

Patent claims

1. A method of operation of a process plant with at least one automation component (PA) to control an industrial process (MP) within the process plant with at least one input ingredient and at least one output product, the method comprising the steps of:

- generating quality attributes of the industrial process as a function of process variables and process parameters using a non-real-time simulation model (OSM) of the industrial process,
- using the generated quality attributes and related process variables as input for a machine learning model (ML) which is used as a real-time process model (RT-PRM),
- generating simulated process variables (SD) of the industrial process using a process plant simulation model (SPM), the process plant simulation model (SPM) simulating automation functions and operation of the process plant,
- combining the process plant simulation model (SPM) and the real-time process model (RT-PRM) to a virtual plant model (VPM),
- using the real-time process model (RT-PRM) as a soft sensor to estimate quality attributes (QA) of the output product as a function of measured or the simulated process variables of the industrial process, and
- optimizing the performance of the process plant based on the estimated quality attributes (QA) of the output product.

2. The method according to claim 1, wherein the process plant simulation model (SPM) is a real-time model (RT-SPM), such that the real-time process plant simulation model (RT-SPM) and the real-time process model (RT-PRM) are combined to a real-time virtual plant model (RT-VPM), and wherein the real-time virtual plant model (RT-VPM) is used to estimate or predict states of the process plant to optimize the performance of the process plant.

3. The method according to claim 1 or 2,

wherein the real-time process model (RT-PRM) or the real-time virtual plant model (RT-VPM) is used for an online control of the process plant, which is preferably an advanced, adaptive process control, like a model predictive control (MPC).

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4. The method according to any of the preceding claims, wherein the industrial process is a pharmaceutical production process, wherein the pharmaceutical production process is a mixture process of two liquids.

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5. A Soft Sensor for a process plant with at least one automation component (PA) to control an industrial process (MP) within the process plant (RP) with at least one input ingredient and at least one output product, comprising:

15 - an interface (I1) to receive quality attributes and related process variables of the industrial process from a non-real-time simulation model component (OSM) to simulate the behavior of the industrial process, and

- a real-time process model (RT-PRM) component,
20 comprising a machine learning model (ML),

wherein the machine learning model (ML) is based on the received quality attributes and related process variables of the simulation model component (OSM), and

25 wherein the machine learning model (ML) is configured to estimate quality attributes (QA) of the output product as a function of measured or simulated process variables of the industrial process.

6. The Soft Sensor of claim 5,

30 further comprising the non-real-time simulation model component (OSM), being connected to the interface (I1).

7. The Soft Sensor of claim 5 or 6,

35 further comprising a Kalman filter which is configured to receive the estimated and measured quality attributes of the output product and to calculate improved estimates based on probabilities of previous and current estimates and measured values of the quality attributes.

8. Use of the soft sensor according to claim 5 to 7 as process model for a model predictive controller (MPC).

5 9. A digital process twin system for operation of a process plant with at least one automation component (PA) to control an industrial process (MP) within the process plant with at least one input ingredient and at least one output product, comprising

10 a virtual plant model component (VPM) with

- an interface (I2) to receive quality attributes and related process variables of the industrial process from a non-real-time simulation model component (OSM) to simulate the behavior of the industrial process,
- 15 - a real-time process model (RT-PRM) component, comprising a machine learning model (ML), wherein the machine learning model (ML) is based on the received quality attributes and related process variables of the non-real-time simulation model component (OSM), and
- 20 - a process plant simulation model component (SPM), which is configured to simulate automation functions and operation of the process plant to generate simulated process variables (SD), wherein the machine learning model is configured to estimate
- 25 quality attributes (QA) of the output product as a function of measured or the simulated process variables of the industrial process.

10. The digital process twin system of claim 9, wherein the measured process variables are real-time data (RT-D) of the process plant (RP).

11. The digital process twin system of claim 9 or 10, wherein the process plant simulation model component (SPM) is

35 a real-time model (RT-SPM).

12. The digital process twin system of claim 9 to 11, wherein the virtual plant model component (VPM) is configured

to be run in real-time (RT-VPM) in parallel to the process plant (RP) to estimate or predict states of the process plant in real-time based on the estimated quality attributes (QA) of the output product.

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13. The digital process twin system of claim 12, wherein the real-time virtual plant model component (RT-VPM) is configured to be run in connection with a control component, preferably a model predictive controller (MPC), to control the
10 real plant (RP) based on the estimated or predicted states generated by the real-time virtual plant model (RT-VPM) thus providing a closed-loop control of quality of the output product.

15 14. The digital process twin system of claim 11, wherein the virtual plant model component (VPM) comprises an interface (I3) to provide the simulated process variables and/or the estimated quality attributes to a model predictive controller (MPC) for tuning the model predictive controller
20 (MPC) for operation in the real plant.

15. Use of the digital process twin system according to claim 9 to 14 to optimize the operation of a plant for a pharmaceutical production process, wherein the pharmaceutical
25 production process is a mixture process of two liquids.

16. A Computer program product comprising program code that when executed, causes at least one processor to carry out any one of the method steps of claims 1 to 4.