Process automation with integrated weighing and batching systems

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Weighing and dosing is an important industrial subprocess which influences quality of production and products importantly. It is embedded in modern production structures which are integrated into business processes. The base of an optimum total process lies in the vertical consistency, from the management level to the process instruments, and in the horizontal consistency over all process steps (from the receipt of raw materials to the delivery of end products).
Aside from the accuracy in weighing and dosing, the conceptual integration of weighing systems into modern automation system contributes increasingly to the lasting success of a business.

1. Demands on weighing scales in the industrial process
Weighing and proportioning systems are assuming an important role in many industrial processes, with the widest possible variety of weighing tasks to be performed. Both programmable controllers (PLCs) and process control systems (PCSs) are used for automating the production process.

There are integrated system solutions available today for the automation hardware of the PLC and process control systems. These solutions break down the technological barriers between programmable controllers and process control systems. Breaking down these barriers opens up a new perspective on sharing weighing functionality between the weighing electronics and the PLC or PCS.

There are different types of weighing systems that work together with automation systems, depending on the task. The weighing systems differ externally in mechanical design. The design of the weighing system forms the basis for fulfilling its function. Since almost all modern weighing systems form a single unit with microprocessor-based electronics, the electronics and the software can be regarded as a component part of the weighing system. Production automation makes the following design demands on weighing systems:

• Flexibility in typical weighing functions
• Simple expandability of the weighing system
• Ability to adapt to the automation task
• Integrated communications concept

Weighing systems that meet these requirements can be regarded as an integral component of the automation system. In this sense, the weighing system is an intelligent automation object comprising

• Sensors
• Closed-loop control
• Actuators
It also performs its tasks in accordance with the specifications of the control system.

1.1 Flexibility in typical weighing functions
When considering typical weighing functions, the weighing systems used in the production process can be divided into two groups:

• Weighing systems for continuous weighing
• Weighing systems for discontinuous weighing

In the case of continuous weighing systems, weighing and proportioning is an ongoing process, e.g. weighing of material on a conveyor belt (belt scales), proportioning of an uninterrupted flow of material from a weighing container (loss in weight).
Discontinuous weighing systems are concerned with weighing portions in a process step, e.g. in producing mixtures according to a recipe (mixture scales), when filling sacks (bagging scales), or when checking product quantities (check weighers).
The differences in the tasks also determine the differences in the type of typical weighing functions of every type of scales. This is explained using the example of mixture scales and differential proportioning scales.
**Batching scales**

In the case of batching scales, it is necessary to control the proportioning operation as well as weight determination. During proportioning, the weighing electronics compare the actual product quantity already proportioned with the setpoint, and switches the proportioning signals for course feed and fine feed. A tolerance check is made at the end of the proportioning operation.

During a proportioning operation, through-flow monitoring checks that a minimum material flow is guaranteed. If required, proportioning aids such as vibrators and aerators can be activated automatically.

Along with the typical proportioning functions of batching scales described here, special demands are made of the weighing electronics in individual cases, such as setpoint correction during a proportioning operation. This can become necessary due to changing product properties, or new specifications from the process chain.

**Loss in weight scales**

With loss in weight scales, the electronics have another task in addition to measuring the weight – calculating the mass flow from the mass curve over time and controlling the mass flow in accordance with the specified setpoint. The proportioning container is filled with the product, and the proportioning equipment is completely weighed while the product flow exits the proportioning equipment in free fall. The weighing electronics measure the weight of the station at fixed intervals (fractions of seconds). The weight loss per time unit is calculated from the weight difference between the two measured values, taking account of the time difference. The follow-on controller uses the calculated actual mass flow and compares it with the setpoint mass flow.

In the case of deviations, the control signals are output to the proportioning equipment in order to achieve the desired discharge.

In a concrete industrial application, different types of disturbance influences are at work in the system such as shocks or vibrations that corrupt the measurements of the weight. There are a variety of strategies for handling such disturbances. In addition, problems such as the refilling of the weighing container have to be managed. The quantity of material stored in the proportioning station is continuously reduced by the discharged mass flow. When the minimum weight is reached, the weighing container must be refilled. During refilling, the proportioning equipment continues to discharge mass. Since control of the mass flow is not possible during this time, material discharge is carried out retaining the operating parameters prior to filling.

To maintain the desired mass flow, there is a variety of strategies available, similar to those used during the gravimetric phase to deal with disturbance. It is important to gain control of the changes in product properties in the weighing container using closed-loop control methods.

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![Fig. 1: Timing diagram of a proportioning cycle on batching scales](image1)

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![Fig. 2: Working principle of differential proportioning scales](image2)

Loss in weight scales that are simultaneously a component part of an automation system offer many methods of optimizing the process sequence in conjunction with the automation components. Detailed study atp 9/98 [3] of integrating weighing technology into process control systems, and practical experience with filling and batch scales show that it makes sense to accommodate part of the scales functionality in special electronics. If these special electronics, that can be used primarily for signal preprocessing, proportioning monitoring, and possibly closed-loop control, are implemented as a module in an automation system, all the benefits can be optimally combined.

By directly embedding the weighing electronics in the automation system, and thus creating optimal interaction with the CPU, the functions can be shared according to requirements. Faults that could occur as a result of violating the sampling theorem are prevented by high measurement resolution, real-time signal processing, and filtering in the weighing electronics.
Freely programmable, modular weighing systems, assembled using standardized components of the automation system, provide good a basis for expanding the weighing functions in an automation system. Thanks to the programmability and scalability of the automation system, the different types of weighing functions can be implemented using just a few types of weighing modules. The weighing module meets the standard requirements, and adaptation to the specific sector takes place in the automation system, making logistics and maintenance easier and more efficient. Practice shows that this approach is extremely promising. It enables plant operators to implement an optimal solution tailored to their requirements. Such a standardized and integrated solution offers significant benefits in all phases of the plant life cycle: sequences for ordering, configuring, programming, startup, operation, maintenance, and service are simplified.

1.2 Simple expandability of the weighing system

With batching scales, bagging scales, filling scales, loss in weight scales, and weighfeeders, extensive closed-loop and open-loop control functions must be implemented in addition to the weighing functionality. Multi-component scales for producing mixtures, for example, can be put together from standard automation system components (e.g., weighing modules, analog input/output modules, binary input/output modules). The weighing modules are not only simple weight transducers. They also handle the function of single-component scales. Two digital outputs direct on the weighing module are sufficient because in the case of multi-component scales, they can be connected to the proportioning equipment of a specific silo via digital output modules of the automation system. Thanks to scalable design, the number of storage silos is not limited by a specific hardware configuration of the weighing electronics. The recipe sequence control of the higher-level control system transfers to the weighing module the product-specific proportioning parameters for individual components such as set-point, coarse flow and fine flow cutoff value, tolerance limits, settling time, and monitoring limit values.

Thanks to the sharing of tasks between the weighing electronics and the PLC CPU, the control functions are independent from the weighing and proportioning function when the PLC program is expanded to suit the task. This reduces the probability of programming errors. The overhead for interface software for external weighing electronics is reduced, possible runtime problems in the case of system expansions are prevented, and the commissioning time is reduced. In addition, this imposes limits on the volume of information to be exchanged, and system efficiency is retained.

1.3 Integration into the automation environment

As integral components of automation solutions [2], scales face additional demands to those of scales functionality (accuracy, resolution). These demands relate to cost of ownership in particular. Scales that on the one hand perform weighing tasks in an automation system, and on the other hand, work optimally together with this automation system in all respects, must appear to the automation system to have all the properties of an integral part of that system. What properties does an automation system expect?

Standardized hardware and software

Standardized and tested hardware and software form the platform for the automation system. Optimized configuring tools reduce the engineering overhead. High quality of the automation components forms the basis for system reliability.

Alarm concept, diagnostics

During operation, it is extremely important not only to quickly detect and diagnose actual faults, but also to detect changes in plant characteristics and thus prevent possible faults in the future. The diagnostics capability of an automation component encompasses system and process diagnostics. System diagnostics includes acquisition, signaling,
and evaluation of statuses within an automation or process control system.

Process diagnostics involves acquisition, signaling, and evaluation of process statuses. Process diagnostics analyses process-oriented statuses and sequences and tests them for, e.g. reliability. The aim of diagnostics functions is to achieve more efficient startup and operation. By using load cells with an exceptionally long service life and weighing modules with an MTBF of well over 100 years in conjunction with modern service methods it is possible to achieve excellent availability.

1.4 Integrated communications concept

The integrated communications concept of an automation system is also used by the integrated weighing module. It is incorporated into the structure of the organization’s communications levels.

Fig. 4: Weighing electronics in the communications network of the automation system

To an increasing extent, scales integrated into an automation system can utilize the full performance power of the system, for example for remote loading of new software, for example. This can refer both to improvements in weighing functionality as well as simple troubleshooting.

The necessary replacement of a module in the event of a fault can be carried out in the shortest possible time because the replacement of tools integrated into the automation system is supported. These can include configuring tools, integrated detection routines for new hardware, and automatic parameterization. A start has already been made in using the Internet for these purposes. Diagnostics functions provide the greatest benefit when statuses from the production process and the automation system are acquired, analyzed, and visualized, or actions are automatically triggered throughout the system and according to standardized principles. The benefits of process diagnostics can be shown clearly using the example of filling scales from Siemens – SIWAREX A/AWS integrated into the automation system.

The SIWAREX A module automatically controls fast filling of the product with a cutoff accuracy of less than 1 ms. It calculates the statistical data from a large number of proportioning operations. Now it is easily possible to analyze the data in an automation system in order, for example, to determine a slow deterioration in the proportioning quality, and to initiate a check of the filling system at the right time, before the deterioration in proportioning quality necessitates actual stopping of the process.

2. Solution approaches for sharing the weighing functions

Sharing of weighing functions in the automation system has been subject to constant change in recent years. The reasons for this are found in the search for efficiency in solving weighing tasks in the automation environment. The performance power of the hardware components is no longer of itself the decisive factor in choosing a certain solution architecture. A modern weighing solution has to meet the following scales-related requirements:

- High level of operating safety
- Simple operation
- Extremely good reproducibility
- High accuracy

It also has to meet the following requirements with regard to the automation characteristics:

- Integration (hardware/software)
- Flexibility
- Standardization

User-oriented implementation results in the following three aspects:

- Accuracy and reproducibility requirements demand the use of special high-quality functional units for signal acquisition, signal adaptation, A/D conversion, pre-processing, and open-loop and closed-loop control functions. The task demands that the weighing signals have a resolution of up to one million digitization steps. Control of material flows in proportioning and filling using the binary signals from the scales must be carried out with a time resolution of down to one millisecond.

- In addition, different functions are necessary for the solution of the overall task, depending on the application. The entire added-value chain of the production system must therefore be considered. The examples given here are the automatic filling of silos or the removal of the end product. A system is required here that allows the necessary functions to be implemented simply.

- It is also necessary to integrate weighing systems as fully as possible into the overall automation system. This not only encompasses the communicati-
on system, but also requires the functional integration and engineering of all automation functions with standard tools.

These aspects result in the following solution that meets all requirements with minimum overhead:

- Weighing function modules possessing the required hardware and firmware as standard, to meet high accuracy requirements and time-critical tasks. These function modules have all the features of the standard automation system and are therefore fully compatible.

- Use of standard automation systems allows the implementation of application-specific tasks. This enables not only the use of the standards for engineering, visualization, and archiving, etc., that are used anyway, but at the same time total integration of the entire automation system without additional overhead. Here, sector-specific and application-specific solutions can be implemented with particular flexibility. Special weighing and process engineering methods or recipes can be software-protected against access by third parties (know-how-protected).

- This concept thus turns weighing technology into an automation object integrated into the overall automation system. Thanks to the total compatibility mentioned above, the standard automation functions and the weighing functions now form a homogenous unit from the user’s point of view, thus meeting demands for integration, ease of use, and flexibility based on existing standards.

Of course, in this solution the components used can be arranged either in centralized or distributed configurations. The advantage of centralized configuration is the time-optimal interplay of the controller CPU and the weighing processor. With distributed configuration, that is, where components are integrated into the scales, the weighing system simply becomes an autonomous field device connected to the automation technology via the open PROFIBUS system.

3. The benefits of integrating scales into the automation system, as shown by automatic filling scales (AWI)

OIML - Automatic Weighing Instrument

Filling scales usually operate within the environment of an automation solution. The product must be supplied, the containers to be filled must be available at the right time, and further transport of the filled quantities must be controlled. The earlier solution of this task provides for automatic filling scales (automatic scales for weighing) connected to a PLC (programmable controller). The scales operate independently and the volume of data to be exchanged with the PLC must be kept low.

Fig. 5 gives a schematic representation of this solution approach.

Fig. 5: Interfaces for weighing data in conventionally connect

Fig. 6: Filling scales based on SIWAREX AWS from Siemens

A new solution provides for the integration of the weighing electronics into the automation system. The weighing electronics are a component part of the automation system. The binary input/output modules are used for system control. The scales and other system sections are parameterized (e.g. proportioning speeds) using the operator panel. If required, a printer can be connected direct to the weighing electronics or to the operator panel, or to the control system via a standard interface module. Non-time-critical tasks can be defined flexibly in the PLC central controller using the standard languages of IEC 61131, for example. An example of just such an integrated weighing system is the combination of SIWAREX (weighing module) + SIMATIC (PLC) from Siemens.

Integration of the weighing electronics into the PLC opens up new, previously unavailable possibilities for the plant planner and operator. These are essentially the following:

- No additional software for connecting external scales
- Optimal coordination of the system modules
• Application-dependent scalability of the system
• Cost optimization through requirement-oriented system expansion
• Integrated documentation
• Integrated function and operator philosophy
• Solution of control tasks within one system
• Customized adaptations thanks to free programmability
• Innovations are system-wide
• Independence in selecting resources

Fig. 7: Automation concept with integral weighing electronics

The benefits of the integrated concept become more marked in multi-scales systems. Functions like human machine interface, signaling and logging, plant control, scales interlocks, and diagnostics, are available once for all scales on a single hardware platform and do not need to be set up in the weighing electronics of every set of scales. This distribution of functions allows efficient dimensioning of the overall system.

4. Summary

The advantages and disadvantages of integrating weighing electronics into automation systems dealt with in this article are summarized in Table 1. From the point of view of the planners, maintenance engineers, and operators, the benefits of the integrated solution outweigh the disadvantages (cf. Column 1 in Table 1).

Table 1: Advantage of integrating weighing electronics into the automation system.

<table>
<thead>
<tr>
<th>Benefits:</th>
<th>Disadvantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration or improved connections of PLC and weighing electronics</td>
<td>Weighing electronics restricted to automation system manufacturer</td>
</tr>
<tr>
<td>Uniform hardware basis</td>
<td>Different hardware platforms</td>
</tr>
<tr>
<td>Uniform interfaces and protocols</td>
<td>Different interfaces and protocols</td>
</tr>
<tr>
<td>Standardized tools for configuring and maintenance</td>
<td>Interface adaptation results in increased planning and startup overhead</td>
</tr>
<tr>
<td>Integrated and automated documentation</td>
<td>Different tools for planning, startup, and maintenance</td>
</tr>
<tr>
<td>Simple expansion facilities thanks to open interfaces and shared hardware platform</td>
<td>Some of the wide variety of functions not required</td>
</tr>
<tr>
<td>Improved spare parts management thanks to uniform hardware basis</td>
<td>High overhead for documentation</td>
</tr>
<tr>
<td>Simplified planning and startup thanks to standardized interfaces</td>
<td>Expansion possibilities frequently limited by interface bottlenecks</td>
</tr>
<tr>
<td>External weighing electronics connected to automation system</td>
<td>Wide variety of types and manufacturers generates high overhead for spare parts management</td>
</tr>
</tbody>
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