Tool PIDMaker

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CONTENTS

1. INTRODUCTION

The tool PIDMaker is a visual superstructure of PID instructions of PLC that is used for easy implementation, tuning and administration of regulation algorithms. According to the entered algorithms, PIDMaker generates automatically an algorithm that is integrated into the user's project. In addition, it offers an interactive preview to the course of regulation that enables correct setting of parameters of the regulator.

1.1. Basic terms for a description of regulation algorithms

Connection of the technologic equipment with a regulator is called generally *closed regulation circuit (URO)*. Its scheme is shown on the following picture.
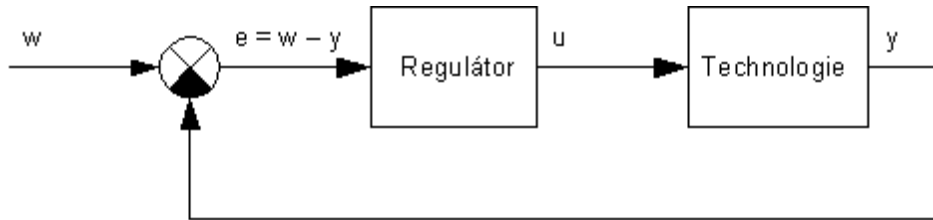
Symbols in the scheme have the following meanings:

w – desired quantity
e – regulating deviation
u – action quantity (action intervention)
y – regulated (measured) quantity

The basic function of the regulator has to set the action quantity so that the regulating deviation (difference between the desired and regulated quantity) is zero.

1.1.1. Algorithm PID

$$u(t) = K \cdot \left[e(t) + \frac{1}{Ti} \int_0^t e(\tau)d\tau + Td \cdot \frac{de(t)}{dt} \right]$$

The regulator, working on the basis of an algorithm PID, calculates the action quantity using three components – proportional, integration and derivation ones.

The proportional component of the quantity is given by the following formula:

$$u_p(t) = K \cdot e(t) ,$$

where *K* is amplification of the regulator. When the regulating deviation approximates to zero, also this component of the action quantity approximates to zero. This means that the proportional component itself cannot eliminate completely the regulating deviation, except regulation of astatic processes. Setting of a high value of amplification leads to lower regulating deviations in stabilized state, however, at the same time it causes oscillation of the regulation process and big action interventions. Too high value of amplification may even lead to instability of the regulation circuit.

The integration component of the action quantity is given by the following formula:

$$u_i(t) = \frac{K}{Ti} \int_0^t e(\tau)d\tau ,$$

where T_i is integration constant of the regulator in time units. Thus based on the formula, the integration components is proportional not only to the size, but also to the time period for which the regulating deviation continues. The integration component of the action quantity eliminates the permanent regulating deviation. As lower setting of the integration constant, as faster growth of the integration component of the action intervention. Too low values of the integration constant lead to oscillating course of regulation or even to instability of the regulation circuit. Too high values of the integration constant lead to slow reaching of the desired value.

The derivation component of the action quantity is given by the following formula:

$$u_d(t) = K \cdot T_d \cdot \frac{de(t)}{dt} ,$$

where T_d is a derivation constant of the regulator in time units. The derivation component is proportional to speed of the change (first derivation) of the regulating deviation. This component itself does not eliminate the regulating deviation, but improves the course of regulation with its effects against changes of the regulating deviation. Too high values of the derivation constant lead to slower regulation and high sensitivity to noise.

1.2. Opening of PIDMaker

The tool PIDMaker can be opened by clicking on the icon on the tool bar of Mosaic or by selecting it in the menu Tools > PIDMaker. After opening of PIDMaker there will be opened the main screen that is used as manager of individual regulation algorithms (the main screen opens in the new project docked in the left panel of the Mosaic desktop).

2. MAIN SCREEN

Tool bar

List of regulators

Information on the tool
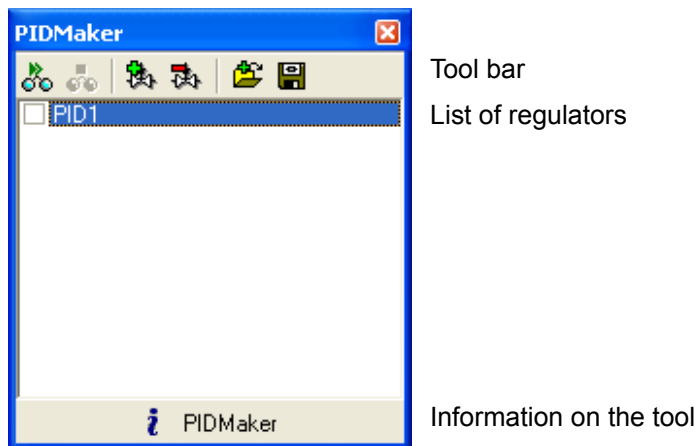
2.1. Tool bar

The tool bar in the main screen provides basic operations for work with implemented regulation algorithms (regulators).

Opening of all visualisations – switches over all visualisations in the list of regulators into active state (see active and passive visualisation states). This option is only active if all visualisations are not opened.

Stoppage of all visualisations – switches over all visualisations in the list of regulators into passive state. This option is active only if at least one visualisation is active.

Adding a regulator – this opens a guide (sequence of forms; a description see the Guide through adding a regulator) for creation of a new regulator. This option is only accessible if no visualisation is active.

Taking a regulator away – this option takes a regulator, selected in the list, from the project. In case that there is no regulator in the list, the option is not active.

Adding a regulator from the set – this option adds a previously saved regulator to the project (saved even in another project). This option is only accessible if no visualisation is active.

Saving a regulator into the set – this option saves the selected regulator into the set that is neither dependent on the project nor on the project group. Thus it can be used for copying of regulators among the projects.

2.2. List of regulators

The list of regulators under the tool bar allows opening and closing of individual visualisations by checking the box at the regulator name. Opening of a visualisation or a double click on the regulator name opens a regulator screen, see below. The context offer of the list of regulators (initiated using the right mouse button) provides all the above described functions on one place.

3. GUIDE TO ADD A REGULATOR

After choosing a regulator from the tool bar or context list menu of the regulator in the main screen the first dialog box opens, where the user shall enter a name of the regulator and its type. The name of the regulator is used later to name the variables relating to the regulator; therefore it is not permitted to use any diacritical signs and non-standard symbols except the underscore character.

In case of a PLC supporting the language ST according to IEC 61 131 there can be chosen whether declarations will be generated in the language ST. Detailed information see Code and generating.

Other dialogs depend on the selected type of the regulator. Now there are two options available: PID and PIDA. All dialogs and settings are accessible later through the regulator screen.

NOTE: It is advisable to translate the project before adding a regulator. Without translation it is not possible to verify declaration of variables.

4. PID TYPE REGULATOR

The automatically generated code for the regulator type PID is based on instructions CNV and PID (see the Set of instructions PLC TECOMAT – TXV 001 05). A description of individual dialogs after adding a regulator follows below:

4.1. Selection of a regulated quantity source Y1

Symbolic name of the input   Type of unit/module

Indication of input overflow

Selection of the range

Setting of filtration   Setting of scaling

Here it is necessary to enter a symbolic name of the variable regulated quantity and select the way of its normalisation (that is ensured by the CNV instruction of a part of the generated algorithm). In most cases it is sufficient to select a correct type of the unit or module for normalisation (selection is limited according to the hardware configuration) and input range. The table with options of ranges includes three columns. The first column shows ranges of analog values, the second column sets units of types on inputs and the third column shows the normalised range.

The input variable shall be in the format INT (WORD), unless specified otherwise in the column "Range (type) of the unit/module".

Unless the input from another source or its normalisation is satisfying, you can select another source instead of the unit/module. The input from another source may be in the format INT (WORD) or REAL (FLOAT). In case that the input is in the format INT, its value is transferred without any modification to the input of the instruction PID. In case of the format REAL the value is converted to a native value of the instruction PID format (INT) and therefore it is necessary to specify a number of fixed decimal places. Selection of the unified range REAL * 10 selects one decimal place (18.543 corresponds to 185, input PID is in tenths). Selection REAL * 100 selects two decimal places (18.543 corresponds to 1854, PID input is in hundredths).

Modifications of filtration and scaling can be applied to all types of the input, see below.

In addition to a name of the variable you can also enter names of bit variables, indicating overflowing/underflowing of the input value. These bits are provided by all analog boards for the series PLC TC700. In case that some of these bits is set to logic 1, this state is evaluated as an error of the input. Independently on the fact whether these bits are used or not, the limit input values $7FFF (32767) and $8001 (-32767) are considered as an error of the input as well.

4.1.1. Modification of the unified signal

Filtration (1ˢᵗ order) – It is suitable to use filtration for elimination of noise of the regulated quantity that causes unnecessary regulation interventions (in particular with the derivation component). The normalised value of the variable is modified by a digital filter of the first order with a time constant, entered in multiplies of the PLC cycle period. At the same time, the PLC cycle period is equal the sampling period of the filter.

Scaling (linear interpolation) – Scaling can be used for a modification of the normalised range. The normalised value of the variable is recalculated to a new normalised value defined by a straight line that is defined by two points. The points are entered using two values of the original unified range and matching values of the new range.

4.2. Selection of a regulator modes

The dialog box offers options of modes in which the regulator has to work.
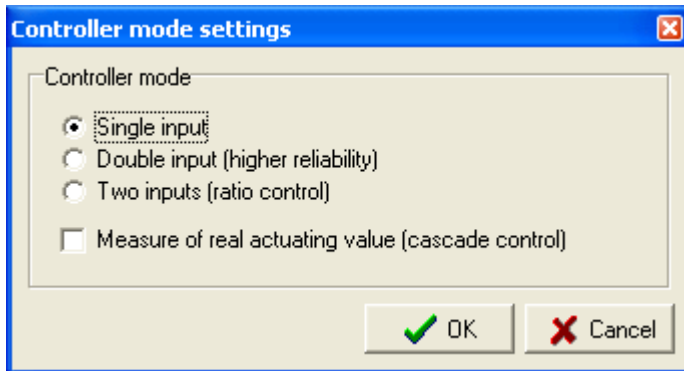
4.2.1. Regulator mode

One input – basic mode of regulation with one input of the regulated quantity.

Two inputs (higher reliability) – the same as one input, however, two sources are used for measurement of the regulated quantity. The value of the regulated quantity is equal to the average of both values. In case that one of the sensors is in an error state, there is only used the value of the other sensor.

Two inputs (proportional regulation) – the same as one input, however, instead of direct entry of the desired value there is entered the desired proportion to the other input. The desired value is then calculated as a product of the desired proportion and value of the other input.

Measurement of the actual action intervention (cascade control) – this option can be used with all the previous modes. This mode allows corrections of the action interventions of the main regulation look according position of the action member. The mode assumes an astatic action member (e.g. servo valve), whose position is measurable.

4.3. Selection of the second source of the regulated quantity Y2

This dialog appears only with selection of the mode Two inputs (higher reliability). The dialog is identical with selection of source of the regulated quantity Y1, only includes a check box "same as Y1" that sets up the values chosen previously for the input Y1.

4.4. Selection of a source of quantity for proportional control Y2

This dialog only appears when the mode Two inputs (proportional regulation) is selected. The dialog is identical with selection of a source of the regulated quantity Y2.

4.5. Selection of a source of actual position of the action member Y3

This dialog appears only with selection of measurement of the actual action intervention. The dialog is identical with the dialog for selection of a source of the regulated quantity Y1. Instead of scaling it is necessary to enter the values of normalised range which correspond to positions 0% and 100% of the action member.

4.6.   Regulator parameters

The dialog allows setting of all parameters of the regulator itself.

Proportionality band (PBnd) (0.1 to 3000%) – this gives indirectly amplification of the regulator. This item is bound with entered amplification by the following relation:

$$K+ = 100\% / PBnd$$

Amplification (K+) = amplification of the regulator (0.03 to 1000).

Relative proportionality band for negative values of the regulating deviation (RelCool) – (0.1 to 3000%) gives indirectly amplification of the regulator for a negative deviation and can be used wherever, where the technology behaves differently with positive (e.g. heating) and negative (e.g. cooling) action interventions. When entering a value 100% this item has no effect. Amplification for negative values of the deviation is determined by the following relation:

$$K– = 100\% / PBnd * 100\% / RelCool$$

Amplification for negative values of deviation (K–) – amplification of the regulator for negative values of deviation (0.03 to 1000-times amplification K+).

Integration time constant (Ti) = integration constant of the regulator (0 to 3000.0 s). After entering 0 the integration part of the regulator is switched off.

Derivation time constant (Td) – derivation constant of the regulator (0 to 3000.0 s). When entering 0 the derivation part of the regulator is switched off.

Symmetric band of insensitivity (0 to 100%) – in case that values of the deviation is in the band of insensitivity, action intervention remains unchanged. This value eliminates unnecessary action interventions in case that the regulated quantity comes sufficiently close to the desired value.

Symmetric band of the integration component effect (0 to 100%) – in case that the deviation value is outside the band of integration component effect, the integration component is inactive. Setting to 0% disables the integration component.

Symmetric band of the derivation component (0 to 100%) – in case that the deviation value is outside the band of derivation component effect, the derivation component is inactive.

Value 100% of the regulated quantity (MaxY), Value 0% of the regulated quantity (MinY) – these two parameters specify which values of the regulator unified input correspond to 0 and 100%. These values are very important as they are used, in addition to the input values Y1 and Y2, also for normalisation of the regulating deviation and desired value, displayed by the tool. The values are pre-entered according to the maximum and minimum of the input Y1.

Period of regulation algorithm sampling (T) (0.01 to 655.35 s) – this specifies the regulation algorithm sampling period that expresses the time interval length between calculations of new values of intervention actions. This value also influences the filter sampling period of the desired value and pulse-width modulation period for the three-position regulation.

Work in 10 ms periods (only for CPU series B) – in case of centres type B it is possible to work in interruption periods 10 ms. The sampling period, entered above, then influences only the pulse-width modulation.

Pre-defined output with a fault (uDef) (0 to 100%) – in case that the option "The last output used in case of an error" is selected, this is value of the output in case of an error.

The last output used in case of an error – in case that the regulator passed to an error state, the last input value before the error is "frozen" on its input.

Establish a structure above regulator data – a structure "<regulator name>_struct" is established above the regulator data, through which all parameters of the regulator are accessible from the user programme. This option is not accessible if generation of definitions in the language ST (where the structure is always established) is selected.

Use remanent registers – this option is a default. Use of remanent registers allows preserving changes of parameters even after PLC restart without updating the code (the restart type shall be set to "warm" for correct function). Parameters backup in the remanent zone can be recalled from the user programme by setting the register "<regulator name>_Control.11" (or register "<regulator name>_struct.CHN" using access through the structure) to value 1. In case the option is not used, it is necessary to provide a regulator setting backup through the user programme. The code of the programme, providing restoration of parameters after restart, shall be placed in the translation after the automatically generated file with the regulator algorithm that includes the part of the code that sets up the default values entered when sending the programme to PLC.

Location in non-remanent registers = this parameter allows to determine a fixed position of the variables in the non-remanent field of the register.

Location in remanent registers = this parameter allows to determine a fixed position of the variables in the remanent field of the register.

4.7. Modification of the desired quantity
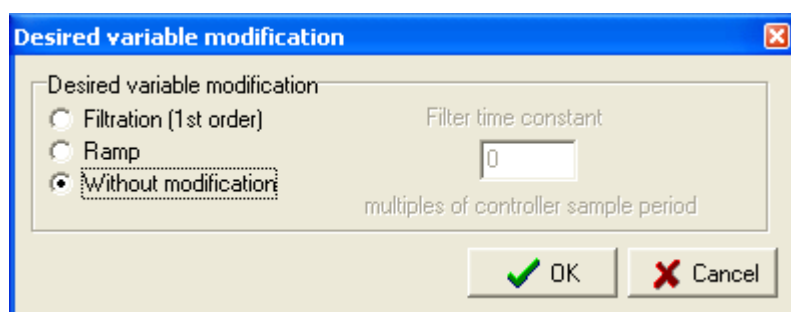
Without modification = the entered desired value is used directly for calculation of the regulating deviation.

Filtration (filter of the 1st order) – before calculation of the regulating deviation, the desired value is modified by the digital filter with a sampling period identical with the regulator sampling period. The filter time constant is entered in multiplies of this sampling period. Filtration should be used in case when a step change of the desired value has adverse effects to the course of regulation. The actual desired value (filter output) can be monitored in the variable "<regulator name>_ConW"

Ramp – the entered desired value is used as the end value of the ramp; the initial point is save in the variable "<regulator name>_ConW" that also gives the actual desired value used for calculation of the regulating deviation. The ramp is activated by entering the time of duration of the ramp in multiplies of the sampling period. This time is decremented in each sampling period as much as the variable "<regulator name>_ConW" is updated. As soon as time of duration of the ramp reaches 0 (zero), the ramp is completed and it is possible to enter a new target point using a desired value.

4.8. Output setting

The dialog is used to enter a symbolic name of the output(s) and their conversion to the regulator output.

Conversion of the regulator output to the PLC output – here you can enter a symbolic name of the output, whose format changes according to the output type; see below. In case that there is selected a 3-state output type, a second field for entering a symbolic name of the variable for negative action interventions appears here. In this case the format of both outputs is BOOL (BIT).

Output to a 8-bit D/A converter – output within range 0 to 255, suitable for 8-bit analog outputs (e.g. TC600). The output variable shall be type USINT (BYTE). This type of the output can be combined with the option "Shift of zero for output 4 to 20 mA" that shifts 0% on the output to the value of the variable 51 that corresponds to 4 mA on the 8-bit output 0 to 20 mA.

Output to a 12-bit D/A converter – output within range 0 to 4095, suitable for 12-bit analog outputs (e.g. OT-04, OT-05). The output variable shall be type UINT (WORD). This type of the output can be combined with the option "Shift of zero for output 4 to 20 mA" or "Bipolar output (OT-04, OT-05)". These two options eliminate each other. The option "Shift of zero" shifts 0% on the output to the values of the output variable 819 that corresponds to 4 mA on the 12-bit output 0 to 20 mA. The option "Bipolar output" shifts 0% on the output to the value of the output variable 2048. Zero on the output variable then corresponds to -100% of the range. See 5XV 001 50 Output unit OT-04 (OT-05).

Output float/real in percents – output in the format REAL (FLOAT), used by analog output modules PLC TC700. In the analog channel structure, variable PCT. In details see TXV 004 21.

Output word/int (30000 corresponds to 100%) – output in the format INT (WORD), used by analog output modules PLC TC700. In the analog channel structure, variable FS. In details, see TXV 004 21.

Own scale – output in the format INT (WORD) with user selected scale that can be entered by two points, in which it is necessary to assign the value within range of the variable type INT (-32768 to 32767) to the percentage value of the output.

Output mode – this determines if the regulator output will give an absolute value (option Positional) or the increment for the sampling period (option Incremental). The incremental mode can be used in case of control with an astatic action member. The incremental mode is necessary for cascade control and any selection is inaccessible.

Output type – here you can set up analog output (option Analog) or use of two digital outputs with pulse-width modulations (option Three-state).

Filtration of short action interventions – this option eliminates short pulses to control with pulse-width modulation. The action interventions smaller than the entered value of the minimal action intervention (0 to 2.24% in steps per 0.32%) are not performed with this option.

Filtration (Filter of the 1st order) – in case that any step changes of the action quantity are not desired, after output of the regulator, using activation of this option, there can be inserted a digital filter of the 1st order with sampling period equal to the PLC cycle period. The time constant is entered in multiplies of the PLC cycle periods.

Minimum permitted action intervention – limits the minimum amount of the action intervention.

Maximum permitted action intervention – limits the maximum amount of the action intervention.

Maximum increment of the action quantity for one period – this item sets up the maximum amount of change of the action quantity for one sampling period of the regulator. In case that the three-state output with pulse-width regulation is used, this value determines, together with the sampling period of the regulator, speed of change of position of the action member (mostly speed of opening/closing of a servo valve).

Example: The maximum increment of the action quantity for one period is 10% and the sampling period of the regulator is 5 seconds; this corresponds to speed of 2% per second and time of run of a valve through the full range 50 seconds.

4.9. Initial parameters
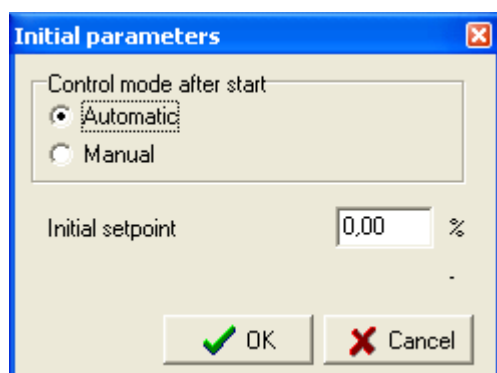
In the dialog you can set up a status in which the regulator will be after start of the system. There can be chosen automatic or manual mode. Depending on this option and mode of the regulator there can be set an initial desired value, initial action intervention or an initial desired proportion.

4.10. Setting of a simulated process

4.10.1. Simulation parameters

Active simulation – this option determines whether visualisation of the regulator has to simulate response of the controlled process. This option provides access to settings of the simulated process.

Sampling period – (0.1 to 100 s) determined the period (in seconds) for which data with PLC will be read. This value, as the only value, has a meaning even in case when simulation is not active. For simulation it is suitable to choose the reading period shorter than the sampling period of the algorithm PID. In case there is set a period shorter than a turn of communication of the environment Mosaic, reading will be performed each turn.

Initial status [%] – this value shows initial status of the simulated process with activation of simulation or with a change of parameters in this dialog.

4.10.2. Parameters of a simulated process

Astatic action member (necessary for cascade control) – places an astatic member that may simulate e.g. a servo valve, before the simulated process. The value of position of the astatic member is necessary for simulation with cascade control.

Time constant (of astatic member) – this value determines the time for which the action member changes its position from 0 to 100%.

Lower limit [%] and upper limit [%] (of the astatic member) – these values determine the action member movement limits.

4.10.3. Types of simulated process

In this group it is possible to choose a mode of a simulated process and its parameters.

Balanced state [%] – here you can enter a value to which the process with action intervention 0% is stabilised.

Transport delay (steps) – defines the time (entered in multiplies of sampling periods) by which reaction of the process is delayed against the action intervention.

Static amplification for u > 0 (u < 0) – defines static amplification of the process, i.e. ratio output/input in stabilised state. The value for u > 0 is used with positive values of the action intervention, the value for u < 0 with negative values of the action intervention.

4.10.4. No

In case that this option is chosen, no process will be simulated. This option is suitable only with a combination in the field "Add to the output", see below.

4.10.5. Process of the first order

Behaviour of the process is determined by one time constant and static amplification. The time constant gives the time, for which the system reaches 63% of stabilised state with a step change of the action quantity.

4.10.6. Process of the second order

It is equivalent to two processes of the first order in series connection. Behaviour is determined by two time constants and static amplification.

4.10.7. Oscillating process of the second order

The process is characterised by an oscillating response to step changes of the action quantity. Behaviour of the process is determined by relative damping, intrinsic frequency and static amplification. The intrinsic frequency is entered in $rad^{-1}s^{-1}$. The period of oscillations is equal to 2π divided intrinsic frequency. The inverted value of relative damping gives a number of half-waves after a step change of the input before the output of the band reaches 4% about the stabilised value. In case that relative damping is equal to 0, the process will oscillate without any damping.

4.10.8. Process of the third order

It is equivalent of three processes of the first order in a series connection. Behaviour of the process is determined by three time constants and static amplification.

4.10.9. Oscillating process of the third order

It is equivalent to a series connection pro the process of the first order with oscillating process of the second order. Behaviour of the process is determined by one time constant, relative damping, intrinsic frequency and static amplification.

4.10.10. Add the PLC variable to the output

Here the user can enter a name of the variable that will be added to the output of the simulated process. In a combination with the simulated process this option is suitable for simulation of errors or noise. In case that no simulated process is chosen, the user can provide data from his simulation through this variable. The format of the variable can be chosen either as INT (WORD) with two fixed decimal places (100% corresponds to the value 10000) or REAL (FLOAT).
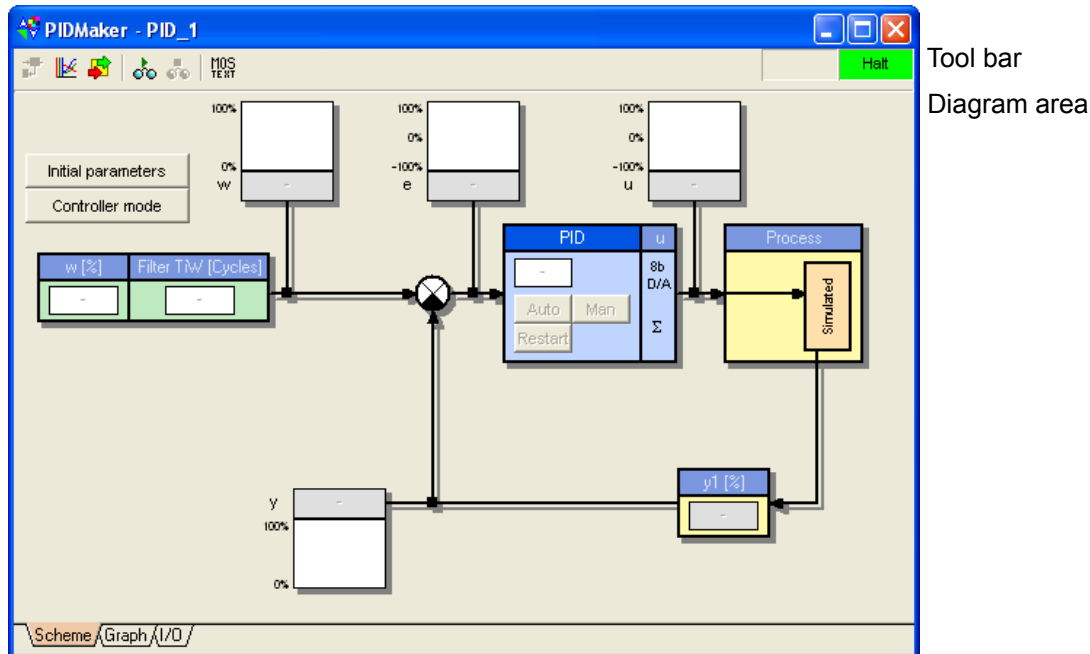
4.11. Window of the regulator

After filling up the series of dialogs there will be displayed a window of the regulator in the desktop middle panel. This window provides an automatically generated algorithm. The window has two modes, active and passive. In the passive mode it is possible to change all parameters entered during creation of the regulator. In the active mode it is possible to change some of the parameters and monitor the course of regulation.
The window of the regulator has three sheets; the first sheet displays a diagram of the regulation circuit, the second sheet shows a diagram of important regulation quantities in the course of time and the third sheet shows inputs and outputs of a PID instruction. Opening of the sheets is possible through the tabs in the lower part of the window or using the tool bar in the window that is described below with individual sheets.

4.11.1. Diagram sheet

The sheet is displayed immediately after creation of a regulator. The sheet consists of three main parts: tool bar, diagram area and tabs for browsing through the sheets.

Tool bar

Diagram area

Tabs

4.11.1.1. Tool bar

Display the diagram – displays the first sheet of the window of the regulator.

Display the graph – displays the second sheet of the window of the regulator.

Display inputs/outputs of PID – displays the third sheet of the window of the regulator.

Open visualisation – sets the window to the active mode; all changes are performed online.
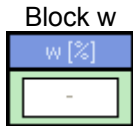
Close visualisation – sets the window to the passive mode in which all changes are reflected only in the programme code; a translation shall be performed for next opening of visualisation.

Display the generated code – opens two sets with generated definitions and algorithm of the regulator.
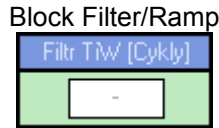
4.11.1.2. Blocks of PID

Block w

This initiates a dialog "Modification of desired quantity". The desired value or desired ratio according to the regulator mode can be set in the text field in the active mode.
All dialog options are accessible in the visualisation active mode.
The desired value is set in percents, the corresponding value of the variable "<regulator name>_gW" is given by the following relation, where *w* means the entered desired value:

$$gW = w[\%] \cdot \frac{MaxY - MinY}{100\,\%} + MinY$$

Block Filter/Ramp

This initiates a dialog "Modification of desired quantity". The time constant of the filter or duration of the ramp according setting of modification of the desired quantity can be set in the text field in the active mode.
All dialog options are accessible in the visualisation active mode.
The entered value corresponds to the variable "<regulator name>_TiW".
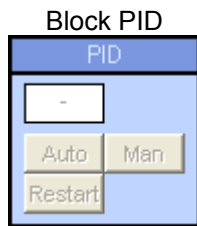
Block PID

This initiates a dialog "Regulator parameters". In the active mode the pushbuttons "auto" and "man" allow to switch between automatic and manual modes. The pushbutton Restart allows restarting the regulator and thus deleting all error attributes. An action intervention can be entered in the text field in the manual mode.
The options "Work in 10 ms periods", "Establish a structure above regulator data" and "Use remanent registers" are not accessible in the active mode.
The action intervention is entered in percents, the corresponding value of the respective variable "<regulator name>_Output" is given by the following relation, where *u* means the entered value:

$$Output = \frac{u[\%]}{0,01\,\%}$$

Block u
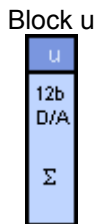
This initiates a dialog "Output setting". The options "Output mode", Output type", "Filtration of the 1st order" and group "Conversion of regulator output to PLC output" are not accessible in the visualisation active mode except setting of an own scale.

Block Process
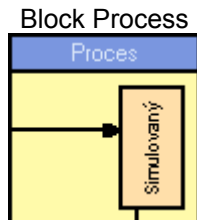
This initiates a dialog "Setting of simulated process". All dialog options are accessible in the visualisation active mode.

Block y1, y2, y3
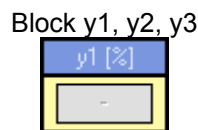
This initiates a dialog "Selection of a source of the regulated quantity Y1", "Selection of the second source of the regulated quantity Y2", "Selection of a source of a quantity for proportional control Y2" or "Selection of a source of a quantity of the actual position of the action member Y3". Only options of parameters of scaling and filtration are accessible in dialogs in the visualisation active mode.
In case of the proportional control, in the text field of the block y2 it is possible to enter the value of the variable, from which the desired value is calculated.
The displayed value is shown in percents; the corresponding value of the respective variable <regulator name>_Input1" (resp. "<regulator name>_Input2" or "<regulator name>_Input3") is given by the following relation, where *y* means the entered value:

$$Input = y[\%] \cdot \frac{MaxY - MinY}{100\,\%} + MinY$$

NOTE: In case of an error at the input y3, control continues without cascade mode
Click on the text field of the block y3 reactivates the cascade control. Background of the text field is yellow during activation.

4.11.1.3. Diagram area

The diagram area shows a block diagram of the regulation circuit that corresponds to the preset mode and parameters of the regulator. Clicks of the left mouse button on individual blocks initiate dialogs with respective settings as described above. In case of visualisation in the active mode settings in dialogs are limited only to the options that can be changed during run of the programme.

This limitation is indicated by a white message "communication" in a violet field and a symbol of a pushbutton for loading of actual values from the PLC.

The opened dialogs display the values used last time with generation of the code until moment of use of the pushbutton "Load from PLC".

In the active mode some blocks display accessible control elements that can be used to change parameters without any necessity to open a dialog.

### 4.11.1.4. Pushbuttons

The pushbuttons "Initial parameters" and "Regulation mode" are only accessible in the passive mode.

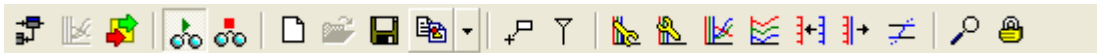*Initial parameters* – this initiates a dialog "Initial parameters".

Regulation mode – this initiates a dialog "Regulator mode".

4.11.2. Diagram sheet

The diagram sheet consists of four parts: tool bar, left panel, diagram area and tabs for browsing through the sheets.
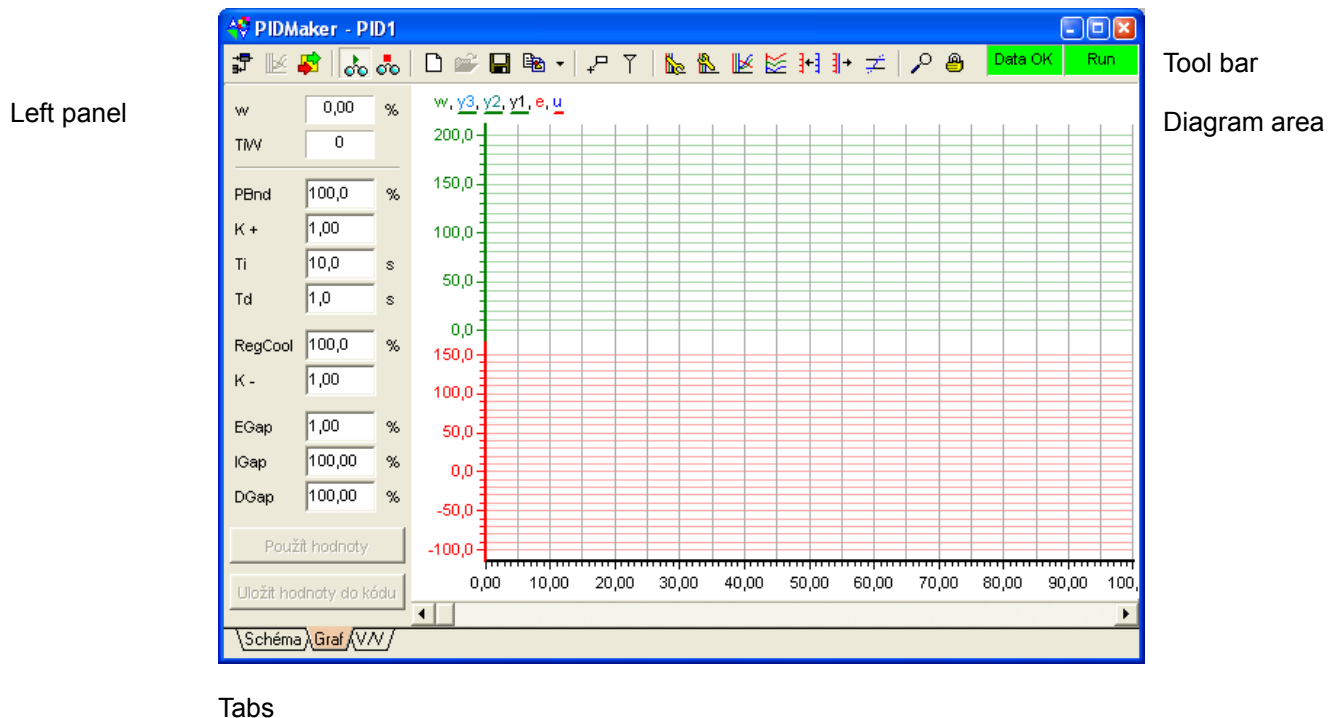
Left panel

Tool bar

Diagram area

Tabs

4.11.2.1. Tool bar

Icon	Description
	Display diagram – displays the second sheet of the regulator window.
	Display graph – displays the second sheet of the regulator window.
	Display PID inputs/outputs – displays the third sheet of the regulator window.
	Open visualisation – sets the window into active mode; all changes are performed online.
	Close visualisation –sets the window to the passive mode in which all changes are reflected only in the programme code; a translation shall be performed for next opening of visualisation.
	New graph – deletes the measured data.
	Load graph – loads the measured data from the file.
	Save graph – saves the measured data to the file.
	Copy graph to clipboard as Windows metafile – saves a copy of the graph area to the clipboard in the format Windows metafile
	Save graph as Windows metafile – saves a copy of the graph area to a file in the format Windows metafile
	Legend – displays coordinates of the course point closest to the cursor

Measuring marks – switch on a measuring mode, whose results are displayed in the left panel of the sheet. The active mode is indicated by a change of the cursor and displaying of the measured values in the left panel of the sheet. This mode eliminates each other with the zoom mode and monitoring of the last sample.

Setting of the axis X – initiates a dialog with setting of the axis X, where you can also enter the maximum number of saved samples. The dialog can also be initiated from the local menu on the graph area.

Setting of axes Y – initiates a dialog with setting of axes Y and individual courses.
The dialog can also be initiated from the local menu on the graph area.

Stretch axes along the whole height –stretches axes Y along the whole height of the graph area.
The function can also be initiated from the local menu on the graph area.

Align the axes one under the other –aligns the axes Y one under the other along the whole height of the graph area.
The function can also be initiated from the local menu on the graph area.

Merge axes with the same range –merges axes Y with the same maximum and minimum values.
The function can also be initiated from the local menu on the graph area.

Divide the merged axes –divides all the merged axes.
The function can also be initiated from the local menu on the graph area.

Trim the courses according to the axis range – trims the courses that exceed the range of their axis.

Zoom – this function switches on the zoom mode by a change of the axis X range. The mode is indicated by moving the cursor position to the zoom symbol. This mode eliminates each other with the mode of measuring marks and monitoring of the last sample.

Monitor the last sample – this function switches on the mode of monitoring of the last sample. In this mode the graph, exceeding the axis X range, is shifted automatically so that the last measured sample is visible. This mode eliminates each other with the mode of measuring marks and zoom mode.

4.11.2.2. Left panel

In the basic mode, the left panel displays only control elements for setting of the desired value and basic parameters of the regulator. The elements are only accessible in the active mode. The desired value is set immediately after entering it. (Attention! In case that the desired value is set using the ramp, there is set only its end point. The ramp is initiated after setting of its time.) Parameters of the regulator are set after their acknowledgement by pushbuttons "Use values" or "Save values to code".
The pushbutton "Use values" saves the entered parameters of the regulator only to the PLC remanent registers (if used). The pushbutton "Save values to code" saves the values both to the PLC remanent registers and to the automatically generated code.

NOTE: Any change of parameters in the dialogs saves all values to the automatically generated code. Thus entering of values into the left panel of the graph and subsequent opening of a dialog from the diagram sheet, acknowledged with closing it by the pushbutton "Use" has the same effect as the pushbutton "Save values to code.

In the measuring marks mode the left panel displays values of courses in places of measuring marks and their differences.

4.11.2.3. Graph area

The graph area displays the selected courses. In the basic mode the right mouse button opens an offer that duplicates some functions accessible on the tool bar. Click by the right mouse button on the displayed axes opens dialogs with their setting options.
Legends to the courses above the axes Y are displayed in the same different colours like the axes. In case that the axes are merged, the legends to the concurring courses of the axes are underlined by colours of the respective axes.

The courses are marked according to the following key:

w	Desired value
u	Action quantity
e	Regulating deviation
y1	Regulating quantity
y2	Acc. to the regulation mode – nothing, the second source of the regulated quantity or the quantity for proportional control
y3	Acc. to the regulation mode – nothing or position of the action member

4.11.2.4. Zoom mode

The mode is activated by the pushbutton on the tool bar (see Tool bar). In case the mode is activated, the cursor in the graph area changes to a zoom symbol. Click of the right mouse button increases resolution of the axis X two times; click of the left mouse button decreases the resolution two times.
By holding the right mouse button pressed you can define the axis X section that has to be enlarged. Beginning of the section is determined by the point where the button was pressed; the end is determined by the point where the button was released.

4.11.2.5. Measuring marks mode

The mode is activated by the pushbutton on the tool bar (see Tool bar). In case the mode is activated, the cursor in the graph area changes to a black-white mark. The right mouse button puts a white measuring mark in the graph area, the left mouse button puts a black measuring mark there, as illustrated by the pictogram of the cursor.
Values of all courses on its position and time are displayed in the left panel. In case that both marks are put in the graph area, differences of all values will be displayed there.

4.11.2.6. Setting of the axis X
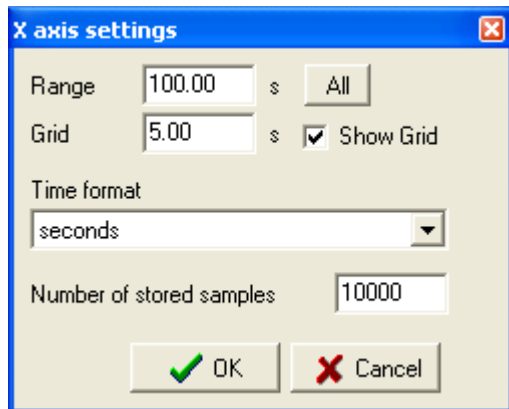
The axis range in seconds can be set in the dialog. The pushbutton "All" sets the range so that all the measured data are displayed.
In case that the option "Display grid" is checked, in the field "Grid per" you can set time intervals of displaying of the grid. The graph adjusts automatically the interval of the grid in case, that lines of the grid are plotted too closely with the given scale.
In the pop-up window "Time format" you can choose a format of legends of the axis X. This option influences also displaying of time in the legend to coordinates of the course point.
The item "Number of saved samples" gives the size of the buffer of measured values. In case that during gathering of data the number of measured values exceeds the preset value, the oldest samples will be rewritten by new values.

NOTE: PIDMaker allocates its memory according to the number of saved samples. It is necessary to take into account that in case of 10,000 saved samples one window of the regulator allocates 0.45MB in its memory, in case of maximum setting of 2,000,000 samples there shall be allocated approximately 92MB for the samples.

4.11.2.7. Setting of axes Y
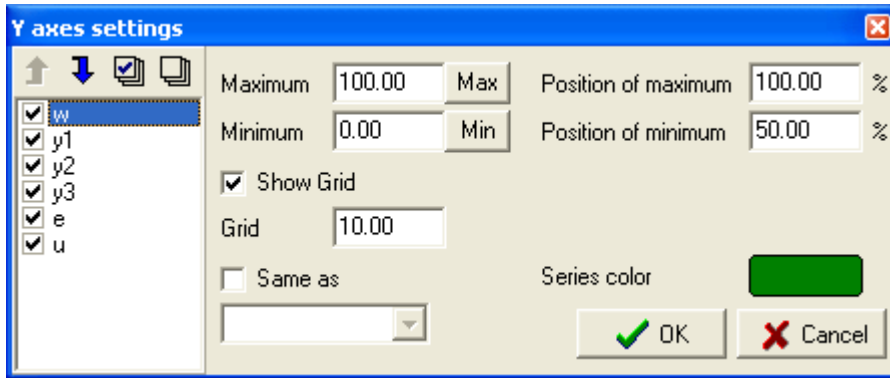
The list in the left part of the dialog includes all courses that can be displayed. The check box next to the course name determines whether the course will be plotted. All courses can be checked using the tool bar above the list. The adjacent pushbutton cancels all checks except the actually selected one.

The order of plotting of the axes can be changed using the blue arrows by checking the item "Same as", except those merged with another axis. As higher position of the course name in the list, as earlier the axis will be plotted. The position of courses of the merged axes has no effect.

The items "Maximum" and "Minimum" define the maximum and minimum of the axis in percents. These values can be set by the pushbuttons "Max" and "Min" according to the maximum and minimum of the measured data.

"Position maximum" and "Position minimum" define positions of edges of the axis in the graph area in percents. The value 100 corresponds to the upper edge of the area and 0 to the lower edge of the area. These values are set automatically by pushbuttons of the tool bar "Merge axes with identical ranges", Stretch axes along whole height" and "Align axes one under the other".
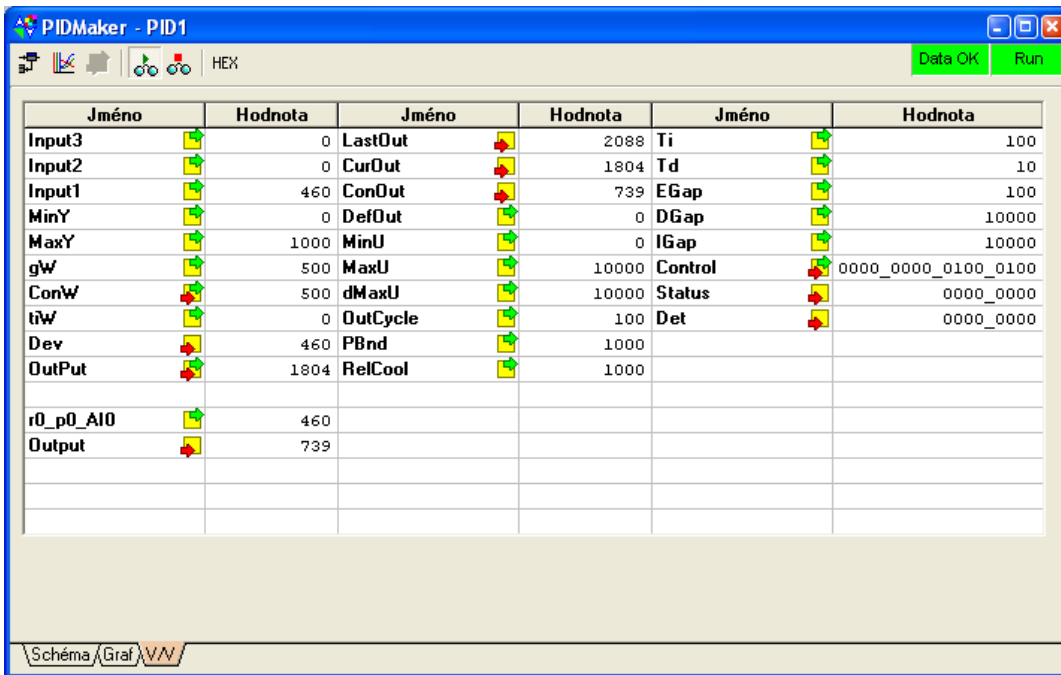
In case that plotting of the grid is enabled and the option "Display grid" is checked, the value "Grid" defines gaps between individual lines of the grid. The graph adjusts the grid interval automatically, if lines of the grid are plotted too closely with the given scale.

Click on the colour field opens a dialog for selection of a colour. The selected colour is then used for the selected course and its axis.

Check of the box "Same as" opens a pop-up window, where you can select the axis with which the actual axis has to be merged. Check of this option disables the options that are taken over from the axis selected in the pop-up window.

4.11.3. Sheet of PID inputs/outputs

The graph sheet includes three main parts: tool bar, table of inputs/output (where PID internal variables are displayed in the upper half and external variables in the lower half) and tabs for browsing through the sheets.

Tool bar

Table of PID
inputs/outputs

External inputs and
outputs

Tabs

4.11.3.1. Tool bar

Display diagram – displays the second sheet of the regulator window.

Display graph – displays the second sheet of the regulator window.

Display PID inputs/outputs – displays the third sheet of the regulator window.

Open visualisation – sets the window to the active mode; all changes are performed online

Close visualisation – sets the window to the passive mode, in which all changes are reflected only in the programme code; a translation shall be performed for next opening of visualisation.

Hexadecimal displaying – switching over between displaying of decimal values with signs (resp. binary values in case of control and status words) and hexadecimal values.

4.11.3.2. Table of inputs and outputs

This table displays the PID inputs and outputs within the instruction data zone and external inputs and outputs selected by the user. The values are not normalised and match with values in the PLC registers. A double click to the value of the variable opens a standard dialog "Calculate & Set", where the value can be edited.

5. PIDA TYPE REGULATOR

The automatically generated code for a regulator type PIDA is based on the instruction PIDA, presented newly in the PLC series TC700 (see Set of instructions PLC TECOMAT, model 32 bits – TXV 004 01). A description of individual dialog after adding a regulator is as follows:

5.1. Setting of the regulator

This dialog is used for setting of a style of generation of a regulation algorithm, its parameters and linking of its input and output to the PLC variables.

Type of regulation algorithm – the pop-up window allows choosing a regulation algorithm of the type P, I, D, PI, PD, ID, PID. The abbreviations define which of the PID algorithm components will be active. Automatic setting of the parameters is accessible only for the PI and PID algorithms.

Sampling period in seconds – defines the regulation algorithm sampling period. The sampling period defines length of the time interval between calculations of a new value of the action intervention.

Reversal acting of the action intervention – check of the option reverses the sense of the action intervention (i.e. the positive action intervention reacts to a negative regulating deviation).

Amplification of the regulator (k) – parameter of a PID regulator.

Integration time constant (ti) – parameter of a PID regulator.

Derivation time constant (td) – parameter of a PID regulator.

Parameter N of the derivation component filter (N) – defines the ratio of the time constant of the filter derivation component to the derivation time constant. The filter time constant is $tf = td / N$.

Weight coefficient for the P component (b) – defines the desired value ratio on the input of the regulator proportional component. It is entered in the range 0 to 1. The value 0 eliminates the desired value from calculation of the proportional component. The proportional component of the action intervention results from the relation $u_p(t) = K (b \cdot w(t) - y(t))$.

Weight coefficient for the component D (c) – defines the ratio of the desired value on the input of the regulator derivation component. It is entered in the range 0 to 1. The value 0 eliminates the desired value from calculation of the derivation component.. The derivation component of the action intervention, with omission of the input filter, results from the relation $u_d(t) = K \cdot d(c \cdot w(t) - y(t)) / dt$.

Monitoring time constant (tt) – time of monitoring of the output.

Symbolic name of the input – a symbolic name of the input can be entered here. The format of the input shall be REAL (FLOAT).

Symbolic name of the output – symbolic name of the output can be entered here. The format of the output shall be REAL (FLOAT).

Maximal value of the output [%] (hilim) – limitation of the maximal action intervention.

Minimal value of the output [%] (lolim) – limitation of the minimal action intervention.

Establish a structure above regulator data – a structure "<regulator name>_struct" is established above data regulator; all parameters of the regulator are accessible from the user programme through this structure. This option is not accessible in case that there is chosen generation of definitions in language ST, where the structure is always established.

Use remanent registers – this option is default setting. Use of remanent registers allows preserving changes of parameters even after PLC restart without updating the code (the restart type shall be set to "warm" for correct function). Parameters backup in the remanent zone can be recalled from the user programme by setting the register "<regulator name>_CHANGED" (or using access through the structure of the variable "<regulator name>_struct.CHANGED") to value 1. In case the option is not used, it is necessary to provide a regulator setting backup through the user programme. The code of the programme, providing restoration of parameters after restart, shall be placed in the translation after the automatically generated file with the regulator algorithm that includes the part of the code that sets up the default values entered when sending the programme to PLC.

Location in non-remanent registers = this parameter allows to determine a fixed position of the variables in the non-remanent field of the register.

Location in remanent registers = this parameter allows to determine a fixed position of the variables in the remanent field of the register.

5.2. Auto-tuner setting

This dialog is used for setting of the auto-tuner parameters and identification experiment that is provided by the auto-tuner.

Type of regulation algorithm – this pop-up window with options allows choosing a type of the regulation algorithm PI or PID, for which the auto-tuner will estimate parameters.

Additional a priori information – this pop-up window with options allows choosing an additional information about the controlled process that is then used for correct setting of the parameters.

Compensation of the trend gradient – initiates estimation of the trend gradient. Allows elimination of the error of the estimation arising from the trend of the process in balanced state.

Time of estimation of the trend gradient – defines the time in seconds, for which the process trend will be estimated.

Time of estimation of noise – defines the time in seconds, for which level of noise will be estimated.

Amplitude of pulse – defines the size of the pulse, which will be used for excitation of the process with the identification experiment.

Threshold for closing of pulse – defines the size of the process value change that finishes the excitation pulse after it is reached.

Desired speed of closed loop – defines a requirement for speed of regulation for estimation of parameters.

Form of a PID regulator – determines whether the estimated parameters will be displayed in a format for the series or parallel structure of the regulator. It has no influence on the format of the regulator itself and its parameters.

5.3.　Initial parameters

These are identical with the dialog for the regulator PID. See 4.9.

5.4.　Setting of a simulated process

It is identical with the dialog for the regulator. See 4.10.

5.5.　Regulator window

After filling a series of dialogs, a regulator window appears in the desktop middle panel. This window is provided by an automatically generated regulation algorithm. The window has two modes, active and passive modes. In the passive mode you can change all parameters entered during creation of the regulator. In the active mode you can change some of the parameters and monitor the course of regulation.
The regulator window includes three sheets; the first sheet displays a diagram of the regulation circuit, the second sheet displays a graph showing important regulation quantities and the third sheet displays inputs and outputs of PIDA instructions. Browsing through the sheets is possible using the tabs in the lower part of the window or using the tool bar that is described below in descriptions of individual sheets.
Okno se z větší části shoduje s oknem pro regulátor PID, proto budou dále popsány jen rozdílné prvky.

5.5.1.   Diagram sheet

The diagram sheet is displayed in the window immediately after creation of the regulator. The sheet consists of three main parts: tool bar, diagram area and tabs for browsing through the sheets.
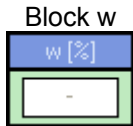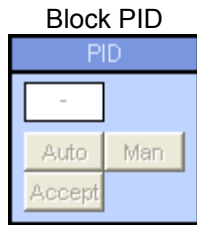

Tool bar

Diagram area
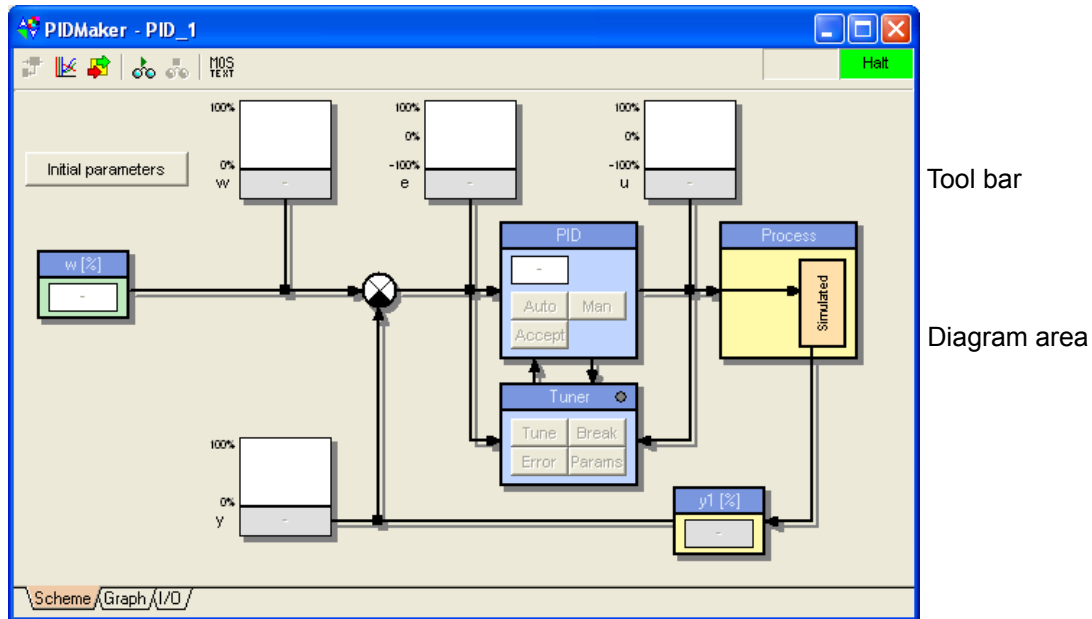
Tabs

5.5.1.1. Tool bar

It is identical with the tool bar for the regulator PID. See 4.11.1.1.

5.5.1.2. Blocks PIDA

Block w

In the active mode this function displays and allows entering the desired value. This corresponds to the variable "<regulator name_sp"
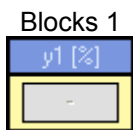
Block PID

This function initiates "Regulator parameters". In the active mode the pushbuttons "auto" and "man" switch over between the automatic and manual control mode. Using the pushbutton "accept", you can set up the attribute TAFF and thus accept parameters from the auto-tuner (pressed pushbutton "accept" mean activated transmission of the proposed parameters from the auto-tuner. An action intervention can be entered in control manual mode in the text field. Symbolic names of inputs and outputs cannot be changed if the visualisation mode is active.

This function initiates a dialog "Auto-tuner settings". In the active mode this function allows to initiate an identification experiment using the pushbutton "Tune" and interrupt it using the pushbutton "Break". The pushbutton "Error" opens a dialog with information on possible auto-tuner errors. The pushbutton "Params" displays the proposed parameters.
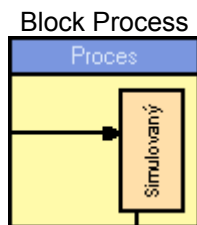
Block Process

This function initiates a dialog "Setting of a simulated process". All dialog options are accessible in the active visualisation mode.

Blocks 1

This function initiates a dialog "Regulator parameters" in the same way as the block PID. In the active mode it displays the measured quantity.

5.5.2. Graph sheet

The graph sheet differs from the graph sheet for PID only in the left panel that offers setting parameters corresponding to the instruction. A detailed description see 4.11.2.

5.5.3. Sheet of inputs/outputs PIDA

Functions of the sheet of inputs/outputs PIDA are identical with the sheet of inputs/outputs PID. The displayed variables correspond to the variables of the instruction PIDA (see the Set of instruction PLC TECOMAT, model 32 bits – TXV 004 01).

6.   CODE AND GENERATION

Each regulator, created by the tool PIDMaker, is completed in the project with two files containing an automatically generated code. Both files are saved in the project sub-directory named PIDMaker. The first file named "<regulator name>_def.mos" or "<regulator name>_def.ST" includes declarations of the variables and if necessary, also a declaration of the instruction CRC16 to ensure remanent data. The other file named "<regulator name>.mos" includes the initiating and regulating algorithm. The file with declaration is located in the translation order immediately after configuration files; the file with the algorithm is located at the end.

The added files are generated again with each change using the tool or translation. Due to this fact, any manual modifications in the PIDMaker files are lost.
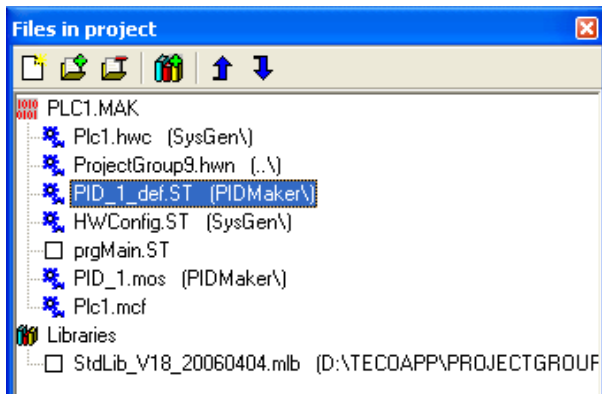
An example of an order of files for the project group "Project9", project PLC1 and regulator PID1.

Mosaic file
File with a HW configuration of the project
A file with a network configuration
A PIDMaker file with definitions
Mosaic file
User programme
A PIDMaker file with a regulation algorithm
Configuration file

An unique group of variables is established for each regulator; their names are in an unified format according to the rule "<regulator name>_<variable name>", e.g. "PID1_Input1". In acse there is chosen "Establish a structure above regulator data", it is possible to access the variables through the structure named "<regulator name>_struct".

Remanent back-ups of the variables are distinguished from their originals by the extension "_rem".

Generated names of the variables for the instruction PID are identical with the marking used in the manual Set of instructions PLC TECOMAT (TXV 001 05.02, TXV 004 01.02).

6.1.   Backing-up of regulator settings in remanent registers

In case that the option "Use remanent registers" is active, the generated code, in addition to the regulation algorithm, provides backing-up of settings of the regulator into remanent registers. Correctness of the saved data is checked using CRC (the check is provided by the instruction CRC16).

This back-up allows preservation of setting of the regulator that is entered during run of the programme even after PLC switch off without resending the code. It is not possible to write into the back-up zone directly, because it is protected by the CRC code. Back-up of parameters can be carried out by setting of a bit variable "<regulator name>_Control.11" (with generating of definitions in the language ST the same bit can be accessed through the symbolic name "<regulator name>_Struct.Control.CHN") to the value logic 1; zeroing of the bit is automatic after performing the back-up.

NOTE: Cold PLC restart PLC deletes the remanent zone and thus back-up of the parameters as well; therefore it is necessary for correct function that PLC is set to warm restart after switch on.

The settings saved in the programme code are used only in cases when the remanent back-up is not filled up, the remanent back-up data are damaged (incorrect length or CRC) or a new version of the code is sent to PLC. The version of the code is determined by the constant "<regulator name>_ReleaseNumber" that is increased by one with each generation of the code.

6.2.   Basic control of a regulator from the user programme

Control of the regulator from the user programme does not differ from the procedures with use of the instruction PID without support of PIDMaker. It is necessary to respect setting of the regulator that mostly differs from the format displayed in PIDr. Some most usual cases are described below.

When writing a programme it is necessary to follow correct sequence of the files. In general, if you wish to use the variables established by the tool PIDMaker, the user programme shall be placed after files with definitions of the regulator "<regulator name>_def.mos". On the contrary, if you wish to use in the regulator the variables declared in the user definition file, this file shall be placed before the file containing the regulation algorithm.

Warning: It is not recommended to use organisation instructions "**EC**", "**ED**", "**EOC**", "**SEQ**" in the user programme. The regulation algorithm shall be executed in each PLC cycle; the above mentioned instructions can prevent its execution by early termination of the process P0.

6.2.1. Setting of the desired value

The desired value is saved in the variable "<regulator name>_Gw". The desired value is saved in this variable as a numerical value within range from the value in "<regulator name>_MinY" to the value in "<regulator name>_MaxY". The range is entered in the dialog of parameters PID as the value 0 % of the regulated quantity (MinY) and value 100 % of the regulated quantity (MaxY).

In case of a proportional regulation the desired ratio is entered into the variable "<regulator name>_Gw". The value is within range 0 to 10000, whilst the value 100 corresponds to ratio 1, entered in PIDMaker.

When using a filtration or ramp of the desired value, the time constant of the filter or time of duration of the ramp can be set in the variable "<regulator name>_Tiw" in the same format as in PIDMaker. Setting of the bit "<regulator name>_Control.8" determines whether a filtration or a ramp will be used. In case that the value of the bit is logic 0, filtration is active; the ramp is active in case of logic 1. The desired value is not modified, if the filter time constant is set to 0.

Status of the actual desired value, used for regulation, can be monitored in the variable "<regulator name>_ConW"

6.2.2. Setting of the regulation mode

Writing of logic 1 to the bit "<regulator name>_Control.6" sets the regulator automatic mode; writing of logic 0 sets the manual mode.

In case that the cascade regulation mode is disabled due to an error, its reactivation from the user programme can be carried out by setting the bit "<regulator name>_Control.3" to the value logic 1. Setting of this bit with the regulator that is not created in the cascade regulation mode leads to a malfunction of the regulator.

6.2.3. Setting of basic parameters of the regulator

The proportionality ban is saved in the variable "<regulator name>_PBnd" as a numerical value in per mille, within range from 0 to 30000 [‰].

The integration time constant is saved in the variable "<regulator name>_Ti" as a numerical value in tenths of seconds, within range from 0 to 30000 [0.1 s]. The value 0 corresponds to the disable integration component.

The derivation time constant is saved in the variable "<regulator name>_Td" as a numerical value in tenths of seconds, within range from 0 30000 [0.1 s].

In case that the entered values should be valid event after PLC switch off, it is necessary to set the bit "<regulator name>_Control.11" to logic 1; this performs a back-up to the remanent registers. The bit is set to zero automatically after the back-up is performed.

Direct entry to the remanent register results in invalidation pf the CRC control code and use of values from the automatically generated code.

7.   ERROR MESSAGES

The error messages, appearing with translation of an automatically generated code, are displayed in the window "Messages1" of the Mosaic in the format:

[Xpro:Error] PIDMAKER\<regulator name>.MOS (7): 'yyyy ... Variable does not exist or it is established later!'

Error: Variable 'yyyy' is not declared in the user programme or it is declared later. In case of occurrence of this error it is necessary to check the order of the files with declarations, if the variable is declared, otherwise to save it.
The message is accompanied by a displayed dialog of PIDMaker, in which the variable was used.

[Xpro:Fatal] PIDMAKER\<regulator name>.MOS (7): 'File "<regulator name>_def.mos" is not present in the project files or not ítomen nebo není předřazen souboru "<regulator name>.mos"!'

Error: The file with definitions of variables was moved after the file with the regulation algorithm. The error can be removed by arranging the files in correct order in the project giles.

8. VERSION LITE

A corresponding hardware key is necessary for full functionality of the tool PIDMaker. Without this key, using this tool you can create in a project only one regulator instead of eight regulators in full version. The tool indicates absence of this key by the extension LITE that id displayed after its name. Detailed information about version of the tool, see the main screen with information about the tool.

When attempting to translate a project with more regulators without the key the environment displays an error message as follows:

[Xpro:Fatal] PIDMAKER\<regulator name>_DEF.MOS (6): Too many regulators! PIDMaker LITE allows only one regulator!'