Automatic Program Generation Software Package "SC MATRIX"

Mitsunori Fukuzumi
Kenji Hirukawa

1. Introduction

Functionality and performance of the programmable controller (PLC) has been enhanced and its price reduced. On the other hand, its control program has become larger in scale and more complex. Therefore it is not unusual for the programming cost to exceed the hardware cost, and there is strong demand for the more efficient generation of control-software.

In the integrated programming support tool D300win of the MICREX-SX series, an innovative environment is provided for the more efficient creation of control programs by adopting such measures as the international standard language IEC61131-3, introducing structured programming, and improving reusability by modularizing the program. In this respect, the authors have recently developed an automatic program generation software package, the "SC MA TRIX".

2. Overview of SC MATRIX

Figure 1 shows the procedure for creating general-purpose control programs. First, a control action specification (an operation plan) is made. Next, this specification is translated into a PLC program, and is executed by the PLC. When changing the operation plan, the same processing is always performed in this cycle. If a PLC program is automatically generated directly from the operation plan, a dramatic improvement in PLC program efficiency can be expected.

As automatic program generation software, the SC MATRIX is a product that is used in combination with the D300win. More specifically, the operation plan related to step transitions of the control procedure is described in a predetermined format in a table form in easy-to-use Microsoft Excel 97 worksheet. Based on this table, the SC MATRIX automatically generates a program, i.e. a program organization unit (POU) of the STL (structured text language) prescribed in IEC61131-3.

Even with no knowledge of ladder diagram programming and such, with approximately 1 hour of study, anyone can describe an operation plan in an easy to visualize manner by using Excel 97. Furthermore, once the worksheets are described, a change of the operation plan specification during monitoring or while on-line can be made with the worksheet format. These features are quite advantageous. Figure 2 shows an overview of the SC MATRIX.

Fig.1 Conventional procedure for creating a control program

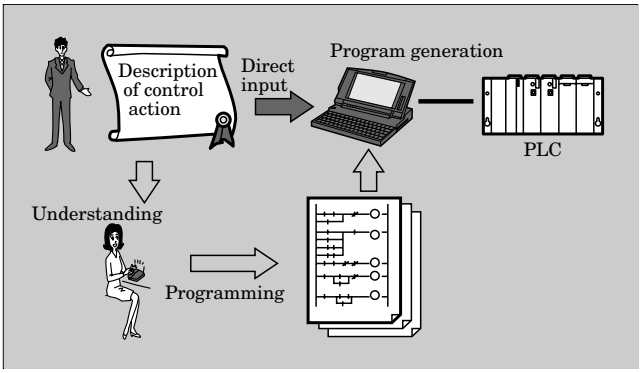
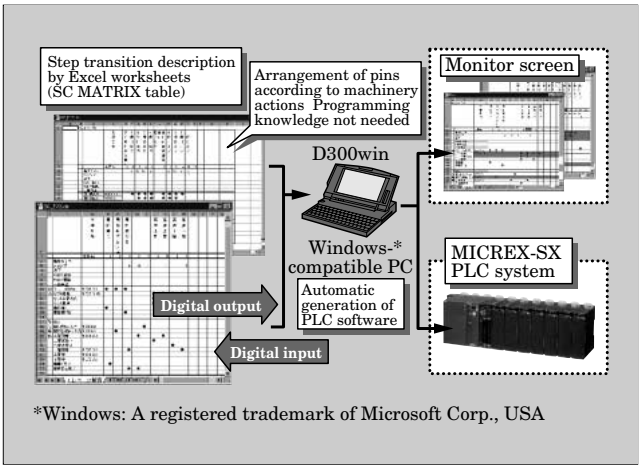


Fig.2 Overview of SC MATRIX



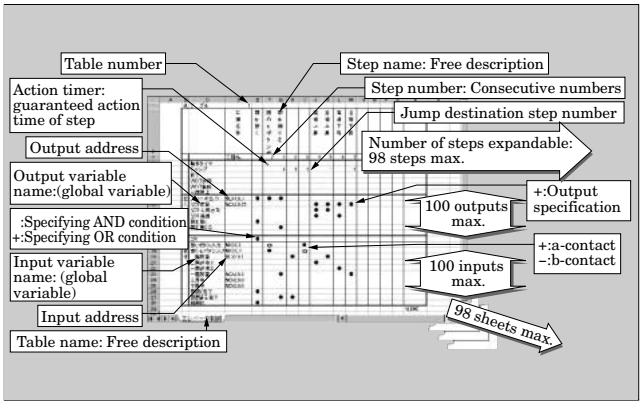
● mark means + symbol.
○ mark means – symbol.

3. Functions of SC MATRIX

3.1 Function of the operation plan description

The details of operation plan description in the SC

Fig.3 Details of operation plan description in SC MATRIX



● mark means + symbol.
○ mark means – symbol.

MATRIX are shown in Fig. 3. The serial steps in the control procedure are compiled in one Excel 97 worksheet. This is called a matrix table and a maximum of 98 sheets is available. According to the matrix tables, step actions can be executed between the matrix tables sequentially or in parallel.

A matrix table lists output signal names ("output" cells) and transition conditions to the next step ("condition" cells) in the vertical direction, and the steps in the horizontal direction.

For each step, the signal to be output at that step is specified in the "output" cell with + (a-contact). At the same time, the transition condition to the next step is specified with a + or – (b-contact) in the "condition" cell. These + and – symbols are called "pins". A "condition" pin basically indicates an AND condition, but it also indicates an OR condition if a + pin is specified in the "OR" cell.

Figure 4 shows an example of the main functions of the SC MATRIX. This table describes the operation plan of an elevator going up to the second floor and down to the first floor, and vice versa.

(1) Step transition function

The step transition function is a basic function of the SC MATRIX and sets the transition condition to the next step and the output signal for each step.

The step number is described with consecutive numbers beginning with 1. If a transition condition is established, the step shifts to the next number.

As shown in Fig. 4, step 1 switches ON output signals "braking output" and "opening door." If the transition condition signal "opening door completed" switches ON, step 1 shifts to step 2. Simultaneously, the output signal is replaced only by the signal "braking output" as specified by step 2.

(2) Jump function

A step can jump to another step if a jump destination is described in the "jump" row of the matrix table. (If nothing is described, the step switches to the next step.)

Based on an input condition, one of several steps

Fig.4 Example of operation plan description in SC MATRIX

MS table 1

		Step name	opening door	waiting for close button	closing door			High-speed going-up	Low-speed going-up	High-speed going-down	Low-speed going-down	
		Step No.	1	2	3	3	3	4	5	6	7	
	Action timer		1 s									
	Jump				4	6	1		1		1	
	End											
	WDT detection		2 s									
	WDT release											
	Temporary halt							+				
Output	Braking output	%QX1.0.7	+	+	+							
Output	Lift start	%QX2.0.15						+	+	+	+	
Output	Lift going-up direction							+	+			
Output	Lift high-speed							+		+		
Output	Opening door		+									
Output	Closing door				+							
Transition condition	OR			+								
Transition condition	Button input to open	%IX3.0.0		−			+					
Transition condition	Button input to close	%IX3.0.1		+			−					
Transition condition	Arrival at second floor	%QX2.0.1				+			+			
Transition condition	Access up to second floor							+				
Transition condition	Access down to first floor									+		
Transition condition	Arrival at first floor	%QX2.0.9			+						+	
Transition condition	Going-up	%QX2.0.0										
Transition condition	Going-down	%QX2.0.8										
Transition condition	Opening door completed		+									
Transition condition	Closing door completed				+	+						

M_END

can be selected and shifted to in the case where more than one jump destination has been described for the same step. Jumping from one matrix table to another matrix table is also possible.

Step 3 of Fig. 4 shows an example of a conditional jump with three branches having three corresponding transition conditions.

In the first condition, the step shifts to step 4 if the signals of both "Arrival at the first floor" and "Closing door completed" are switched ON. In the second condition, the step shifts to step 6 if the signals of both "Arrival at the second floor" and "Closing door completed" are switched ON. In the third condition, the step shifts to step 1 if the signal "button input to open" is switched ON and the signal "button input to close" is switched OFF.

(3) Step time assurance function (an action timer)

The minimum action time of the step is assured by setting a value as an action timer in the "action timer" row of the matrix table. In other words, when switched to a new step, that step will remain active for the duration of the time set with the action timer, even if a transition condition becomes established in the meantime. The action timer can select a setting or no setting at each step.

In the example of Fig. 4, when the state is switched from step 3, 5 or 7 to step 1, it will not switch to step 2

Fig.5 Example of time chart description in SC MATRIX

M: table 3

		Step name				
		Step No.	1	2	3	4
	Action timer		500ms	1 s	250ms	10ms
	Jump					1
	End					
	WDT detection					
	WDT release					
	Temporary halt					
Output	DO8	%QX1.0.8	+		+	
Transition condition	OR					
	Switch 8	%IX3.0.8	+	+	+	+
	Switch 9	%IX3.0.9				

M_END

If switch 8 is continuously on

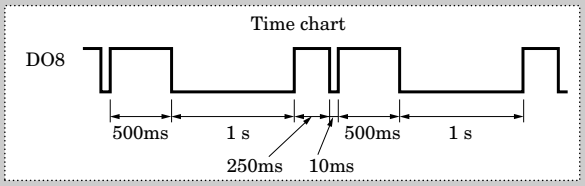
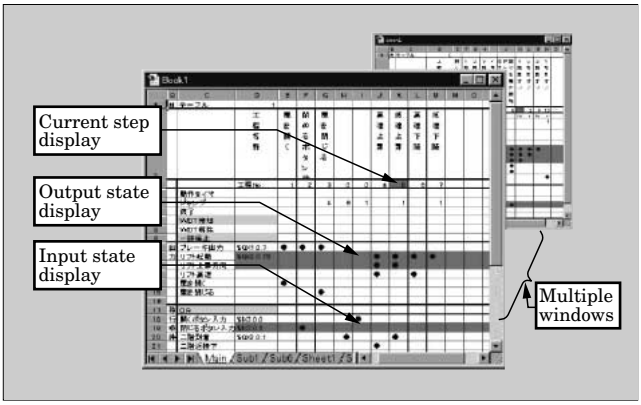
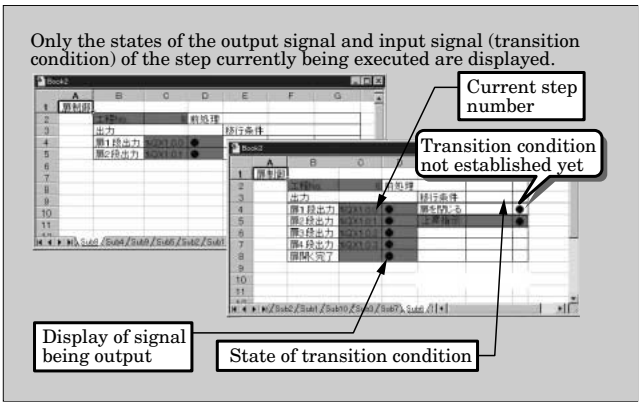


Fig.6 Example of overall monitoring in SC MATRIX



● mark means + symbol.
○ mark means – symbol.

Fig.7 Example of partial monitoring in SC MATRIX



● mark means + symbol.
○ mark means – symbol.

until one second elapses, even if the input signal of "opening door completed" is already given.

In addition, if an action timer is applied, a time chart can be drawn as shown in Fig. 5.

(4) Retardation monitoring function (watch dog timer (WDT) function)

Setting a timer value in the "WDT detection" row of the matrix table makes it possible to monitor the time remaining in a given step. The signal "WDT detection n" (where n is the matrix table number) switches ON when the set watch time has elapsed and stops the step transition control of the relevant matrix table.

The signal "WDT detection n" can be used as a transition condition for other matrix tables and the a-contact signal in ladder programs.

The signal "WDT detection n" can be released by switching ON the signal "WDT release n" from another matrix table or ladder program.

In the example of Fig. 4, unless the signal "opening door completed" switches ON within 2 seconds after the transition to step 1, the signal "WDT detection 1" will switch ON and the step transition control will be stopped.

(5) Temporary halt function

When the + or – pin is set to the "temporary halt" row of the matrix table, the step transition control can be stopped temporarily or restarted. A temporary halt pin acts on judgment of the transition condition with an AND condition. In other words, when a temporary halt is set (the pin is set in the temporary halt cell), the next step will not be transitioned to unless a condition in the halt cell is temporarily established, even if the transition condition is established.

At step 4 of Fig. 4, even if the transition condition signal "access up to the second floor" switches ON, there will be no transition to the step 5 if the pin "temporary halt" is ON.

(6) Data setting function

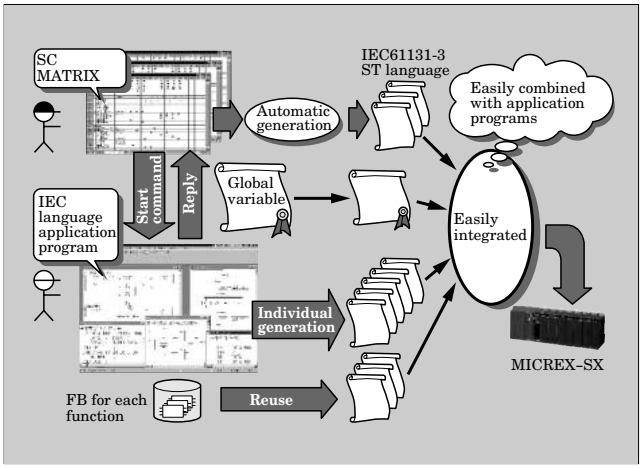
The data setting function can renew specific data in the PLC memory at an arbitrary step of the matrix table. In addition, it can enter a series of data strings into the PLC by manual operation. This function is also used to change control parameters locally or globally.

3.2 Monitoring functions

(1) Overall monitoring

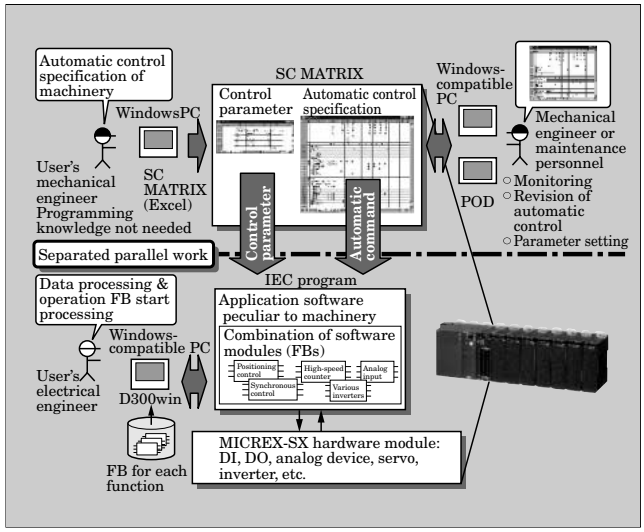
This function monitors the entire matrix table with the format that has been created. The current state of the step in execution, its input signal and output

Fig.8 Example of combination with PLC program



● mark means + symbol.
○ mark means – symbol.

Fig.9 Example of efficient use of SC MATRIX



● mark means + symbol.
○ mark means – symbol.

signal are displayed. In addition, this function can monitor more than one sheet simultaneously as shown in Fig. 6.

(2) Partial monitoring

This function is provided to automatically gather and display only the current state of the step in execution, its output and transition-condition signals. This function is called partial monitoring. Only the signals specified by the current step are displayed. When the number of steps and signals is large, use of partial monitoring makes it possible to identify at a glance which signal is being output currently and which transition condition signal is being waited for. Figure 7 shows one such example.

The use of overall or partial monitoring can be switched at any time.

3.3 On-line revision function

When setting up and adjusting a control object, it is important that the operation plan can be revised repeatedly within a short time. In the SC MATRIX, a data file is compiled which contains information regarding the existence of pins and the timer setting values. As a result, regeneration of the PLC programs becomes unnecessary based on the following revision operations. Data revision can be performed as if it was an online operation in an extremely short period of time (approximately ten seconds).

(1) Addition or removal of pins (– or +) in the transition condition cell
(2) Addition or removal of the pin (+) in the output signal cell
(3) Time revision of action timer
(4) Time revision of watchdog timer
(5) Revision of jump number

4. Combination with a PLC Program

The SC MATRIX can easily be combined with an application program described by a ladder diagram and the like. The matrix table of the SC MATRIX is compiled and converted into STL programs (POU) of IEC61131-3 for each matrix table unit and are registered on the project tree of the D300win. These programs are equivalent to the user-made programs created with a ladder diagram using the D300win, and can easily be combined with each other on the project tree.

In addition, all the signal names defined in each matrix table are automatically converted to global variables. An application program to be generated with the D300win receives command signals from the matrix table through these global variables and sends back reply signals in the transition conditions of the SC MATRIX (Fig. 8).

As a result of further applications, for example, it becomes possible to interlock the output signal of the SC MATRIX with a ladder program and output that signal, or to generate with an application program a positioning function which is issued a start command from a step of the SC MATRIX and inputs the completion of positioning as one step transition condition of the SC MATRIX.

5. Efficient Use of the SC MATRIX

Figure 9 shows an example of efficient operations with the SC MATRIX. In this figure, the upper section shows the domain of an engineer who fully understands the mechanical operations (mechanical engineer), and the lower section shows the domain of an engineer who fully understands PLC programming for sensor and actuator controls (electrical engineer).

In the upper section, an operation plan using the SC MATRIX is described, for example, as “when (a work sensor switches ON)”, “what” (drives the loader)”

and "how (to raise up)". At the operation plan level, the engineer generally does not refer to the classification of sensors or actuators (general-purpose motors, servos, inverters, etc.) nor the input and output interlocks.

In the lower section, machine-specific application software is provided beforehand as the actual control program and the interlock circuits which are compatible with the types of sensors and actuators.

The following effects are obtained by distributing the programming work.

(1) Parallel work between the mechanical and electrical engineers can shorten the work term.
(2) A mechanical engineer at the work site can easily describe automatic controls without knowledge of the PLC programs.
(3) According to the action behavior of the machinery, a mechanical engineer can revise the operation plan in an extremely short time.

6. Conclusion

This paper has described the advantageous features of the "SC MATRIX" automatic program generation software package of the MICREX-SX, its functions and methods for efficient use. Fuji Electric will continue to advance the study of automatic programming in the future, and will contribute to improving the efficiency of application program development for control systems which are becoming increasingly complicated.