Recipe Control

Introduction

For multipurpose plants it is not reasonable to create a complete PLC-code for one product. It is much more effective to define an interface and a recipe description language, which can be used by the production enginer to configure production logic. This leads to more intelligent and advanced control applications for batch plants. Control modules provide a powerfull interface to control the plant and sequence logic is described in the widely used Sequential Funkction Chart. All control details are solved within the module and the user has only to draw a SFC and define the parameters to specify the operation mode of the modules. A recipe define the parameters values of the control modules for all production steps. A recipe is therefore a minimal collection of information that defines the manufacturing requirements for a specific product. This processing is called a batch process and is ubiquitous. It is most prevalent in pharmaceutical, food processing and specialty chemical industries.

In order to be able to realize a recipe controlled plant, it is necessary to well structure plant software. A commonly used structure, defined in the ISA SP88 norm, will be described. In order to get a feeling of a control module a short description of a sample module is provided. Finally further concept for recipe structuring and handling are provided.

Plant control model

For batch control a hierarchical software model is preferred. The complete task of controlling a plant is split into control units as shown in Figure 1. It is reasonable to structure the PLC-software in a corresponded form. As a consequence, modules can be exchanged with a minimal effect to the control software. Furthermore, the equipment module defines the natural interface for recipe control. In the following, the modell in Figure 1 is explainde in detail.

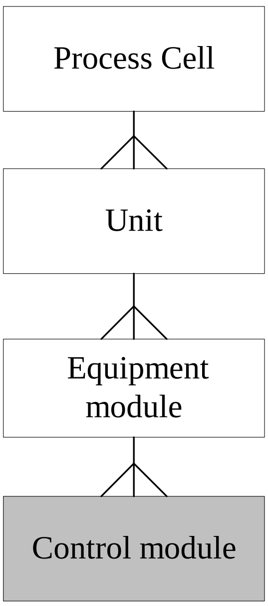


Figure 1 physical Model

The bottom layers consists of the control module. The control module software handles the PLC-interface to the plant and provides, due to ist control logic, smart devices to be used in the quipment module control. Examples of control modules are motor control or sophisticated sensors which are controlled from the PLC-Logic. Furthermore, control module units may contain elements to define display properties on a SCADA-System, including limit control to create warnings. In intelligent devices like frequency controlled motors, a control module can also implement feedback control.

The next level is the equipment module control. An equipment module is a functional group of equipment and/or control modules that can carry out a finite number of specific processing activities. It offers a secure interface for plant control, without having to know all the details the module. This is also the interface for most of the recipe control systems. In Figure 2 a batch plant example is shown. The units in a coloured rectangle are equipment modules, e.g. Feeder-Modules, Temperatur Control Modules and so on. The equipment module software usually contains most of the plant control know how. It also the re-used software entities in industrial automation and are therefore kept in user libraries.

The next level is the 'unit'. A unit is a collection of Equipment Modules that can carry out one or more processing activities. Unit control is usually realised as a recipe control system, which defines control of the Equipment Modules. Several Units a grouped to a Process Cell. This is the entity capable for production of a product. Its control logic is teh managenemt of recipes for its Units.

Structuring of control software into modules was standardized in various produktion industries. In Chemical process control the German Norm NAMUR NE33 proposed control modules similar to the equipment modules in ISA SP88.1.

Corresponding standardisation occured in the machin, for example in OSACA (Europa) or OMAC (USA, Japan).

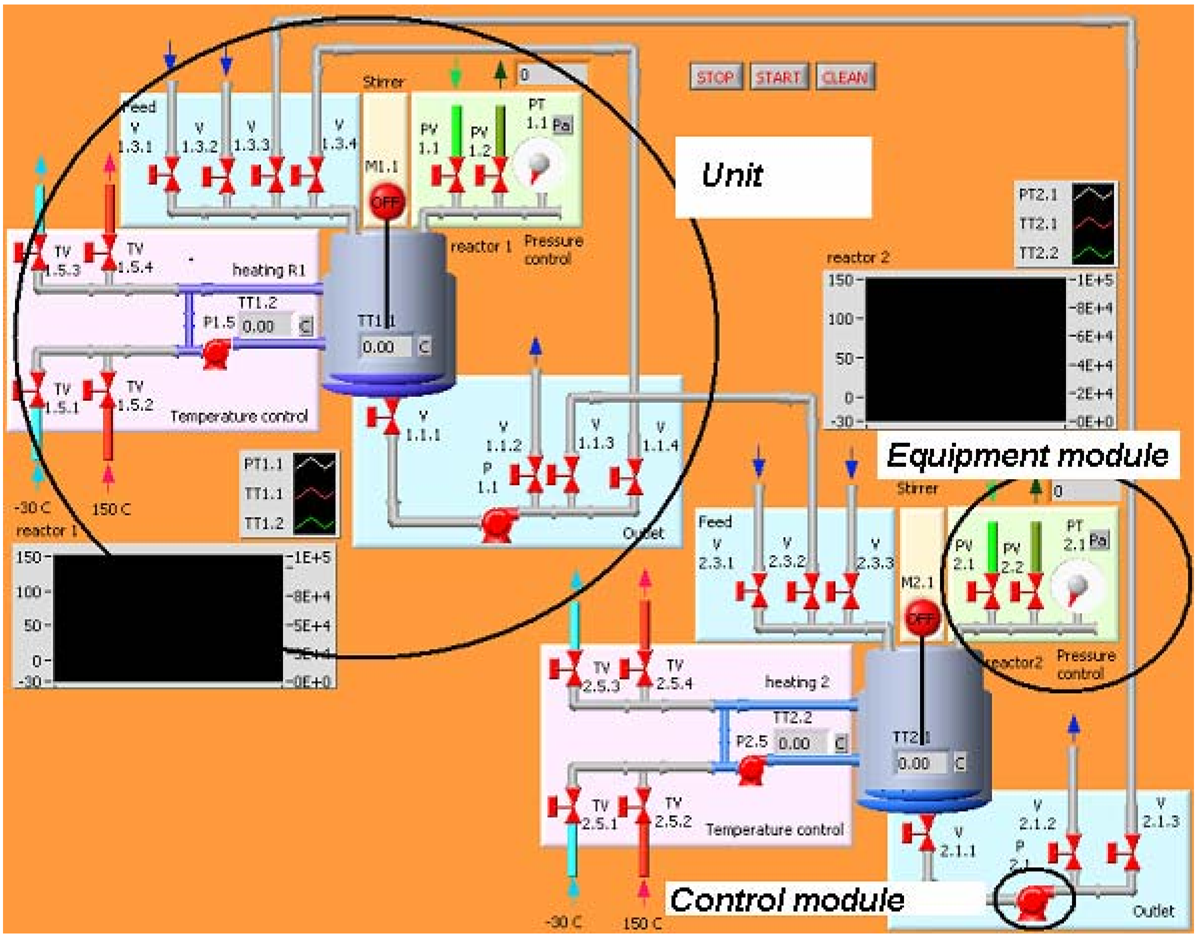


Figure 2: Structuring of a Batch Plant

Equipment module control

Since the equipment module control provides the user interface for recipe control, a detailled description of its use is necessary. Today, production is often transferred from one production site to another. As a consequence, a general recipe has to be mapped to different site recipes. This process is strongly simplified if similar modules are parametrized in the same way. For example, it is reasonable to have a similar interface to all modules in charge of temperature control. In information sciences, Object Oriented Design with classes and class inheritance are widely accepted. Similar concepts can be used for equipment modul control and ist documentation. A class description for all temperature controlling modules can be build. For individual modules the class description is extended or specialized. A major focus has to be set on the operation modes of the modules. The more the operation modes are standardised, the easier it is to create a recipe, to control the equipment modules on the HMI and to document the module.

In the following an example of a class oriented description of a control modul is provided.

Documentation of equipment module control

The documentation of a class of equipment modules may consist of the following chapters:

1. General
    - 1.1 General Description
    - 1.2 Abbreviations and Definitions
    - 1.3 Class History
2. Parameters
    - 2.1 Description of Operation Modes
    - 2.2 Parameters Description
    - 2.3 Parameters and Ranges as a function of Operation Modes
3. Safety
    - 3.1 Description of Safety Functions
    - 3.2 Safety Table
    - 3.3 Safety vs. Operation Modes
4. Controls
    - 4.1 Description of SCADA control
    - 4.2 Description of local controls
    - 4.2 manual control
    - 4.3 drawing of local controls
5. Devices

A simplified, table based description of chapter 2 and 3 für a temperature control module is proposed in the sequel.

2.1 Operation Modes

	Processparameter		
Operation Mode A	Description	active Devices	GoOn Condition
0: Off	Not active	no	TRUE
1: Wall Temperature Control	The temperature feedback controller regulates wall temperature Tx.2 to setpoint (Par 3)	Temperature Control Valve TV x.5.1 - 4	TRUE if temperature is inside range for 5 min
2: Reactor Temperature Control	The temperature feedback controller regulates reactor temperature Tx.1 to setpoint (Par 3) using a cascaded control structure with wall temperatur control.	Temperature Control Valve TV x.5.1 - 4	TRUE if temperature is inside range for 5 min
3: Reactor Temperature Control with Temperature difference limitation	The temperature feedback controller regulates reactor temperature Tx.1 to setpoint (Par 3) using a cascaded control structure with wall temperatur control. Setpoint of the wall temperature controller is limited to [Tx.1 - ΔT ... Tx.2 + ΔT]. (ΔT: Par 4)	Temperature Control Valve TV x.5.1 - 4	TRUE if temperature is inside range for 5 min
4: Ramped Reactor Temperature Control	The temperature feedback controller regulates reactor temperature Tx.1 to setpoint (Par 3) using a cascaded control structure with wall temperatur control. Setpoint of the reaktor temperature controller is ramped with Ramp velocity(Par 5)	Temperature Control Valve TV x.5.1 - 4	TRUE if temperature is inside range for 5 min and final setpoint value is attained

2.2 Parameter description

Nr.	Name	Unit	Description
1	manual control enabled	Bool	enables manual control
2	operation mode A	Enum	Temperature control mode
3	Setpoint	°C	Setpoint for Temperature Control, Controller selected according to operation mode
4	Delta T	°C	allowed Temperature difference
5	Ramp velocity	°C/min	maximal rate of change of a setpoin
6	T-limit high	°C	Low Limit for Temperature Monitor
7	T-limit low	°C	High Limit for Temperature Monitor

2.3 Parameters and Ranges as a function of Operation Modes

Parameter	Parameter and Range (X: no special limits)														
Operation mode	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1: Wall Temperature Control	X	X	X			X	X								
2: Reactor Temperature Control	X	X	X			X	X								
3: Reactor Temperature Control with Temperature difference limitation	X	X	X	X		X	X								
4: Ramped Reactor Temperature Control	X	X	X		X	X	X								

3. Safety

3.1 Description of Safety Functions

Name	Description
TSL	- Softswitch, can be parameterised (Par 6) - creates Alarm 1, acknowledge not necessary. - cooling valve is forced to close
TSH	- Softswitch, can be parameterised (Par 7) - creates Alarm 1, acknowledge not necessary. - heating valve is forced to close
TSHH	- Temperature limit switch, Device - leads to fast stop - acknowledge necessary. - emergency cooling is started

3.2 Safety Table

In a safety table all safety related actions of the control software are summarized.

Name			Safety Level							Action				State			Remarks
	Sensor	H:Hardware Switch	Fast Stop	Fault 2	Fault 1	Warning	parametrised?			Cooling valve	Heating Valve	Pump		state bad			Si = Safety Action AU = automatic control
TSL	TT x.1	S			X					SI	Au	Au		X			
TSH	TT x.1	S			X					Au	Si	Au		X			
TSHH	TSHH	H	X				X			Si	Si	Au		X			

3.3 Safety vs. Operation Modes

Functionality of safety action may depend on the operation mode. This is documented in the following table.

	Operation Mode					
Safety Switch	0	1	2	3	4	5
TSL		X	X	X	X	
TSH		X	X	X	X	
TSHH		X	X	X	X	

Recipe Control

A sequential function chart with parameterized action is called a recipe. The PLC-Norm IEC61131-3 does not foresee to use actions with parameters. Nevertheless, based on the former GRAPHCET-Norm SFC-programmable recipe control in process industrie was available since 1994.

Recipe control provide the tools and formalism for a production engineer to configure unit control without changing code and without help of a control engineer. Today, it is desirable that a production recipe can be formulated in a way that it is independet off the production plant. A plant independent description can be transferred from one production site to another. Obviously a plant independet recipe cannot be used directly to control a plant. The recipe has to be adapted to a specific plant. In order to do this in a standardised was, the ISA SP88.01 Norm was borne in a rather lengthy and cumbersome way. In the following, the recipe modell will be described.

Recipe model:

The recipe model of the Norm is shown in Figure 3.

The „General Recipe“ is a plant independent description, how a product has to be manufactured. The „Site Recipe“ will be created from the „General Recipe“ and takes account of the local materials, language and also for locale product variants (e.g. 220V power supply). The „Master Recipe“ ist a map of the 'Site Recipe' to a plant specific recipe. Here, the capabilities of the plant, i.e. the available variants of equipment modules have to be considered. Finally the recipe for one product batch is called the 'Control Recipe'. Mapping a recipe from a Master recipe to a control recipe is not an easy task. Several research project were done to investigate, how this map can be supported. Whenever a step has to be refined into substeps, it is a benefit to include hierarchical concepts into SFC.

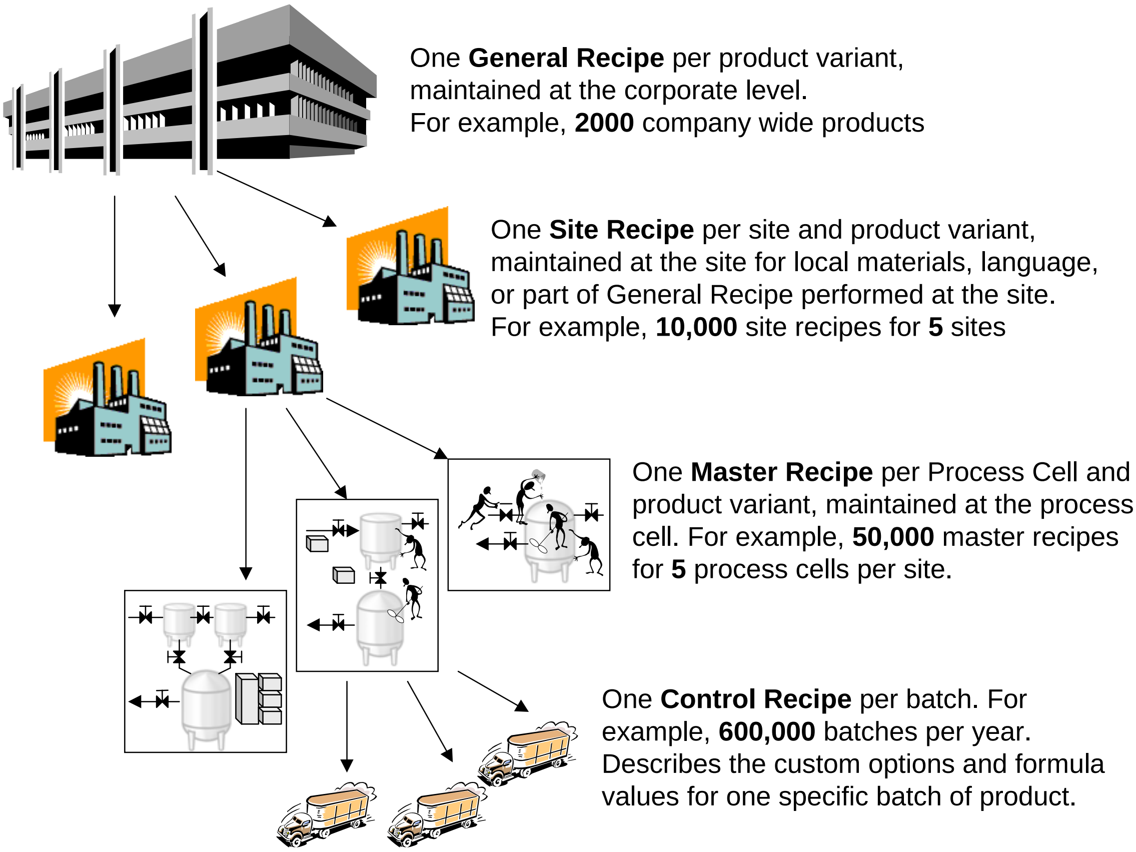
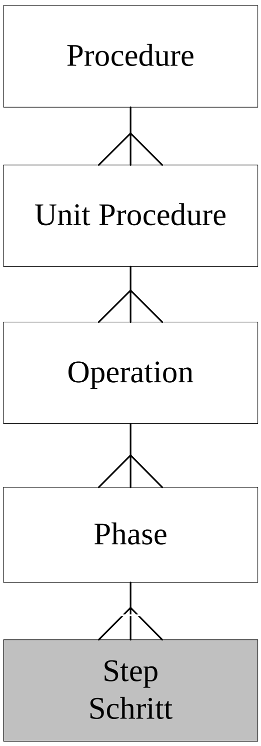


Figure 3: Recipe Structure



A hierarchical structure results from the procedural structuring of a recipe, as shown in Figure 4. A General Recipe and a Site Recipe are a manufacturing description at the Procedure and Unit Procedure level. As soon as it is clear, on which type of plant a product will be produced, it is reasonable to specify the operation and phase level. For a specific plant with a know set of equipment modules, it is possible to specify the step level. A Control Recipe may contain step sequences, but it is worthwhile to handle step sequences within the equipment module control software.

Figure 4: recipe hierarchy