

Tracking in PV Production: Part 2

Complete plant tracking

This is the second article in a series entitled “Tracking in PV Production”, from Prediktor. These articles cover all aspects of tracking in PV production and the series is divided into 4 parts. This 2nd part deals with tracking in batch and continuous processes.

Plant verses Production chain tracking

Let’s begin with a short comparison of plant and production chain tracking. Production chain tracking is tracking between different business units. For instance, in the photovoltaic industry this could be tracking from polysilicon production, through wafer, cell and module production, and all the way to PV system integration. Production chain tracking usually has great depth, but little breadth.

Production chain tracking is usually limited to registering and storing material flow data. Tracking at the plant level is usually not like this, with the most common differences being:

- Plant tracking, usually tracks more information and has greater breadth. In other words, process parameters that are connected to resource use, efficiency, product quality, etc. are stored and associated with identified feedstock, intermediate products and finished products.
- Plant tracking is not dependant on using agreed upon standards for data exchange and communication since everything is done internally within the company. When using production chain tracking, the business units have to agree on how data should be exchanged.
- With plant tracking, all data can be collected and used. With production chain tracking, there will probably be restrictions on what production related data can be exchanged between the independent business units.

When using plant tracking, the optimal level of precision must be determined, that is the resolution of the tracking of feedstock, intermediary products and finished products as well as choosing which processing details should be included. Precision is often decided by what is technically possible, but also by what is practical and appropriate.

Continuous processes

Tracking in continuous processes, such as polysilicon production, can be achieved by using mass balance modeling of the process mass flow. From a tracking perspective, the best precision will be achieved if the mass flow through the production is linear, i.e. there is an ideal plug flow, no large mixing tanks or any significant amounts of recycling in the process.



Polysilicon deposition chambers (Ref. Poly Plant Project Inc.)

The mass flow can then be divided into mass plugs, which are defined amounts of material that are flowing one after each other through the process. These mass plugs can be joined together or split up, such as when a flow stream is separated into two or more streams. Every new mass plug is given a unique identifier that is related to its “parent” and “child” mass plugs. Just like tracking precision, the size of the mass flow is determined not only by what is technically possible, but also by what is practical and appropriate.

In a continuous process, the tracker is fed data from flow measurements, level measurements and other quantity measurements. It is important to have enough measurements to be able to estimate both the mass plugs’ speed and transformations throughout the process. It is also important that relevant data, analysis results and specifications can be linked to the correct mass plugs.

Mass balances must always be adjusted in continuous processes, simply measuring the in-flow and out-flow to integrate the mass in the tank is not sufficient. Corrections need to be made with physical checks such as level indicators, dipstick measurements or high/low level switches. This can easily be realized through technology such as a Kalman filter.

Batch processes



Plant tracking is characterized by great “breadth”, i.e. a large amount of detail.(Ref. DVT)

The process steps in wafer, cell and module plants are mainly batch processes. Tracking in batch processes is also done by modeling mass flow to describe how the materials move through the process. These models are more logical and simpler than continuous flow models. In batch processes, materials and material movement can be identified in several ways:

- Using process knowledge, material transport can be derived from process signals. One example could be a robot moving wafers from the wire saw to the washing equipment. If the wafers are being transported via a “first in – first out” rule, a MES solution can keep track of material movement.
- Manually through operator input. The operator uses an input screen to inform the system that a batch or material unit has been moved.
- In situations where signals from robots or handling systems cannot be used because intermediary inventories don’t have a fixed system for “in- out” movement, then identification technology, such as laser marking, is required.

Different types of marking technologies, as well as active and passive tracking will be covered later.

Real-time tracking engine

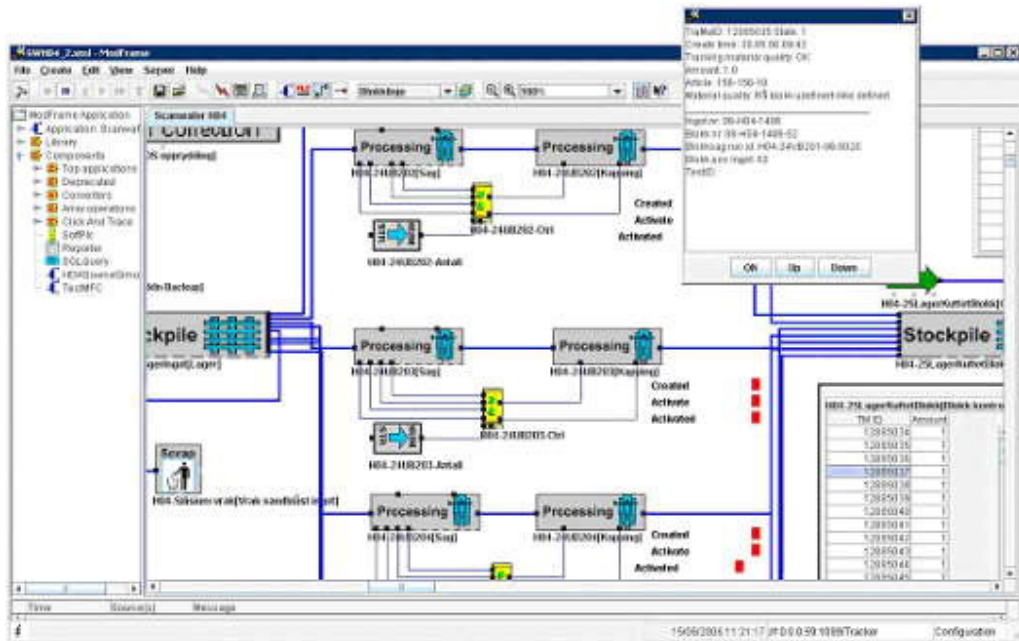
All tracking systems need a real-time tracking engine. The tracking engine logs signals and measurements related to material flow and processes. This can be done in the following ways:

- **Automatic data collection:** Measurements can be automatically collected from the process equipment via PLCs, a control system or similar system. The tracking engine collects the data via OPC or another communication protocol. The data collection rate can be from several 10- to 100 thousand signals per second.
- **Manual input:** User input via operator input screens, e.g. to check in feedstock, register manual measurements or to signal that an intermediate product has been moved from one process unit to another.
- **Combination manual and automatic:** Data can also be collected from manual or automatic identification mechanisms, such as bar code readers or RFID chips (Radio Frequency Identification).

Based on the collected data, the real-time tracking engine will calculate where the different material units are located within the factory at all times. When the tracking engine registers that a material unit is being transported in the process, it makes the necessary transactions with the tracking database to store tracking data as well as arrival and departure times to or from the processing, transport or storage unit.

The tracking engine will also aggregate or create new material units where this is necessary. For example, if an ingot is cut into blocks, new materials “child units” are created for the blocks from which the ingot was the “parent unit”. The ingot itself will disappear as an existing active element in the tracking engine.

In Prediktor’s tracking system the tracking engine is configured graphically (see figure below). Process elements are dragged into a drawing area where material flow paths are defined by connecting the process elements together. The tracking engine also has graphical modules where modeling calculations, logical calculations as well as any other needed calculations are performed. This graphical interface makes it easy for customer super-users to make changes to the process flow as changes occur in their factory.



Example of graphical configuration of real-time tracking engine (Ref. Prediktor)

The “Tracking in PV Production” articles are written by Steinar Saelid, C.E.O of Prediktor AS and professor in technical cybernetics at Norwegian University of Science and Technology (NTNU). Saelid has wide experience with process data systems, model based control, soft sensor technology and the control of quality in processes. Prediktor develops and delivers MES solutions for data collection, storage, analysis and reporting.

