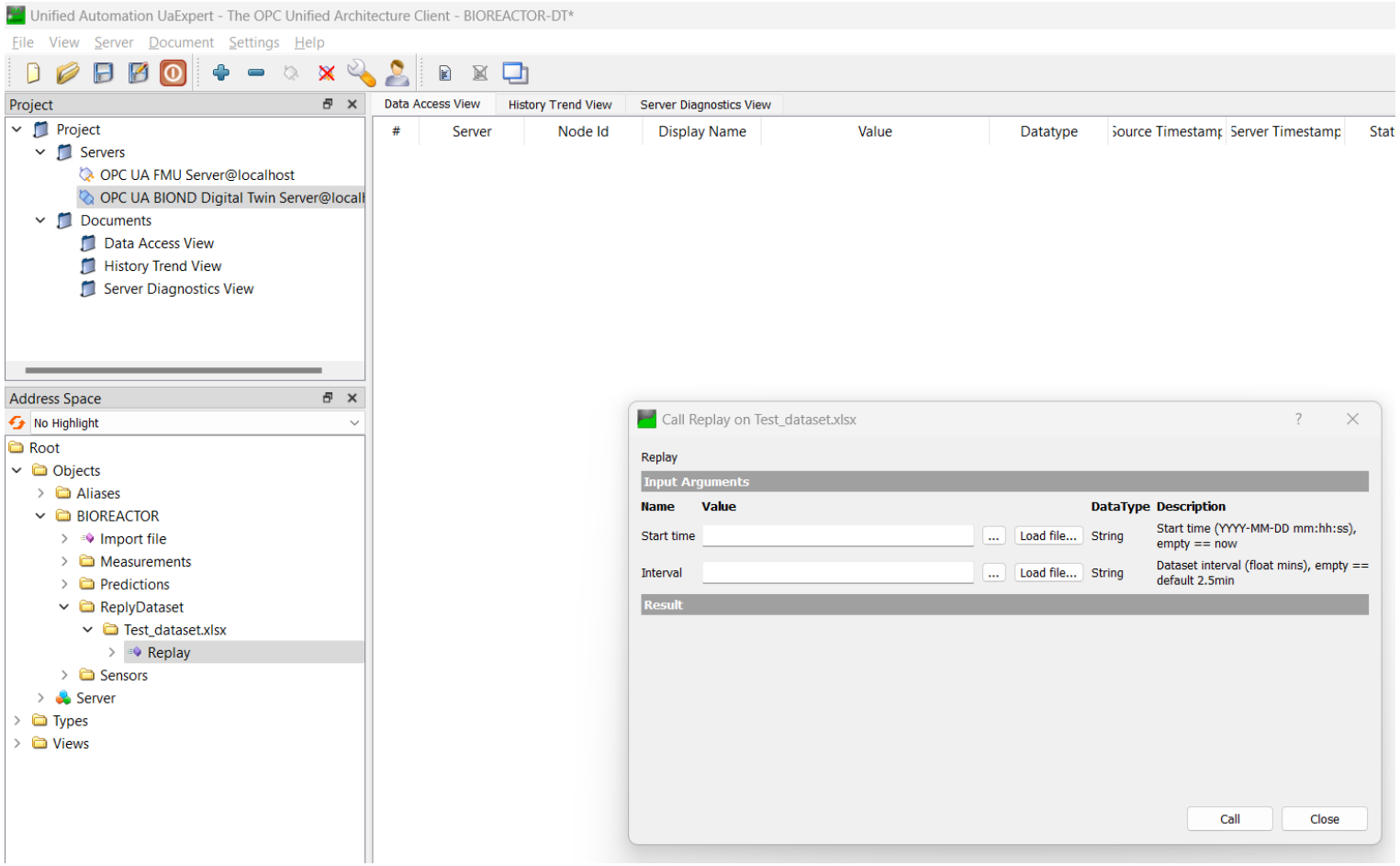
NOTE: You need to **Rebrowse** folder to see variables



Screenshot from the Bioreactor Digital Twin OPC UA Server

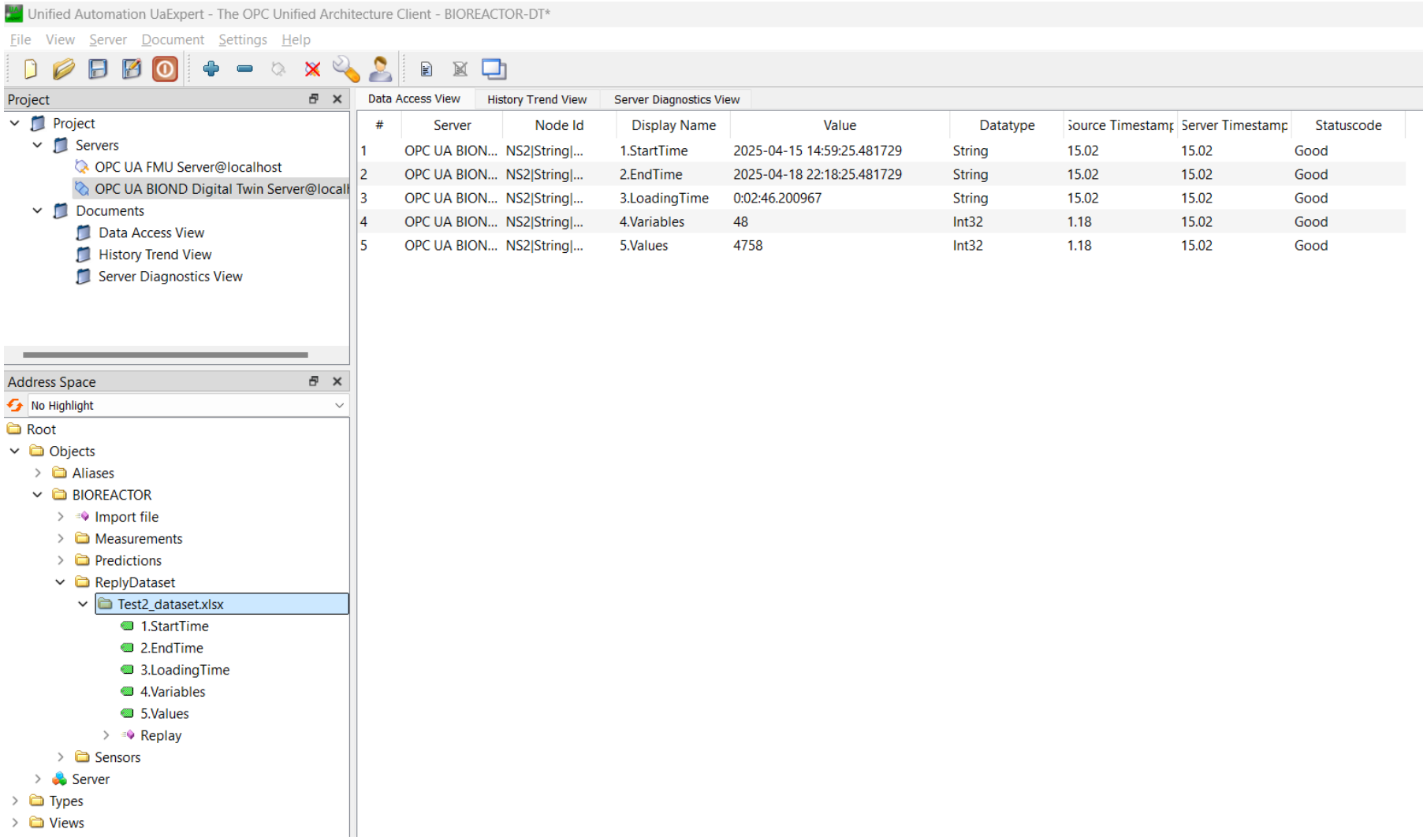
BIOREACTOR Server: Replay – load values to variables

- Replay will store values into the history, so trends are available
- Client(s) can used read_raw_history to retrieve values for the forecast model fit
- Forecast client(s) can write values under variables under Predictions folder variable
- Prediction variables are in the own namespace index and each variable has suffix ns=3;s=*VariableName*_prediction



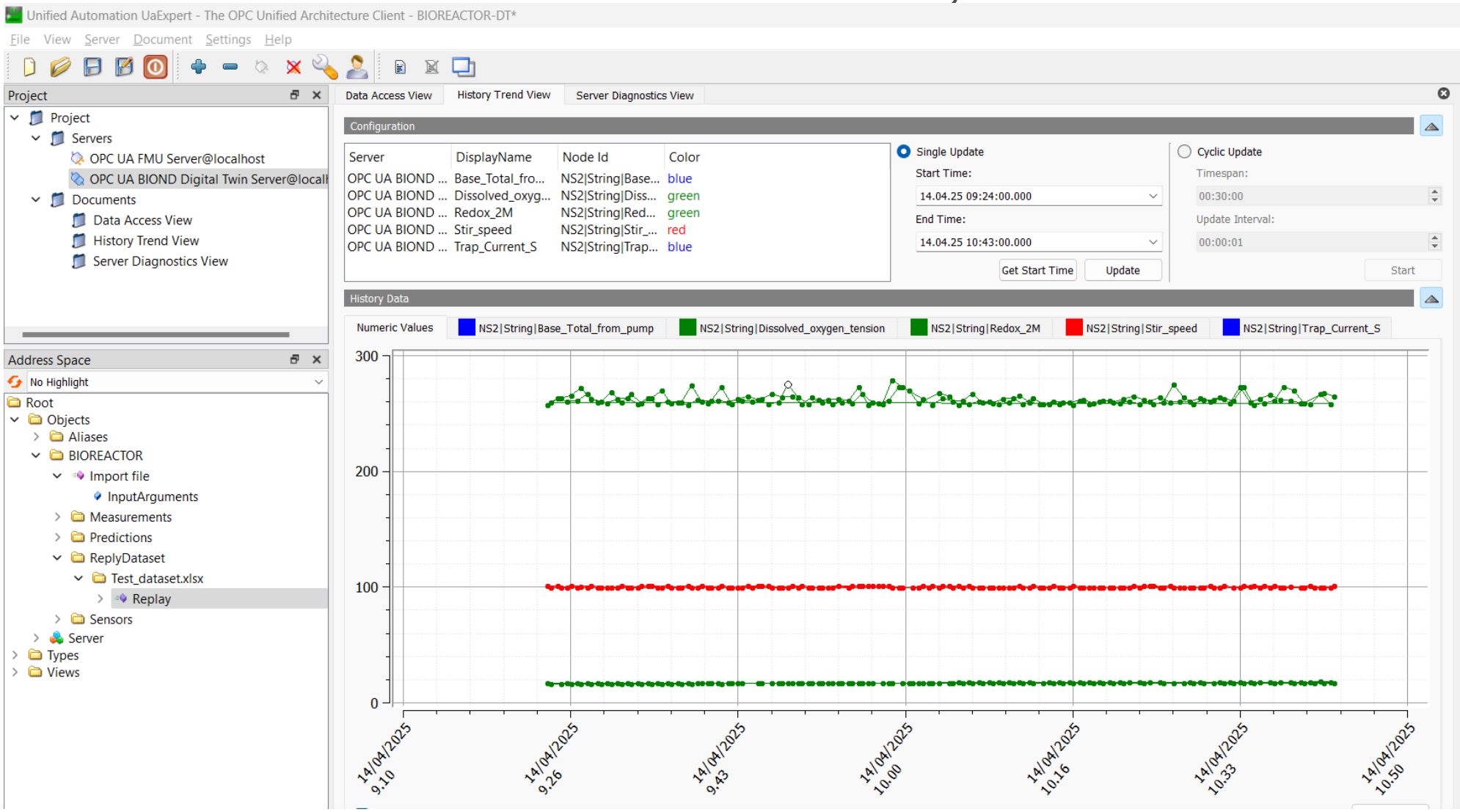
Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Values loaded from the current time to the end of recorded time



Screenshot from the Bioreactor Digital Twin OPC UA Server

BIOREACTOR Server: Data can be studied with History Trend view



Next steps – actions & vision

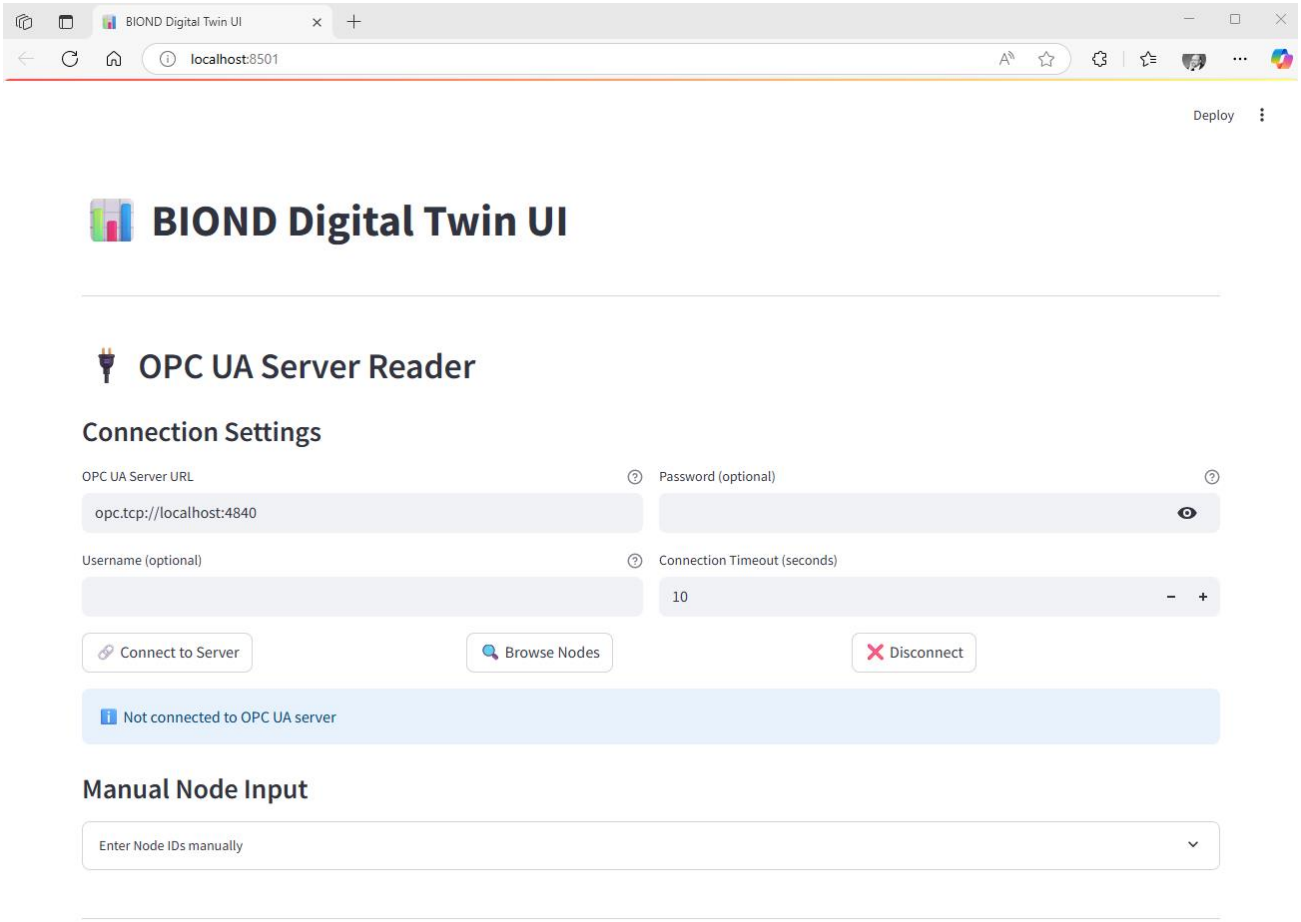
- FMI server connected with OPC UA client to rerun offline demo with forecasts
  - Waiting for feedback and results from Aalto

- Another forecast model / algorithm to rerun demo
  - AutoTS / Prophet not giving good / exact results
  - TimesNet or N-BEATS with some time series tuning next candidate

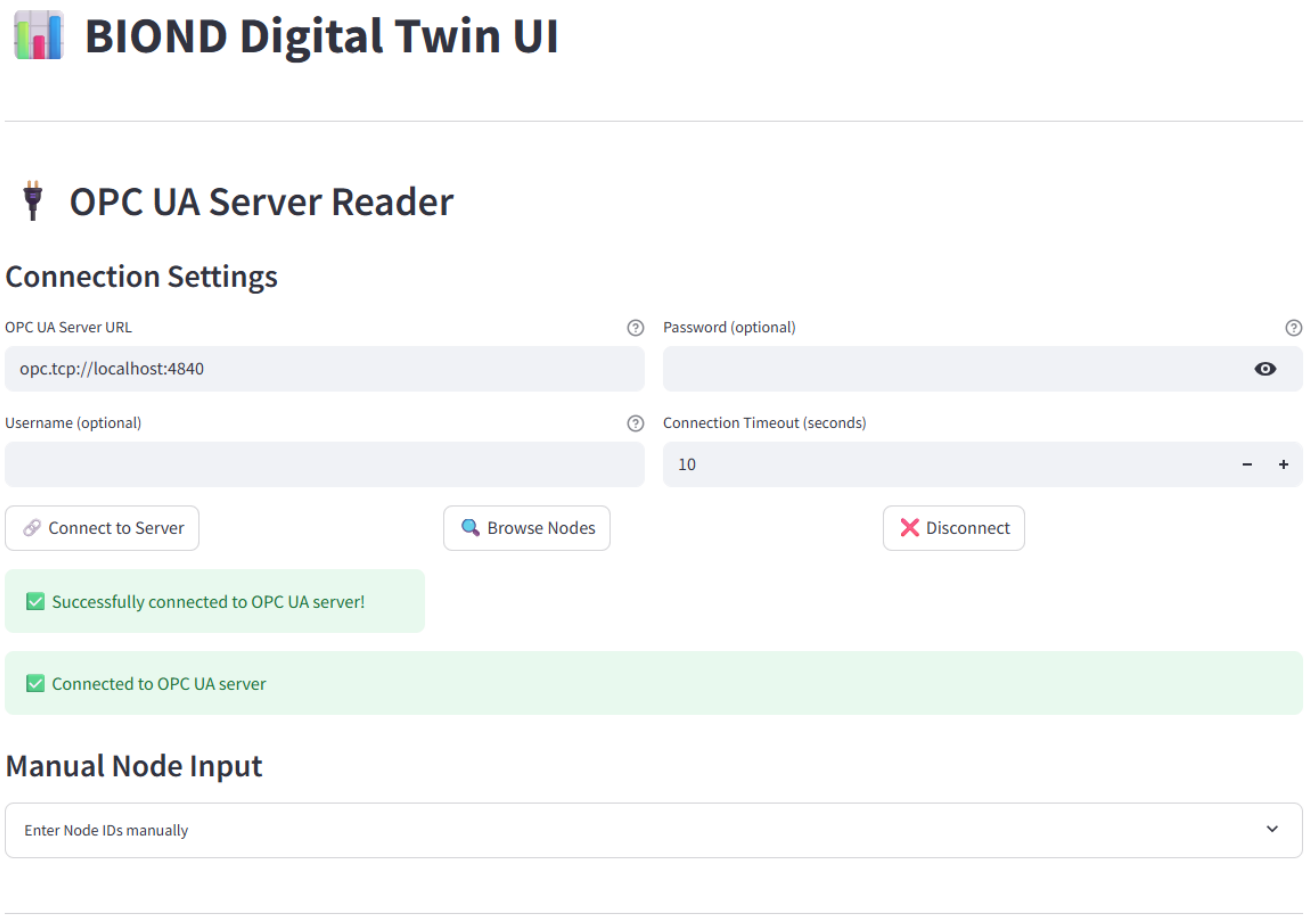
- More data to rerun tests and find better Digital Twin model for forecasting
- Proto-typing web server UI (Streamlit based)
- Vision:
  - Federated learning as one solution to tune actual model

Web server UI – OPC UA Server parameters

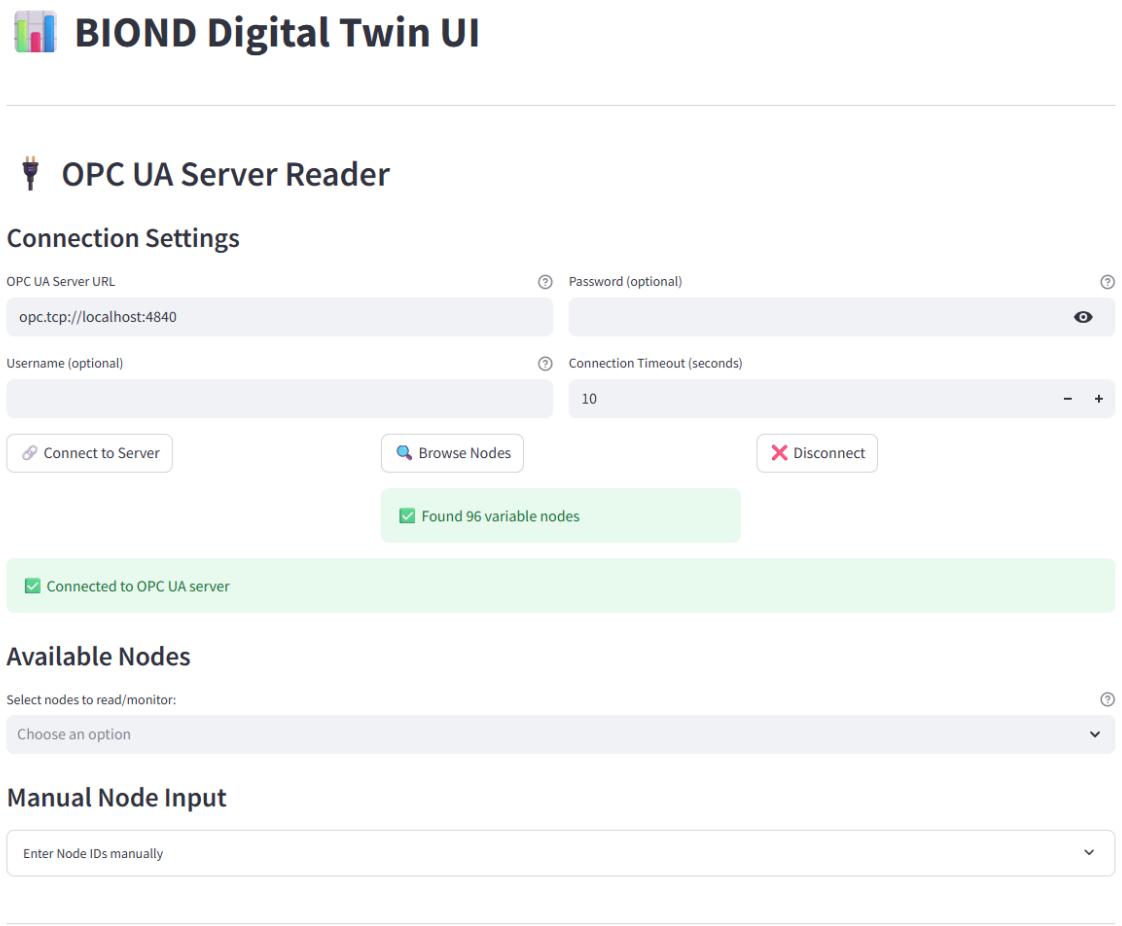
Streamlit based proto-type



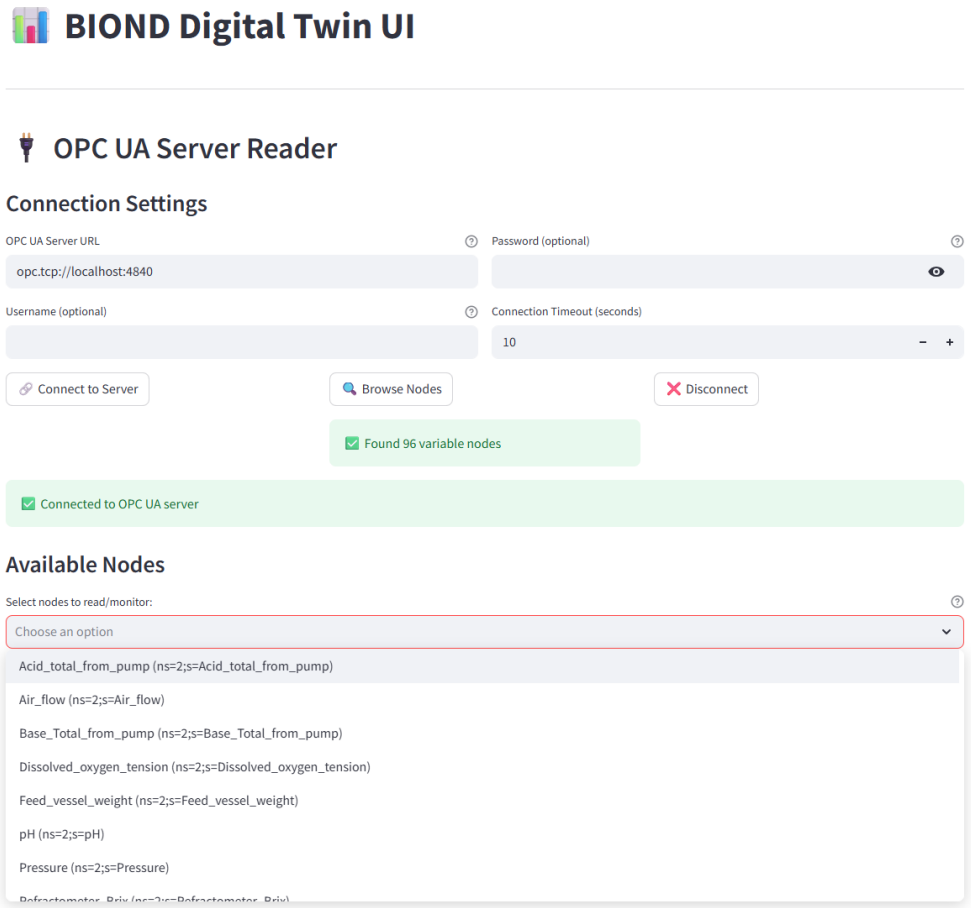
Web server UI – Connected to OPC UA Server



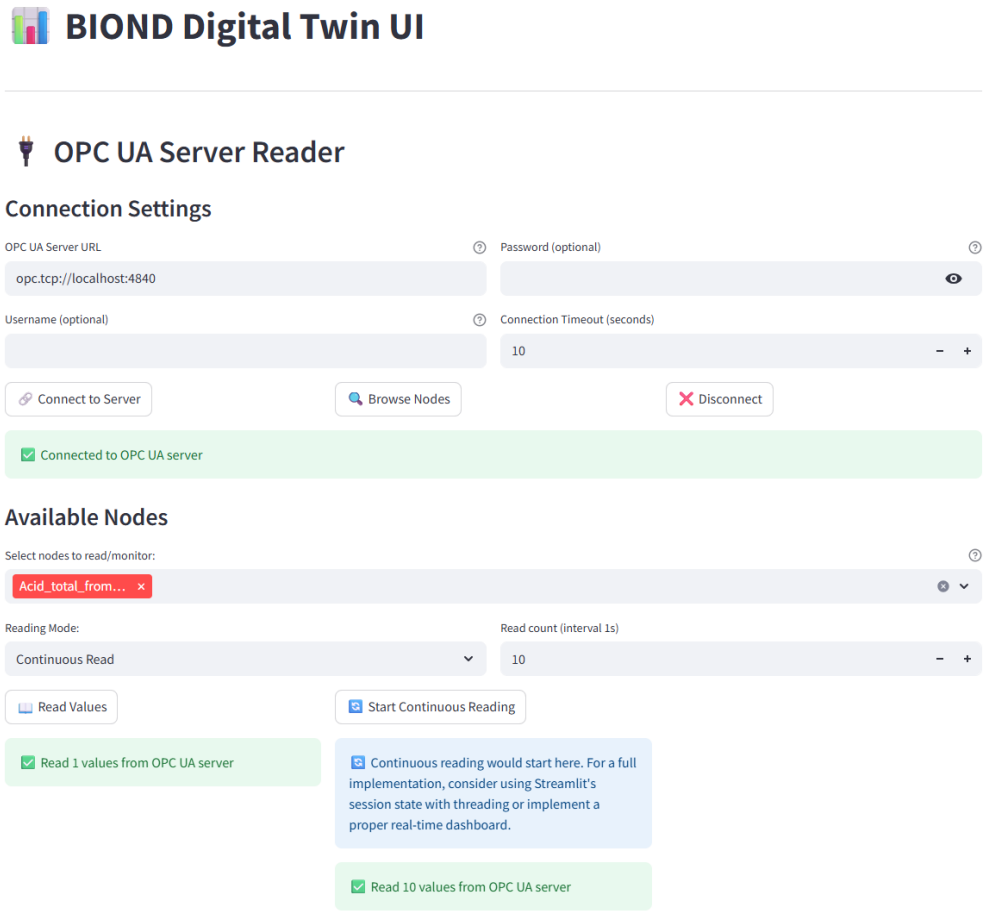
Web server UI – Browsing variables under ns=2;s=BIOREACTOR



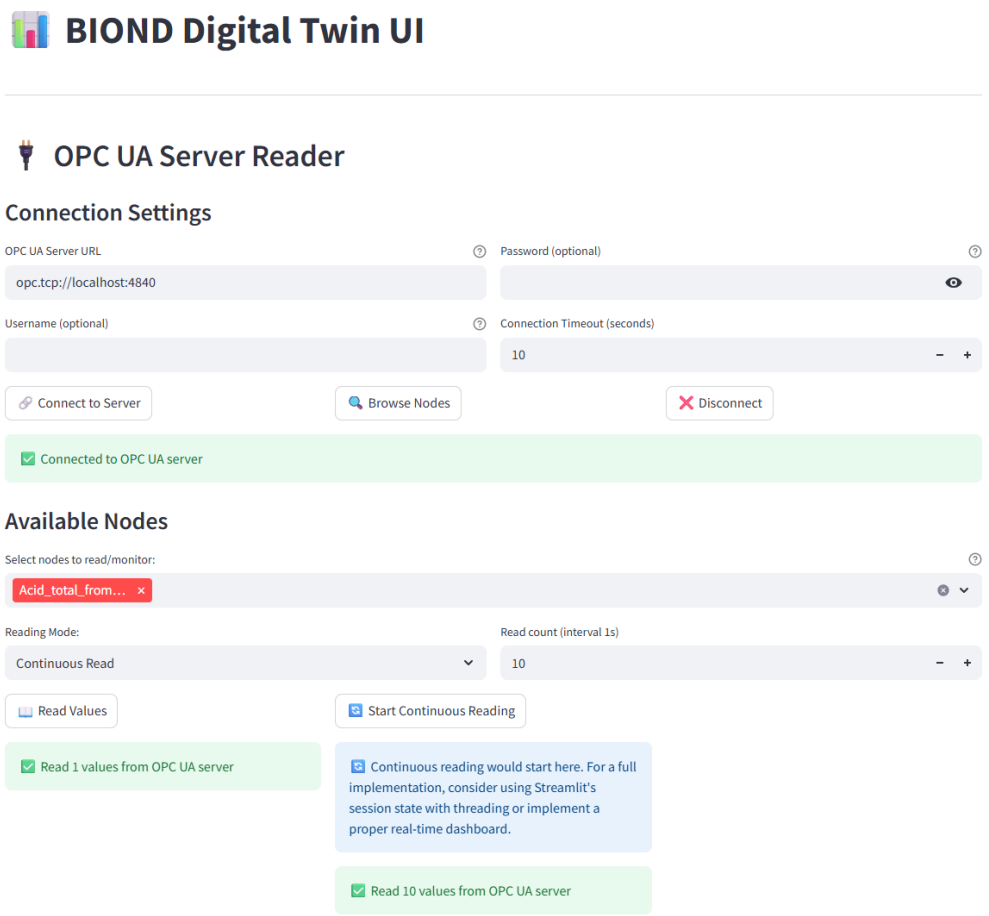
Web server UI – Selecting variable(s)



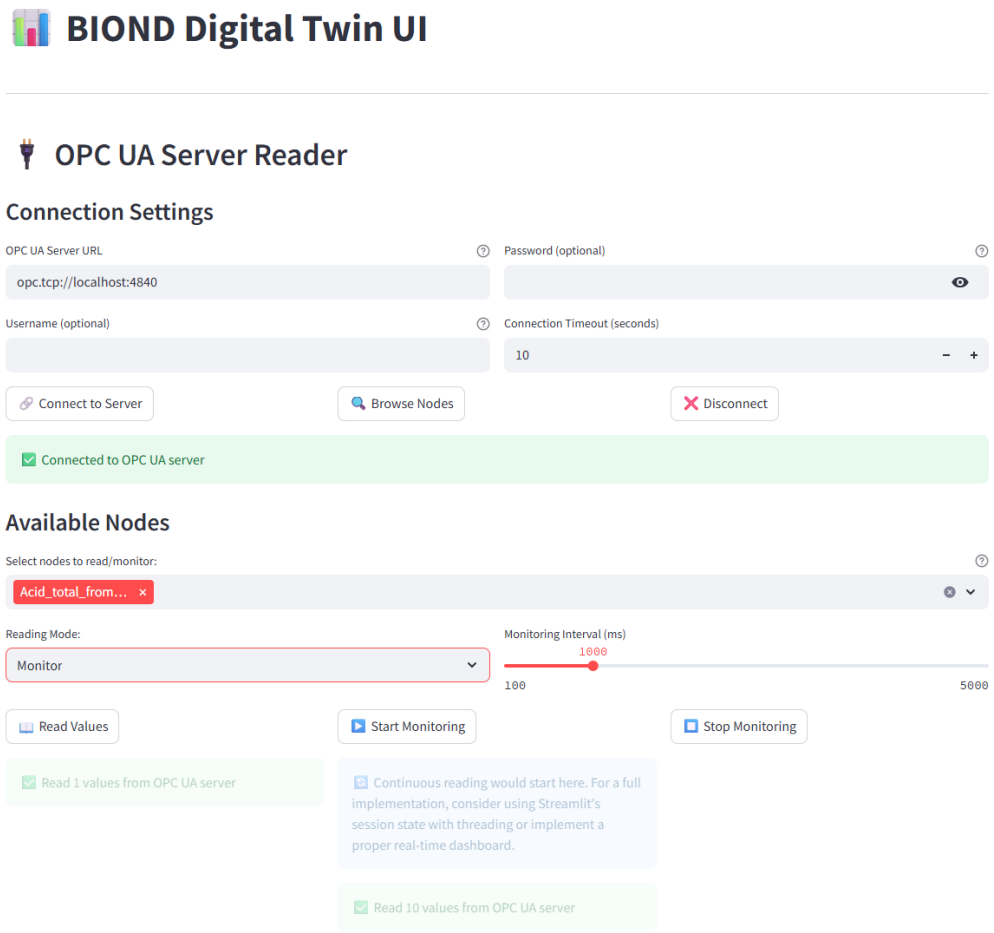
Web server UI – Single Read variable(s)



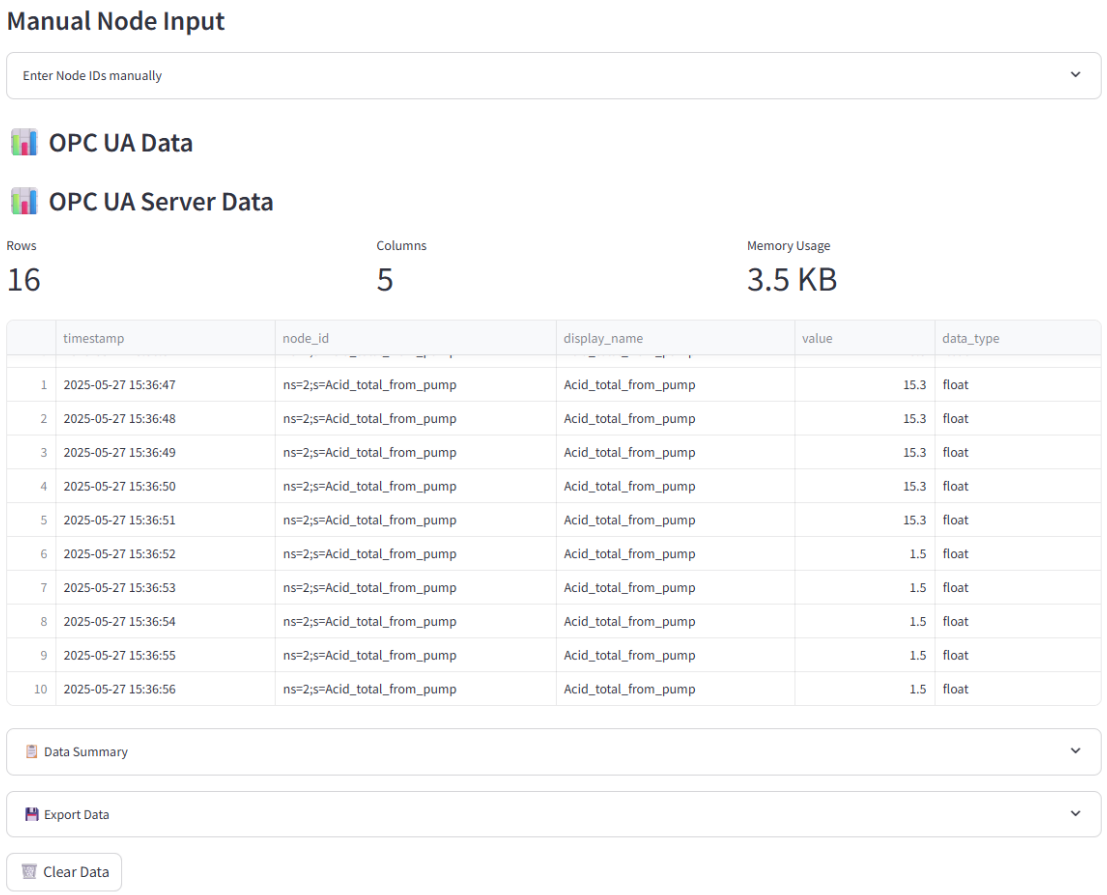
Web server UI – Continuous Read variable(s)

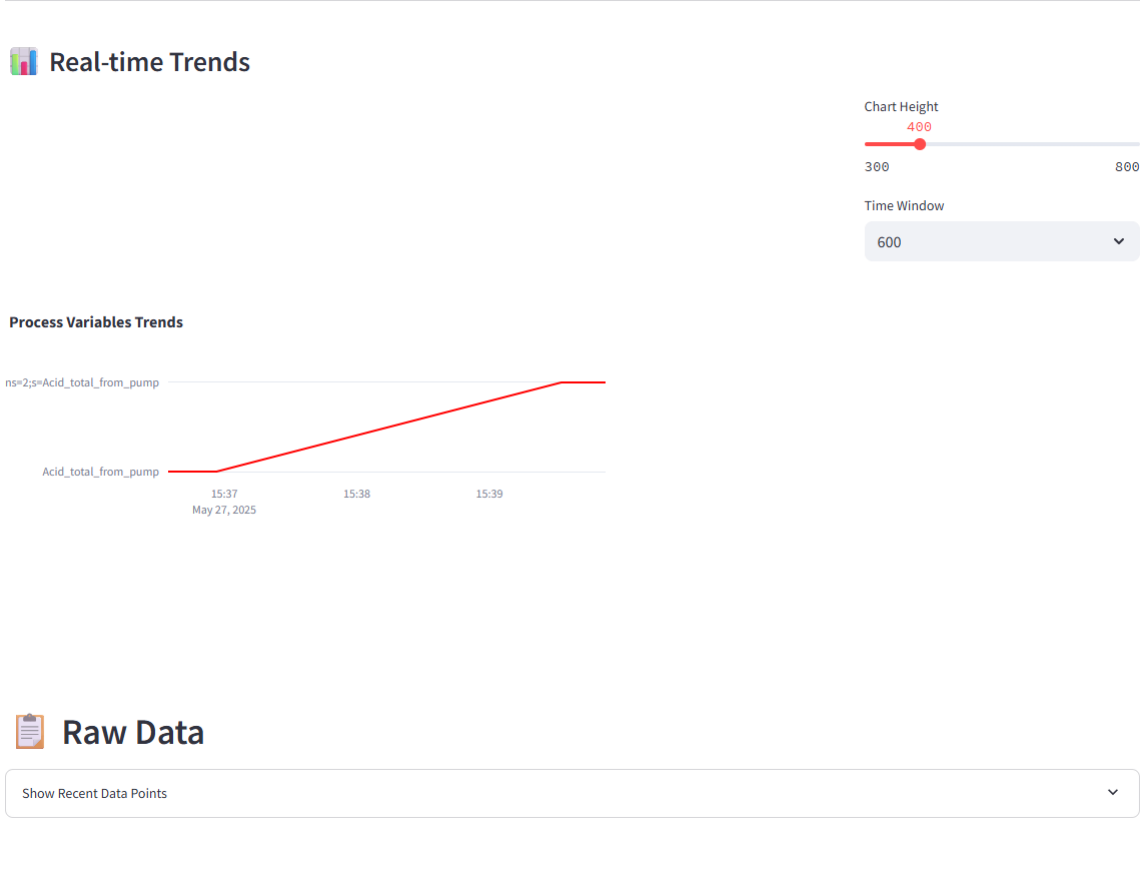


Web server UI – Monitor variable(s)



Web server UI – OPC UA Data and Real-time Trends





Summary

OPC UA standard as key enabler

- Enables interoperability between different vendors and actors
- Tests can be rerun with different simulation/prediction models
- Real-time data can be used with historical data
- Different user interfaces for needed use case:
  - Monitor values
  - Compare model and prediction values to validate model

- Vision:
  - Control actual Bioreactor with model predictions, write setpoints to actual controller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FORWARD