Material Flow Simulation of TF Production Lines – Results & Benefits (Example based on CIGS Turnkey)

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Contents

1. Simulation of TF Manufacturing Lines
2. Enabling Factors for a Successful Simulation Project
3. Example Model
4. Simulation Output & Results
5. Benefits from Manufacturing Simulation
Material Flow Simulation of TF Manufacturing Lines

- **TF manufacturing lines**
  - high degree of automation for transport & material handling

- **Layout:** flow line, job shop or mix of both

- Typically a **tact time drives a flow line.**

- Substrates **MOVE, STOP, WAIT, ACCUMULATE**
  - Tact is often interrupted. → There is no flow of material!

- **Simulation clarifies the timing dynamics** in the manufacturing line.
Enabling Factors for a Successful Simulation Project

Systematic Input Data Acquisition
- Fab Layout
- Equipment Key Data (Timing Behavior, Availability)
- Constraints of Processes

Short Build-up Time of First Model
- Library-based EQ Components
- Standardized Interfaces of the EQ Components
- Flexibility to Add Features to EQ Components

Fast Model Execution and Flexible Output Generation
- Fast Simulation Execution
- Time Measurement between any Points in the Manufacturing Process
- Powerful Online-Statistics

Systematic Input Data Acquisition
- Fast Build-up Time of First Model
- Library-based EQ Components
- Standardized Interfaces of the EQ Components
- Flexibility to Add Features to EQ Components
- Fast Simulation Execution
- Time Measurement between any Points in the Manufacturing Process
- Powerful Online-Statistics
Building-up the Model – Think in Components!

- Model conception: **Separation** of the line in components.
- Each line component to be modeled with specific **timing behavior** including **unscheduled** & **scheduled down** time.
- Consideration of **total system availability** in a flow line.

![Diagram showing conveyor, process equipment, conveyor EQ & FiLo buffer, and inspection EQ.](image-url)
## Single Point Failures in a Flow Line

### Example Calculation

<table>
<thead>
<tr>
<th></th>
<th>Processing EQ</th>
<th>Material Handling &amp; Transport EQ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Availability in %</strong></td>
<td>96%</td>
<td>99%</td>
</tr>
<tr>
<td><strong>Unscheduled Down Time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>per year in days</td>
<td>14,6</td>
<td>3,65</td>
</tr>
<tr>
<td><strong>Repair Time Distrib</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 h</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>2 h</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td>4 h</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>8 h</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>24 h</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>MTTR in hours</strong></td>
<td>3,61</td>
<td>1,95</td>
</tr>
<tr>
<td><strong>MTBF in hours</strong></td>
<td>86,7</td>
<td>193,5</td>
</tr>
<tr>
<td><strong>Number of EQ in the Line</strong></td>
<td>33</td>
<td>140</td>
</tr>
<tr>
<td><strong>Average Number of EQ in Down State at One Specific Time</strong></td>
<td>1,38</td>
<td>1,41</td>
</tr>
</tbody>
</table>
Maintenance Scheduling & Buffer Management

EXAMPLE CONFIGURATION

Process Seg 4

WIP Buffer 3

Process Seg 3

WIP Buffer 2

Process Seg 2

WIP Buffer 1

Process Seg 1

Production  Scheduled Maintenance
Buffer WIP – Theory vs. Simulation

EXAMPLE CONFIGURATION

Process Seg 4
WIP Buffer 3
Process Seg 3
WIP Buffer 2
Process Seg 2
WIP Buffer 1
Process Seg 1

Production  Scheduled Maintenance

Buffer WIP Timeline

Simulation Output
InFrame Synapse Simulation Library - Rapid Simulation Model Building

InFrame Synapse Simulation Library Contents:

- Processing & Material Handling EQ for PV Manufacturing
- Routing and Dispatching Functions
- EQ State Models (processing, loading/unloading, maintenance, breakdown)
- Reports for Line Performance Monitoring & Online Statistics
- Optional: Interfaces for Communication with Control Systems (MES)
Systematic Input Data Acquisition

- **Example: Sputter Process EQ**

  - Substrate with SubstrateID & Size
  - Capacity: Number of Substrates in the Equipment
  - MTBF, MTTR
  - Maintenance Cycle
  - Yield Rate

  - Speed of Sputter Process
  - Constraint: Closed Carpet in the Process Chamber

  - Pumping Chambers:
    - Capacity
    - Pump Time → Tact
Timeline Reports & Cycle Time Histogram

WIP Timeline

Buffer WIP Timeline

Throughput Timeline

Cycle Time Histogram

Photon’s 4th Production Equipment Conference, 05.03.2009, Munich
Simulation Results & Input Data for TCO

- Variability in Material Supply & Safety Levels
- WIP Timeline, Inventory Statistics
- Buffer Capacity
- Required Equipment Capacity
- Product Cycle Time Statistics
- Line Throughput as Timeline
- Overall Line Yield
- Equipment & Line Utilization

TCO: Total Cost of Ownership
FC: Fixed Cost
RC: Running Cost
YC: Yield Cost
L: Lifetime
T: Throughput
Y: Yield
U: Utilization

\[
TCO = \frac{FC + RC + YC}{L \times T \times Y \times U}
\]
Line Simulation – Benefits for TF Manufacturers

- Systematic **input data collection** for engineering team
- Proof of **line control policies** → MES & line controller
  - Ramp-up, maintenance scheduling, buffer management
  - PUSH and PULL analysis
- **Transparency for factory dynamics**
  - Effect of single point failures
  - Verification of buffer capacities → investment!
- Proof of **capacity profile**
  - “De-Bottlenecking”
  - Required redundancy to guarantee output targets
- **Feeding TCO analysis** with dynamic data
  - Utilization and throughput considering dynamic yield and line dynamics
Benefits of Manufacturing Simulation

- **Planning Phase**
  - Material Supply Planning
    - Safety Levels
  - Early Bottleneck Identification, Line Configuration
    - Throughput Max.
  - Time-to-Volume
    - Risk Analysis, Data for Total Cost of Ownership

- **Ramp up Phase**
  - Line Simulation with MES
    - Shortening MES Integration Time
  - Appropriate Maintenance Scheduling
    - Verification of Higher Line Efficiency

- **Volume Production**
  - Detection of Efficiency Potentials
    - Cost Reduction

- **New Technology / Capacity Expansion**
  - Output Estimation in Transition Phase
    - Optimized Capacity Adaptation
Thank you for your attention!

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