Universidade do Minho

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Automation of a Flash Cell Programming

Credit Unit Safe Automation

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Introduction

In this work, we had to define the control of an equipment. This control has to be done by a OMRON PLC.

The chosen equipment is a Flash programming Cell used in the BOSCH plant of Braga, used to flash the processor of car radio devices.

All the process like GRAFCET , GEMMA and Ladder program Cx-Programmer is detailed in this document. Cx-Designer as also be used to verify the Ladder program.

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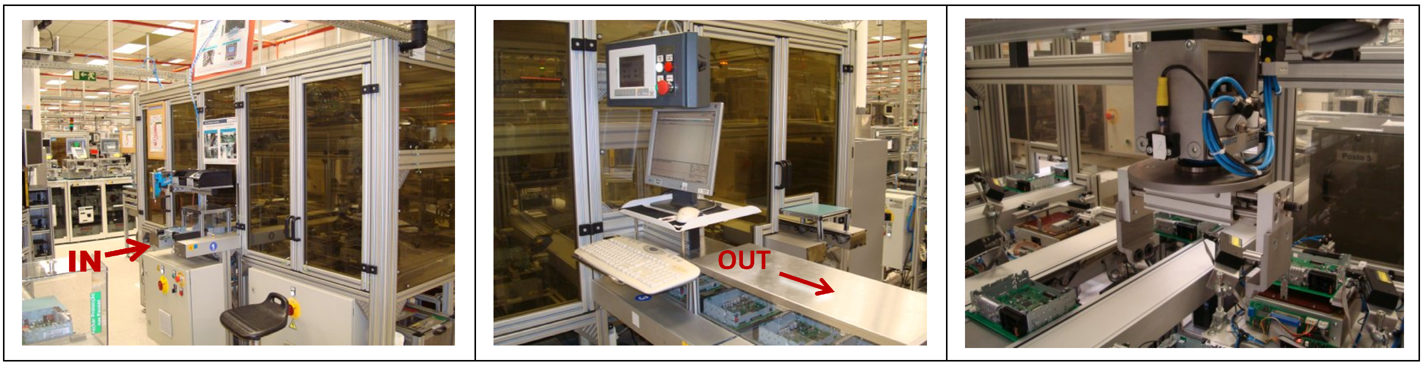
1 . Description of the Flash Cell programming

The Flash Cell programming allows to program flash processor of electronic devices. The cell has four programming stations allowing to flash 4 devices at same time, three conveyor belts, one for introduce devices and the other two for getting them out. A handler is used to manipulate the devices inside the cell. It is closed to ensure a safety environment.

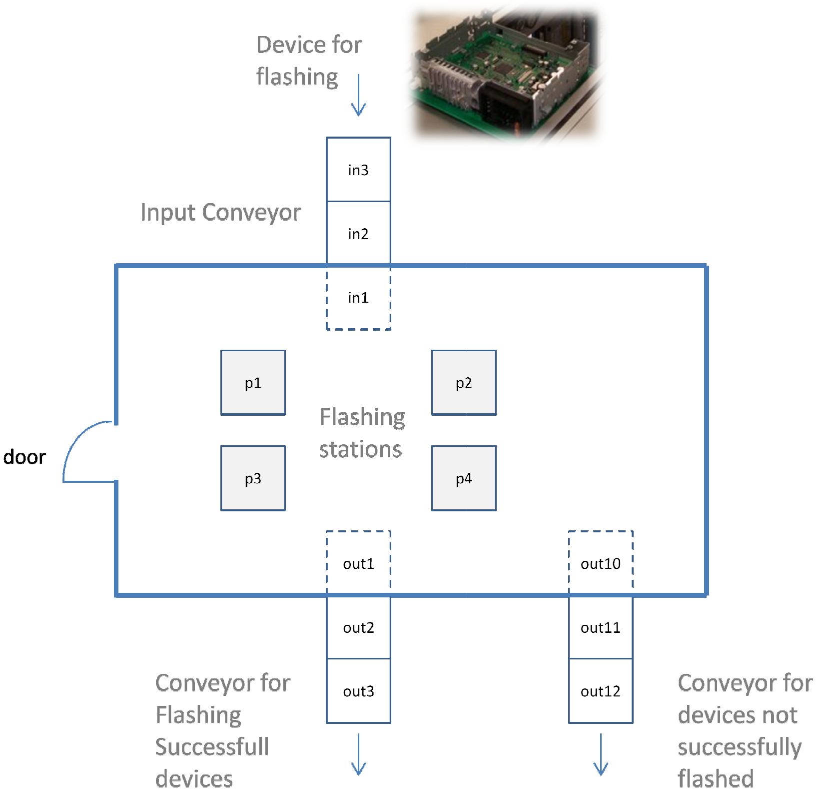


Sensors p1, p2, p3 and p4 detect devices in the 4 stations.

All conveyors have 3 positions:

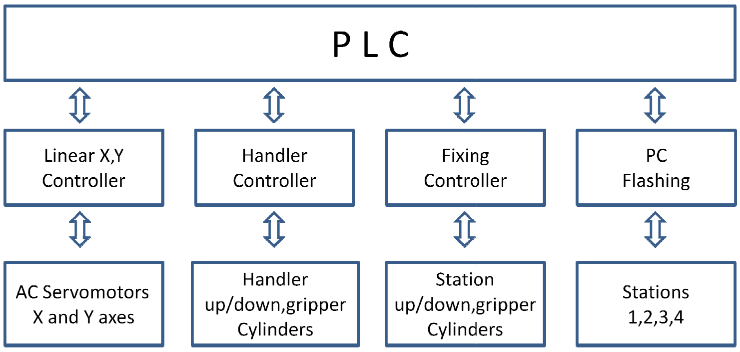
- Sensors in1, in2, in3 detect devices in Input conveyor.
- Sensors out1, out2, out3 detect devices in Output conveyor for well flashed devices.
- Sensors out10, out11, out12 detect devices in output NOK conveyor for bad flashed devices.

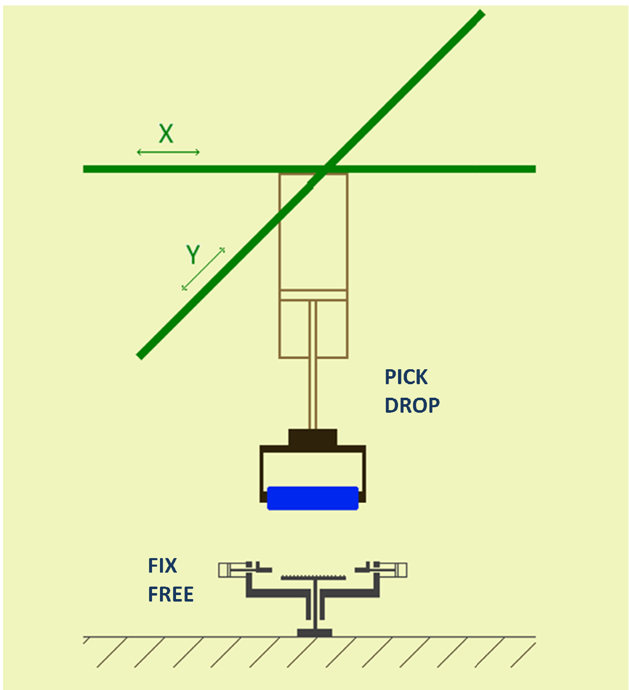
The door has a sensor to detect if it is opened or closed.



2. Control

The control is assured by an OMRON PLC, model CP1L. It is supported by a *Linear controller* to drive the handler in the X and Y axes, a *Handler controller* to coordinate actions of picking and dropping devices, and by a *Fixing device controller* on the flashing stations.

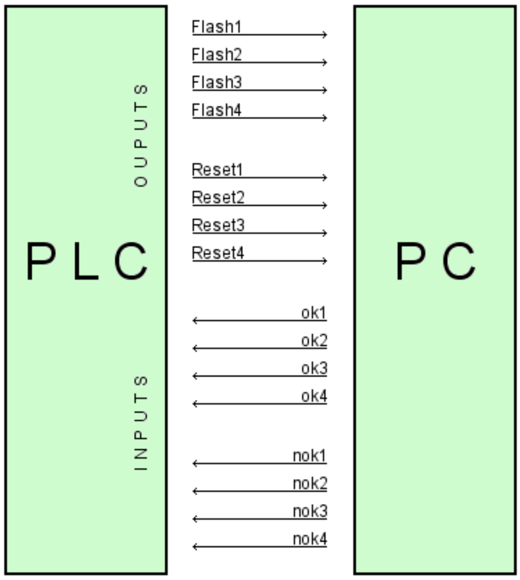




In the figure is illustrated the handler grabbing a device (in blue). In the bottom of the image we see the station where the device is flashed.

The device is fixed in the station by two pneumatic cylinders, and then goes down to come into contact with needles which provide connection to a PC that will program the device.

A sensor *down* indicates if handler is down or not.

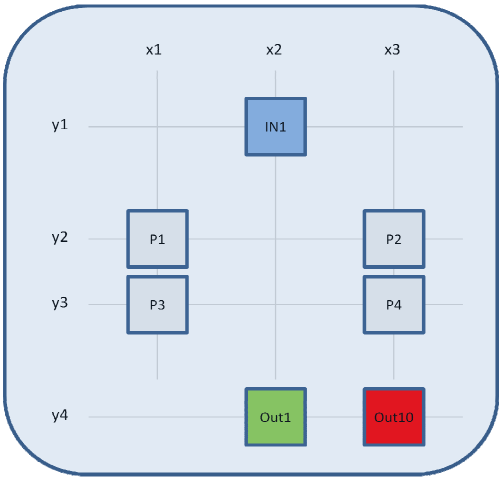


A communication between PLC and PC is necessary to inform if the devices have been well programmed (communications bits ok1, ok2, ok3, ok4) or not (nok1, nok2, nok3, nok4). The handler will get out the devices to one of the two output conveyor, one for “good” devices, and other for “bad” devices.

PLC outputs will command the stations to start flashing (Flash1, Flash2, Flash3, Flash4) , and reset the result of the flashing when the device is removed of the stations (Reset1, Reset2, Reset3, Reset4).

The position of the handler is defined by the sensors x1, x2, x3, y1, y2, y3 and y4 as we can see in the picture below.

The communication between PLC and the *Linear X,Y Controller* is done by outputs C0, C1 and C2.



Linear X,Y Controller

GRAFCET actions	C2	C1	C0
Move_IN1	0	0	1
Move_P1	0	1	0
Move_P2	0	1	1
Move_P3	1	0	0
Move_P4	1	0	1
Move_OUT1	1	1	0
Move_OUT10	1	1	1

The communication between PLC and Handler Controller is done by outputs C3 and C4, for the actions Pick-UP and DROP.

The same for Fixing Controller, with PLC outputs C5, C6, C7, C8, C9, C10, C11, C12.

The output C13 will stop the handler.

Handler Controller (Pick_UP/DROP actions)
Outputs C3,C4 are used to execute PICK and DROP actions
The *Handler controller* can be stopped by the input C13.

	C4	C3
Pick_UP	0	1
DROP	1	0

GrippON and GripOff sensors define if handler gripper is closed or opened

Fixing Controller (FIX/FREE actions)
Outputs C5,C6,C7,C8,C9,C10,C11,C12 are used to execute FIX and FREE actions in the four flashing stations

	C6	C5
FIX1	0	1
FREE1	1	0

	C8	C7
FIX2	0	1
FREE2	1	0

	C10	C9
FIX3	0	1
FREE3	1	0

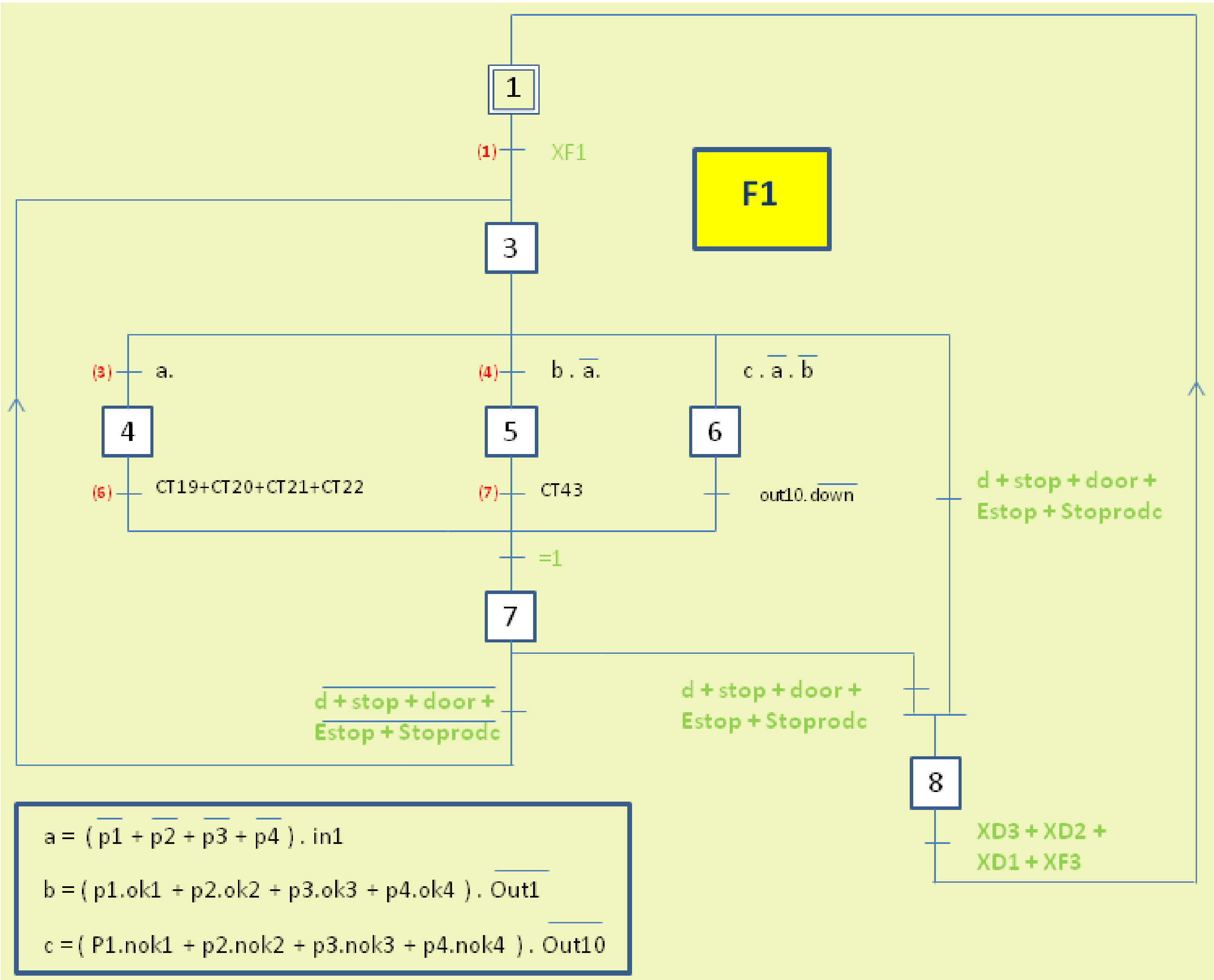
	C12	C11
FIX4	0	1
FREE4	1	0

3.GRAFCET

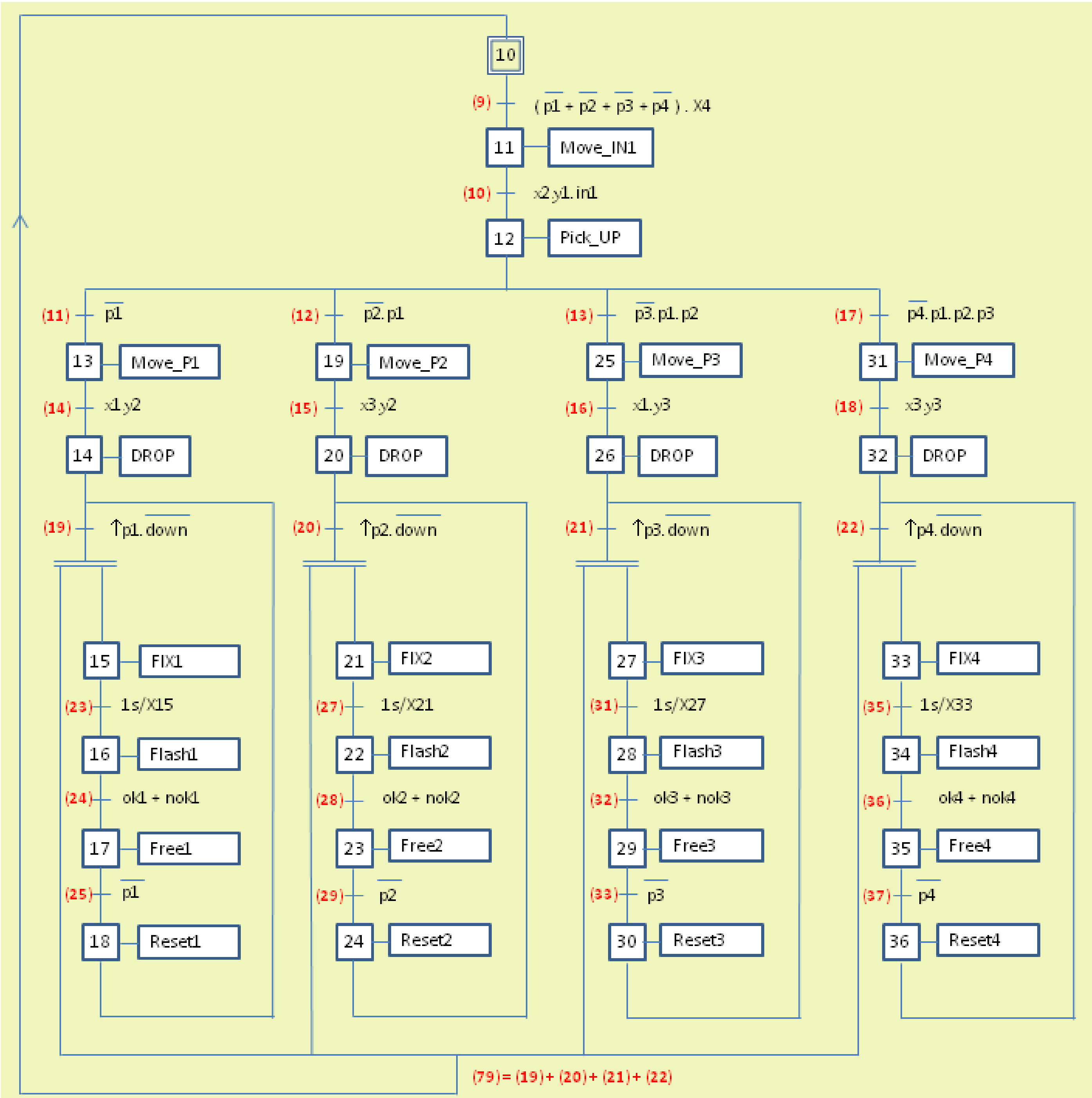
The GRAFCET has been divided in three parts, one for picking devices coming to the cell and placing them in the stations, another for picking devices from stations to output well flashed conveyor, and finally one for routing bad flashed devices to NOK conveyor.

A main GRAFCET coordinate the three actions .Stages 4, 5 and 6 corresponds successively to the actions previously defined. The high priority action is to put devices for flashing (stage 4), and the lowest priority is to remove bad flashed devices (stage6) and they are defined by the variables a, b and c which are defined below in the picture.

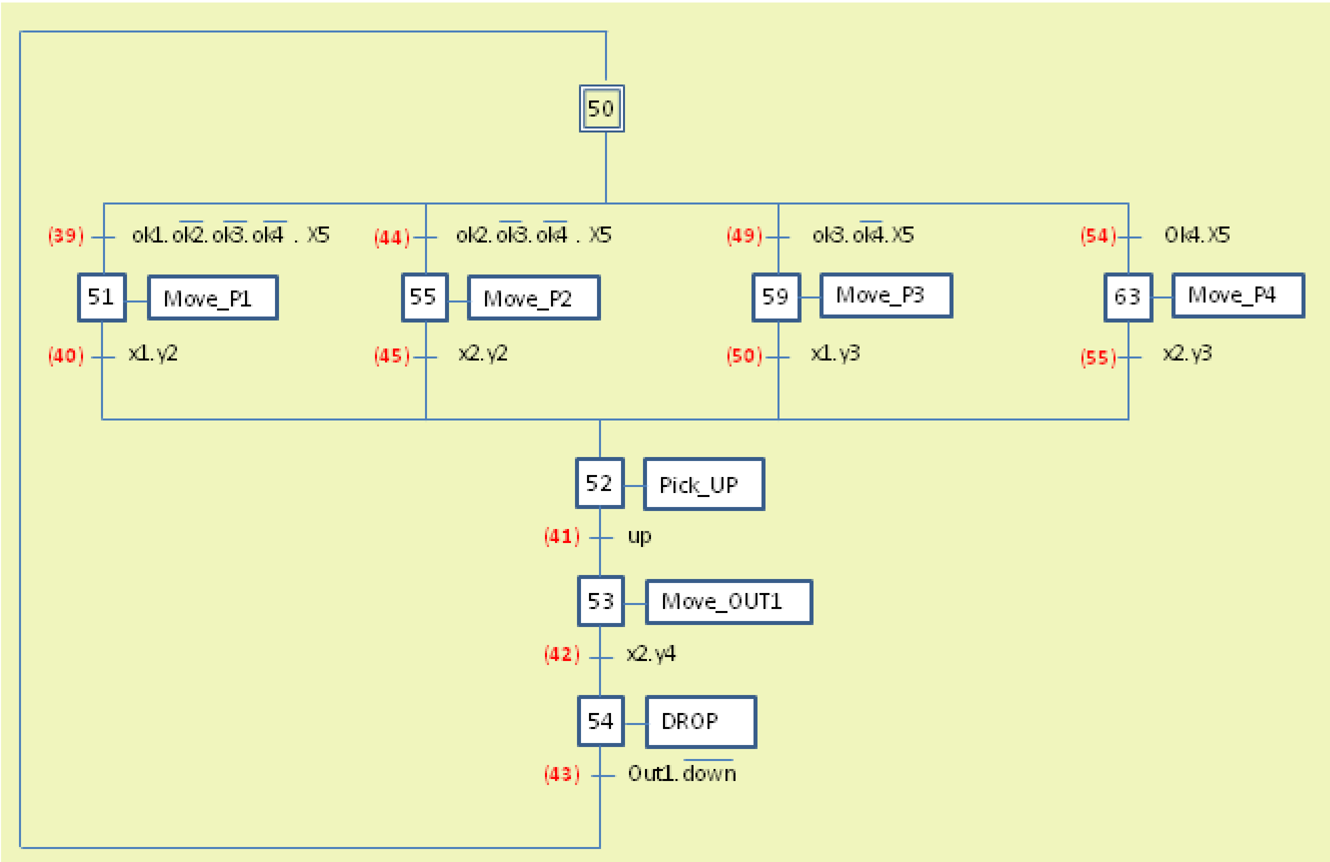
In all GRAFCETs, the red comments are the numerations of the *transaction conditions CTs.* If GRAFCET has no transaction numbers, it means that it has not been translated to Ladder, and so not included in the CX-Programmer software. The green transactions correspond to GEMMA structure that is defined forward.



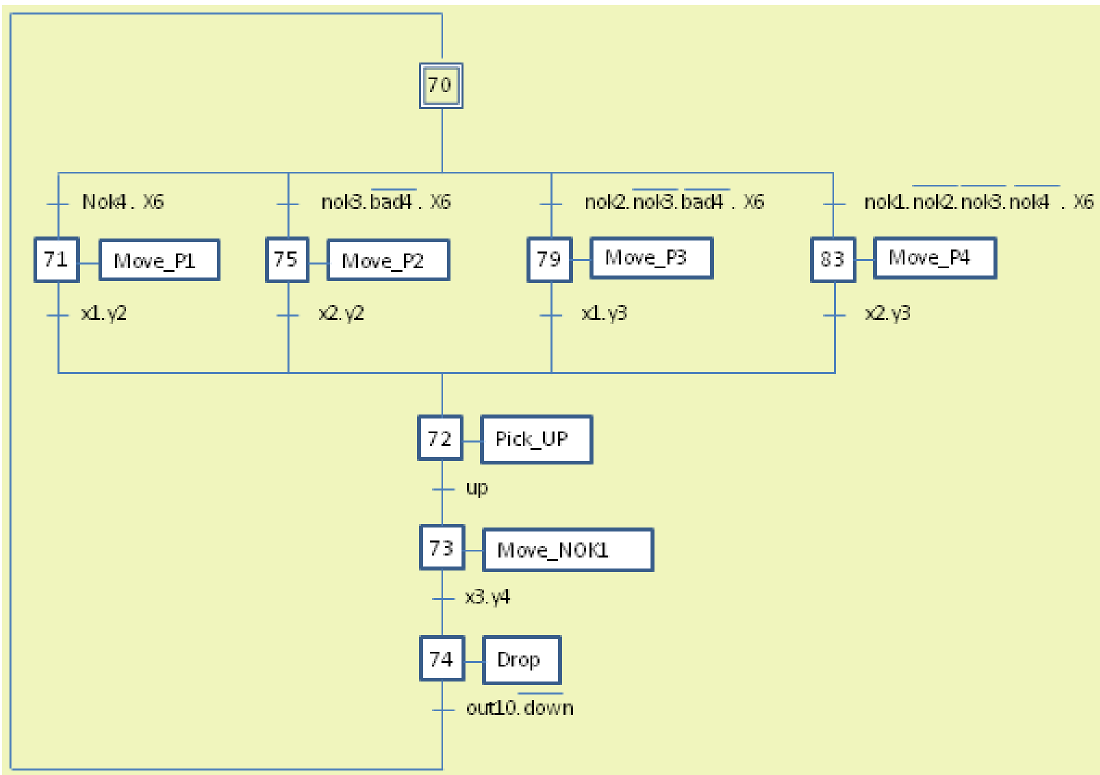
The GRAFCET related to the action of moving devices from input to flashing stations are divided in 4 parts, each one correspond to the stations 1, 2, 3 and 4. To simplify the Ladder translation, a virtual transaction (79) has been defined as the (79) = (19) + (20) + (21) + (22).



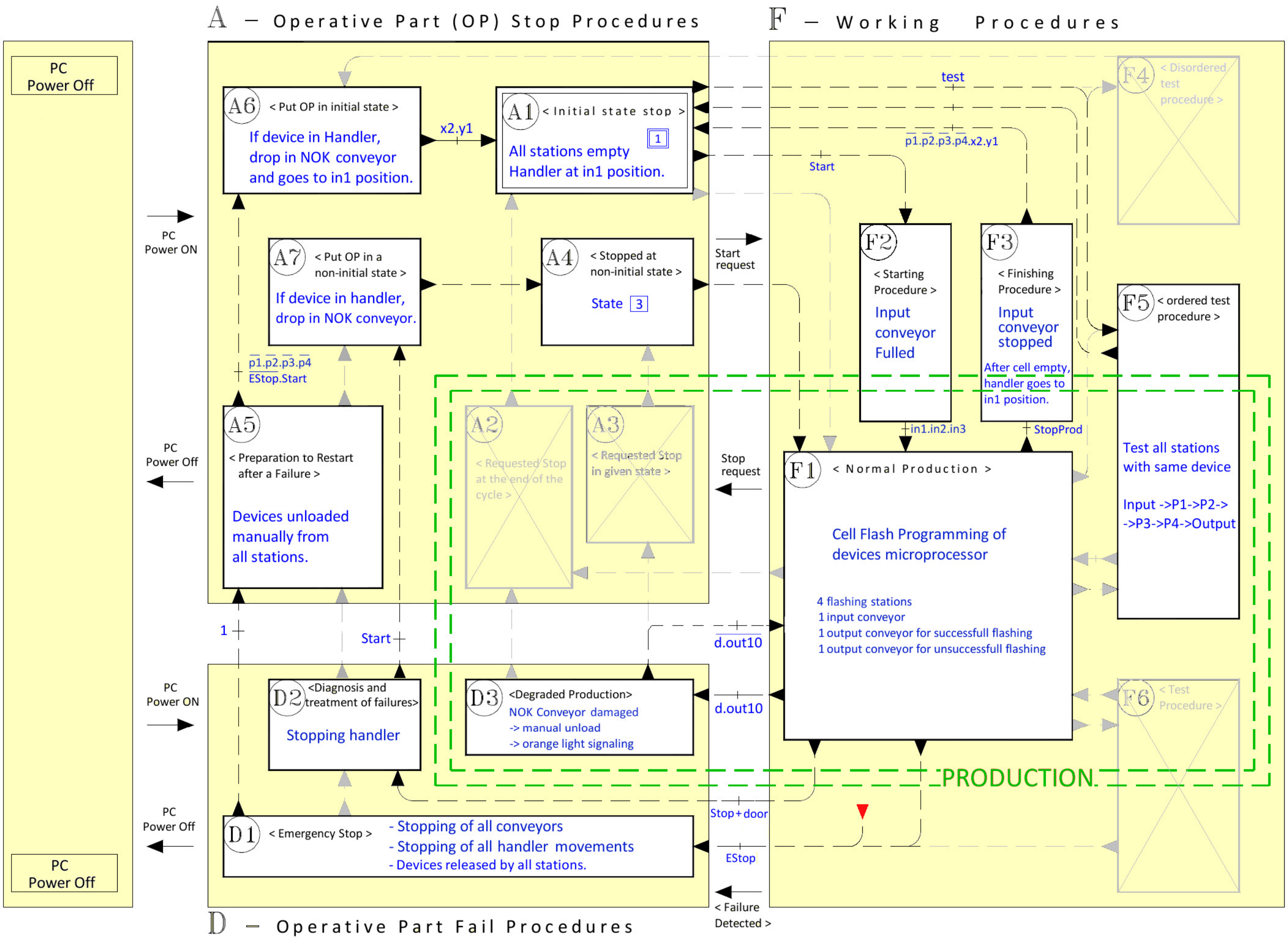
The GRAFCET related to the action of moving devices to the well flashed conveyor is also divided 4 parts.



The GRAFCET related to the action of moving devices to the NOK conveyor has not been included in the Ladder program, and is similar to the previous GRAFCET.



4.GEMMA



Description of GEMMA modes

F1 – Initial state stop. All stations empty, and handler in its initial position in1.

F2 – Normal production start if input conveyor has its 3 positions fulled.

F3 – For end of shift. Input conveyor stopped, Handler continues working until all stations empty.

F5 – A single device is used to test all station : Input -> P1 -> P2 -> P3 -> P4 -> Output. Device is flashed in all stations. Then goes back to A1.

D1 – Emergency Stop actived by operator or when door opened. Handler and conveyors are stopped .

D2 – Treatment of failure activated by stop switch. Handler is stopped.

D2 goes directly to A7, stage A5 not applied.

D3 – NOK Conveyor damaged. Unload had to be done manually. If device in conveyor , signalling orange ligth on.

A1 - Initial state stop has the four stations empty, handler in position in1.

A4 – Corresponds to state 3 in GAFCET**,** restart flashing devices in filled stations.

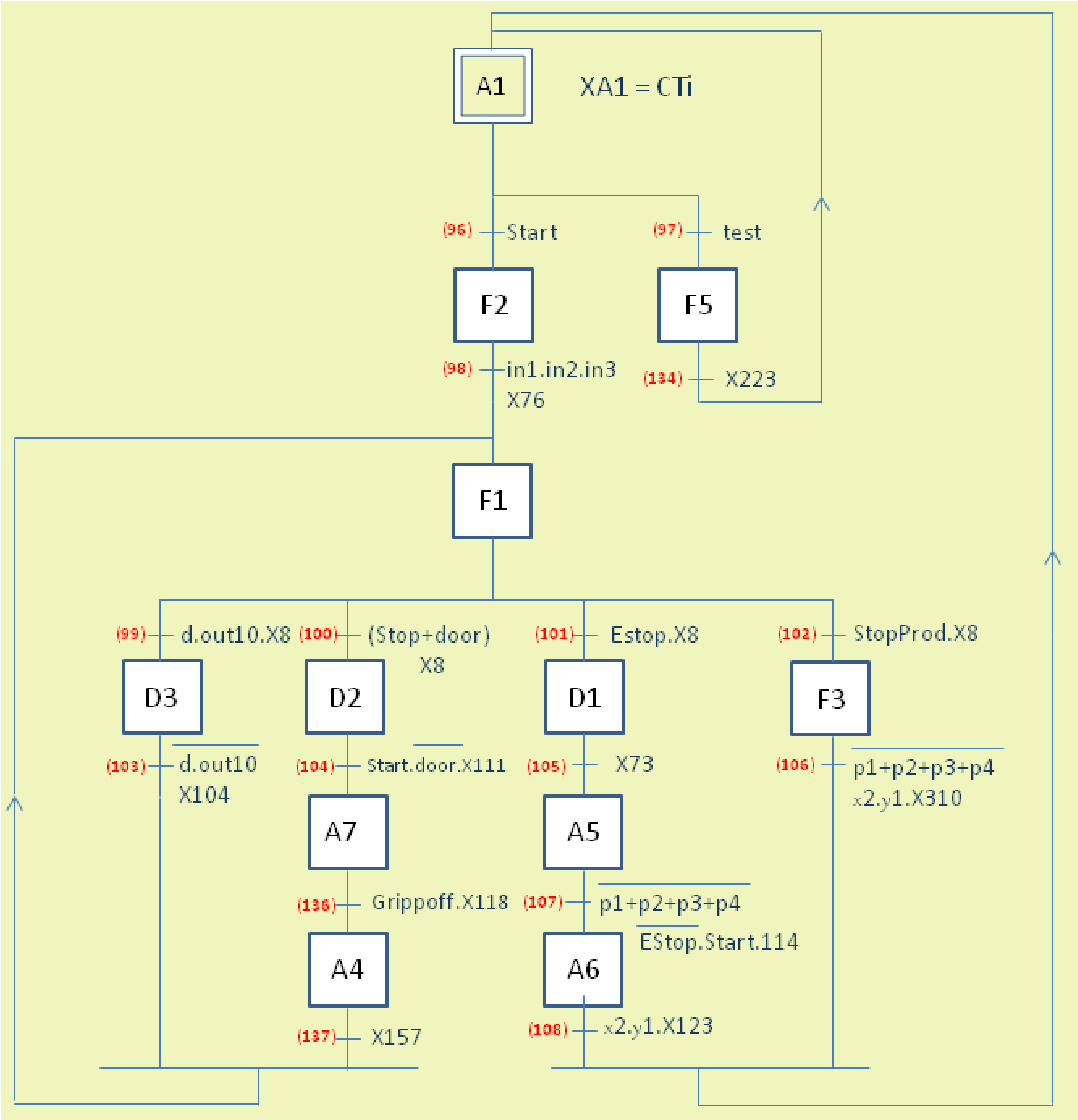
A5 – All devices have to be removed manually out of flash cell.

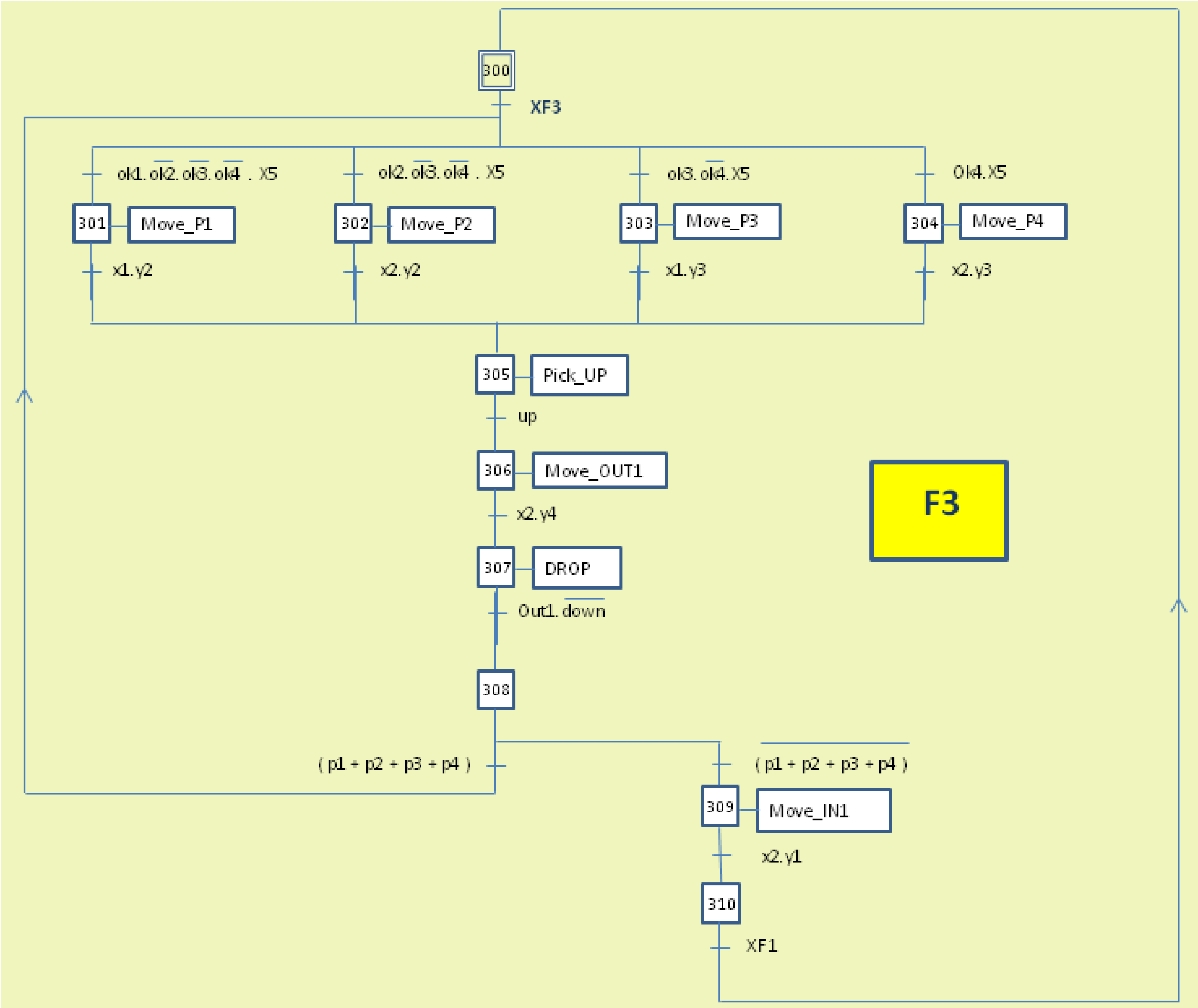
A6 – If device in handler, drop in NOK conveyor, and the handler goes to initial position in1.

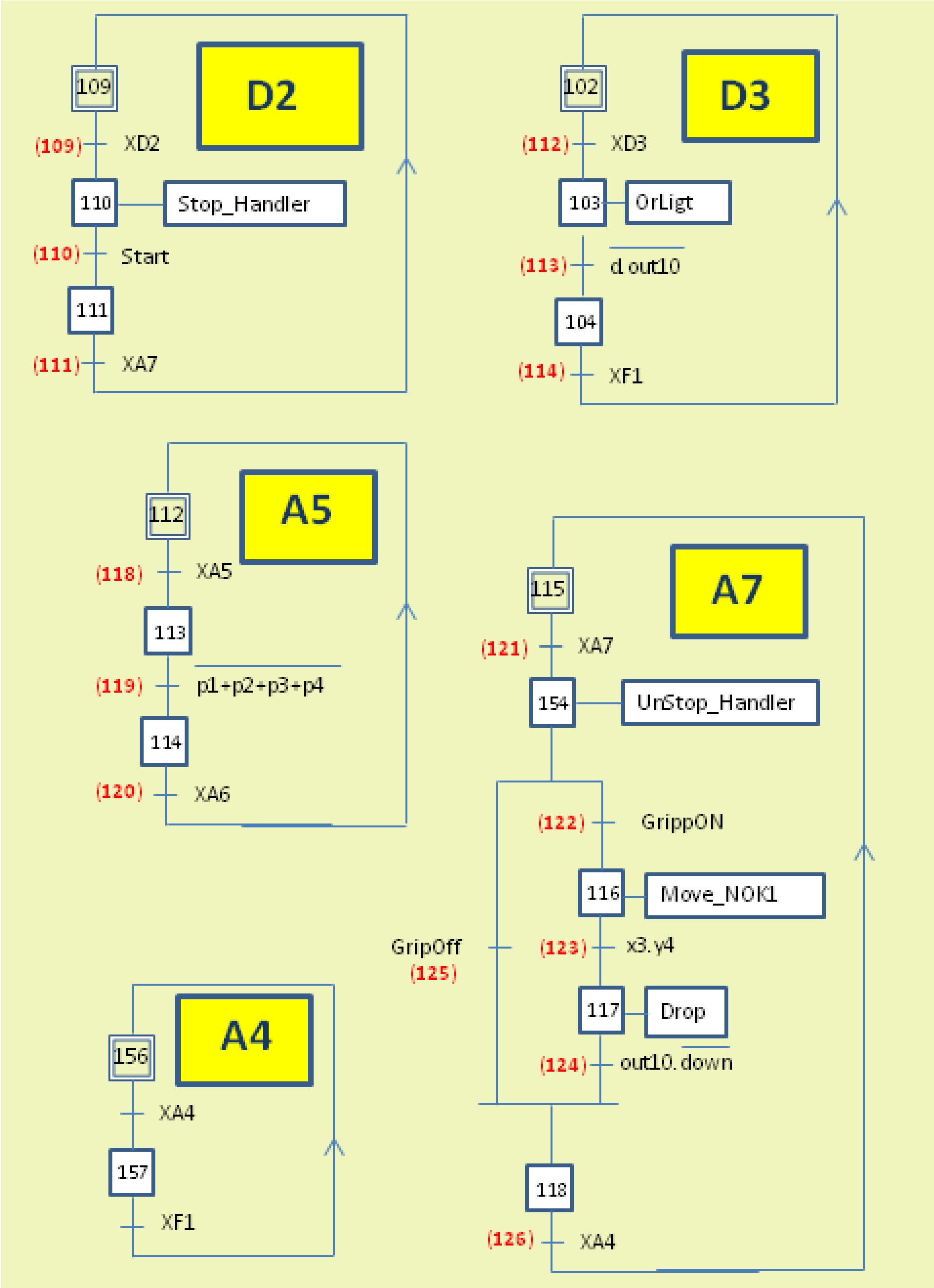
A7 – If device in handler, drop in NOK conveyor.

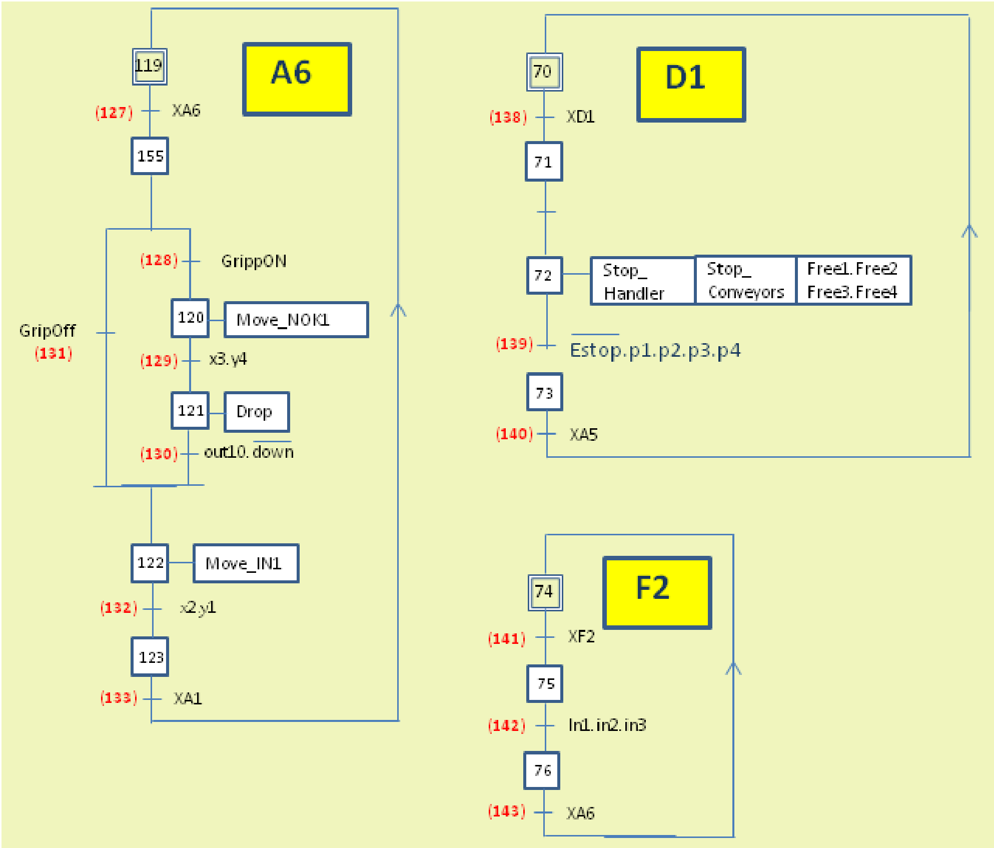
5.GEMMA GRAFCET

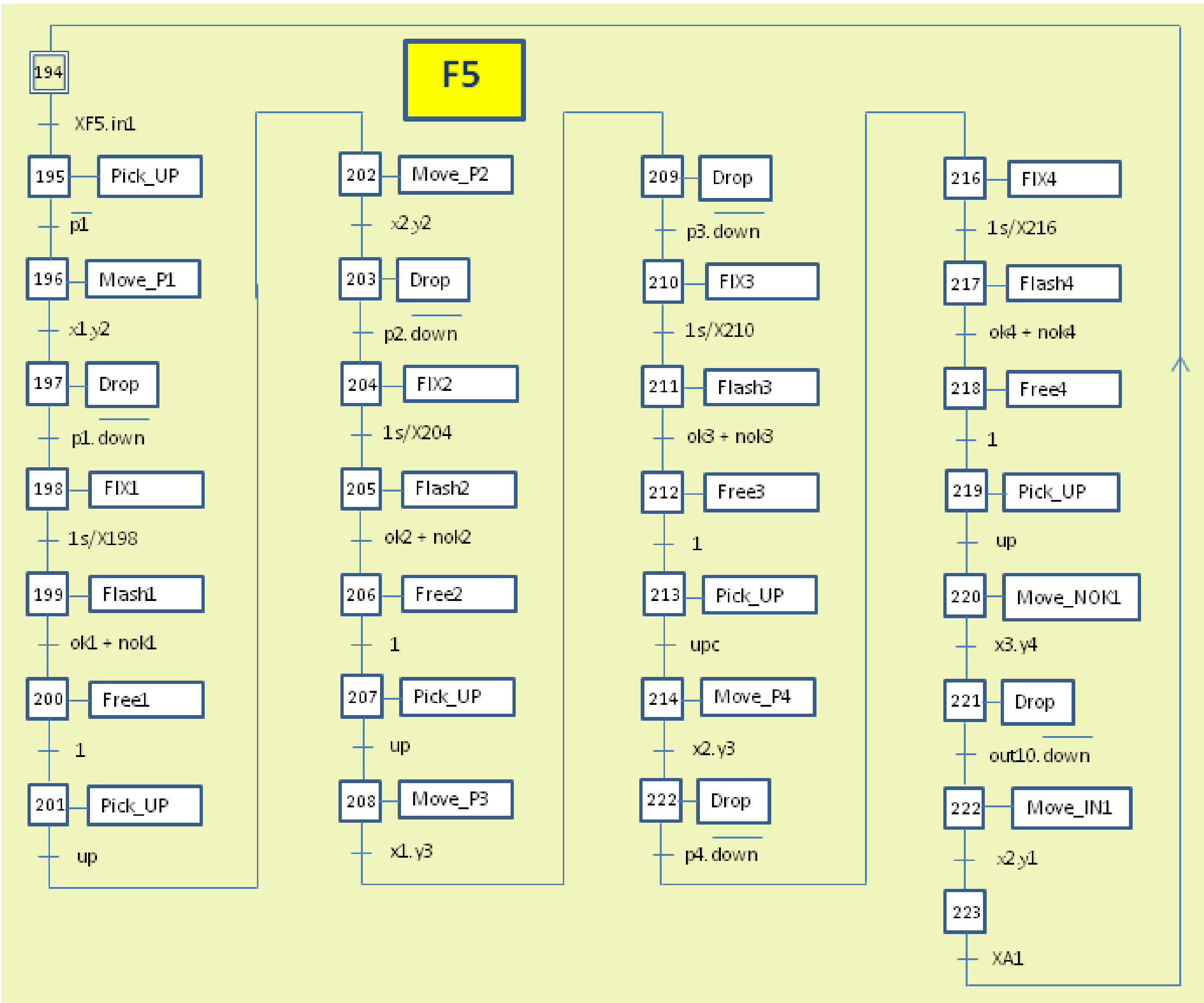
The next GRAFCET are related to the GEMMA, starting with the high level GRAFCET




300
XF3
ok1. ok2. ok3. ok4 . X5
ok2. ok3. ok4 . X5
ok3. ok4. X5
Ok4. X5
301
Move_P1
302
Move_P2
303
Move_P3
304
Move_P4
x1. y2
x2. y2
x1. y3
x2. y3
305
Pick_UP
up
306
Move_OUT1
x2. y4
307
DROP
Out1. down
308
(p1 + p2 + p3 + p4)
(p1 + p2 + p3 + p4)
309
Move_IN1
x2. y1
310
XF1
F3


D2
109
(109) XD2
110 Stop_Handler
(110) Start
111
(111) XA7
D3
102
(112) XD3
103 OrLigt
(113) d out10
104
(114) XF1
A5
112
(118) XA5
113
(119) p1+p2+p3+p4
114
(120) XA6
A7
115
(121) XA7
154 UnStop_Handler
(122) GrippON
116 Move_NOK1
GripOff
(125)
(123) x3.y4
117 Drop
(124) out10.down
118
(126) XA4
A4
156
XA4
157
XF1


A6
119
(127) XA6
155
(128) GrippON
120 Move_NOK1
(129) x3.y4
121 Drop
(130) out10.down
GripOff
(131)
122 Move_IN1
(132) x2.y1
123
(133) XA1
D1
70
(138) XD1
71
72 Stop_ Handler Stop_ Conveyors Free1.Free2 Free3.Free4
(139) Estop.p1.p2.p3.p4
73
(140) XA5
F2
74
(141) XF2
75
(142) In1.in2.in3
76
(143) XA6


F5
194
XF5.in1
195 Pick_UP
p1
196 Move_P1
x1.y2
197 Drop
p1.down
198 FIX1
1s/X198
199 Flash1
ok1 + nok1
200 Free1
1
201 Pick_UP
up
202 Move_P2
x2.y2
203 Drop
p2.down
204 FIX2
1s/X204
205 Flash2
ok2 + nok2
206 Free2
1
207 Pick_UP
up
208 Move_P3
x1.y3
209 Drop
p3.down
210 FIX3
1s/X210
211 Flash3
ok3 + nok3
212 Free3
1
213 Pick_UP
upc
214 Move_P4
x2.y3
222 Drop
p4.down
216 FIX4
1s/X216
217 Flash4
ok4 + nok4
218 Free4
1
219 Pick_UP
up
220 Move_NOK1
x3.y4
221 Drop
out10.down
222 Move_IN1
x2.y1
223
XA1

6.Ladder

The initialization is done by the initial transition CTi = /p1 . /p2 . /p3 . /p4 . x2. y1 /X3 . X4 . X5. X6

The translation of the GRAFCET to Ladder are defined in the next tables.

CTs : Main GRAFCET	Xs	Outputs
CT1 = X1 . /p1 . /p2 . /p3 . /p4 . x2. y1. start	X1 = CTi	No Outputs
CT3 = X3 . a	X3 = CT1+CT6+CT7+CT8+X3. /(CT3+CT4+CT5)	
CT4 = X3 . b . /a	X4 = CT3 + X4 . /CT6	
CT6 = X4 . (CT19 + CT20 + CT21 + CT22)	X5 = CT4 + X5 . /CT7	
CT7 = X5 . CT43	X6 = CT5 + X6 . /CT8	

CTs : Input GRAFCET	Xs	Outputs
CT09 = X10 . (/p1 + /p2 + /p3 + /p4) . X4	X10 = CT79 + X10 . /CT9 + CTi	X11 = C0
CT10 = X11 . x2 . y1 . in1	X11 = CT9 + X11 . /CT10	X12 = C3
CT11 = X12 . /p1	X12 = CT10 + X12./CT11./CT12./CT13./CT14	X13 = C1
CT12 = X12 . p1 . /p2	X13 = CT11 + X13 . /CT14	X14 = C4
CT13 = X12 . /p3 . p1 . p2	X14 = CT14 + X14 . /CT19	X15 = C5
CT14 = X13 . x1 . y2	X15 = CT19 + X15 . /CT23	X16 = Flash1
CT15 = X19 . x3 . y2	X16 = CT23 + X16 . /CT24	X17 = C6
CT16 = X25 . x1 . y3	X17 = CT24 + X17 . /CT25	X18 = Reset1
CT17 = X12 . /p4 . p1 . p2 . p3	X18 = CT25 + X18 . /CT19	X19 = C0 . C1
CT18 = X31 . x3 . y3	X19 = CT12 + X19 . /CT15	X20 = C4
CT19 = X14 . ↑p1 . /down + X18 . p1 . /down	X20 = CT15 + X20 . /CT20	X21 = C7
CT20 = X20 . p2 . /down + X24 . p2 . /down	X21 = CT20 + X21 . /CT27	X22 = Flash2
CT21 = X26 . p3 . /down + X30 . p3 . /down	X22 = CT27 + X22 . /CT28	X23 = C8
CT22 = X32 . p4 . /down + X36 . p4 . /down	X23 = CT28 + X23 . /CT29	X24 = Reset2
CT23 = X15/1s	X24 = CT29 + X24 . /CT20	X25 = C2
CT24 = X16 . (ok1 + nok1)	X25 = CT13 + X25 . /CT16	X26 = C4
CT25 = X17 . /p1	X26 = CT16 + X26 . /CT21	X27 = C9
CT27 = X21/1s	X27 = CT21 + X27 . /CT31	X28 = Flash3
CT28 = X22 . (ok2 + nok2)	X28 = CT31 + X28 . /CT32	X29 = C10
CT29 = X23 . /p2	X29 = CT32 + X29 . /CT33	X30 = Reset3
CT31 = X27/1s	X30 = CT33 + X30 . /CT21	X31 = C0 . C2
CT32 = X28 . (ok3 + nok3)	X31 = CT17 + X31 . /CT18	X32 = C4
CT33 = X29 . /p3	X32 = CT18 + X32 . /CT22	X33 = C11
CT35 = X33/1s	X33 = CT22 + X33 . /CT35	X34 = Flash4
CT36 = X34 . (ok4 + nok4)	X34 = CT35 + X34 . /CT36	X35 = Free4
CT37 =X35 . /p4	X35 = CT36 + X35 . /CT37	X36 = Reset4
CT79 = CT19 + CT20 + CT21 + CT22	X36 = CT37 + X36 . /CT22	

CTs GRAFCET OUTPUT	Xs	Outputs
CT39 = X50 . ok1 . /ok2 . /ok3 . /ok4	X50 = CTi + CT43 +	X51 = C1
CT40 = X51 . x1 .y2	X50 . /(CT39+CT44+CT49+CT54)	X52 = C3
CT41 = X52 . up	X51 = CT39 + X51 . /CT40	X53 = C1.C2
CT42 = X53 . x2 . y4	X52 = CT40 + CT45 + CT50 + CT55 + X52 . /CT41	X54 = C4
CT43 = X54 . out1 . /down	X53 = CT41 + X53 . /CT42	X55 = C0.C1
CT44 = X50 . ok2 . /ok3 . /ok4	X54 = CT42 + X54 . /CT43	X59 = C2
CT45 = X55 . x2 . y2	X55 = CT44 + X55 . /CT45	X63 = C0.C2
CT49 = X50 . ok3 . /ok4	X59 = CT49 + X59 . /CT50	
CT50 = X59 . x1 . y3	X63 = CT54 + X63 . /CT55	
CT54 = X50 . ok4		
CT55 = X63 . x2 . y3		

I/O and Work Area addresses

The PLC addresses for the CP1L OMRON are defined in the next tables.

I/O Inputs

Stoprd	Start	Stop	EStop	door	up	down	Out12	Out11	Out10	Out3	Out2	Out1	In3	In2	In1
00.15	00.14	00.13	00.12	00.11	00.10	00.09	00.08	00.07	00.06	00.05	00.04	00.03	00.02	00.01	00.00
					p4	p3	p2	p1	y4	y3	y2	y1	x3	x2	x1
01.15	01.14	01.13	01.12	01.11	01.10	01.09	01.08	01.07	01.06	01.05	01.04	01.03	01.02	01.01	01.00
				d	test	GripOff	GrippON	nok4	nok3	nok2	nok1	ok4	ok3	ok2	ok1
02.15	02.14	02.13	02.12	02.11	02.10	02.09	02.08	02.07	02.06	02.05	02.04	02.03	02.02	02.01	02.00

CTs (Work Area)

CT16	CT15	CT14	CT13	CT12	CT11	CT10	CT9	CT8	CT7	CT6	CT5	CT4	CT3	CT2	CT1
W20.15	W20.14	W20.13	W20.12	W20.11	W20.10	W20.09	W20.08	W20.07	W20.06	W20.05	W20.04	W20.03	W20.02	W20.01	W20.00
CT32	CT31		CT29	CT28	CT27		CT25	CT24	CT23	CT22	CT21	CT20	CT19	CT18	CT17
W21.15	W21.14	W21.13	W21.12	W21.11	W21.10	W21.09	W21.08	W21.07	W21.06	W21.05	W21.04	W21.03	W21.02	W21.01	W21.00
			CT45	CT44				CT40	CT39		CT37	CT36	CT35		CT33
W22.15	W22.14	W22.13	W22.12	W22.11	W22.10	W22.09	W22.08	W22.07	W22.06	W22.05	W22.04	W22.03	W22.02	W22.01	W22.00
				CT60	CT59				CT55	CT54				CT50	CT49
W23.15	W23.14	W23.13	W23.12	W23.11	W23.10	W23.09	W23.08	W23.07	W23.06	W23.05	W23.04	W23.03	W23.02	W23.01	W23.00
	CT79														
W24.15	W24.14	W24.13	W24.12	W24.11	W24.10	W24.09	W24.08	W24.07	W24.06	W24.05	W24.04	W24.03	W24.02	W24.01	W24.00
CT96	CT95	CT94	CT93	CT92	CT91	CT90	CT89	CT88	CT87	CT86	CT85	CT84			
W25.15	W25.14	W25.13	W25.12	W25.11	W25.10	W25.09	W25.08	W25.07	W25.06	W25.05	W25.04	W25.03	W25.02	W25.01	W25.00
CT111	CT110	CT109	CT108	CT107	CT106	CT105	CT104	CT103	CT102	CT101	CT100	CT99	CT98	CT97	CTi
W26.15	W26.14	W26.13	W26.12	W26.11	W26.10	W26.09	W26.08	W26.07	W26.06	W26.05	W26.04	W26.03	W26.02	W26.01	W26.00
CT127	CT126	CT125	CT124	CT123	CT122	CT121	CT120	CT119	CT118	CT117	CT116	CT115	CT114	CT113	CT112
W27.15	W27.14	W27.13	W27.12	W27.11	W27.10	W27.09	W27.08	W27.07	W27.06	W27.05	W27.04	W27.03	W27.02	W27.01	W27.00
CT143	CT142	CT141	CT140	CT139	CT138	CT137	CT136	CT135	CT134	CT133	CT132	CT131	CT130	CT129	CT128
W28.15	W28.14	W28.13	W28.12	W28.11	W28.10	W28.09	W28.08	W28.07	W28.06	W28.05	W28.04	W28.03	W28.02	W28.01	W28.00
									CT150	CT149	CT148	CT147	CT146	CT145	CT144
W29.15	W29.14	W29.13	W29.12	W29.11	W29.10	W29.09	W29.08	W29.07	W29.06	W29.05	W29.04	W29.03	W29.02	W29.01	W29.00

Xs (Work Area)

	c	b	a	XF5	XF3	XF2	XF1	XD3	XD2	XD1	XA7	XA6	XA5	XA4	XA1
W0.15	W0.14	W0.13	W0.12	W0.11	W0.10	W0.09	W0.08	W0.07	W0.06	W0.05	W0.04	W0.03	W0.02	W0.01	W0.00

								X8	X7	X6	X5	X4	X3	X2	X1
W3.15	W3.14	W3.13	W3.12	W3.11	W3.10	W3.09	W3.08	W3.07	W3.06	W3.05	W3.04	W3.03	W3.02	W3.01	W3.00

X25	X24	X23	X22	X21	X20	X19	X18	X17	X16	X15	X14	X13	X12	X11	X10
W4.15	W4.14	W4.13	W4.12	W4.11	W4.10	W4.09	W4.08	W4.07	W4.06	W4.05	W4.04	W4.03	W4.02	W4.01	W4.00

					X36	X35	X34	X33	X32	X31	X30	X29	X28	X27	X26
W5.15	W5.14	W5.13	W5.12	W5.11	W5.10	W5.09	W5.08	W5.07	W5.06	W5.05	W5.04	W5.03	W5.02	W5.01	W5.00

		X63	X62	X61	X60	X59	X58	X57	X56	X55	X54	X53	X52	X51	X50
W6.15	W6.14	W6.13	W6.12	W6.11	W6.10	W6.09	W6.08	W6.07	W6.06	W6.05	W6.04	W6.03	W6.02	W6.01	W6.00

X155	X154				X76	X75	X74	X73	X72	X71	X70	X69	X68	X67	
W7.15	W7.14	W7.13	W7.12	W7.11	W7.10	W7.09	W7.08	W7.07	W7.06	W7.05	W7.04	W7.03	W7.02	W7.01	W7.00

X117	X116	X115	X114	X113	X112	X111	X110	X109	X108	X107	X106	X105	X104	X103	X102
W8.15	W8.14	W8.13	W8.12	W8.11	W8.10	W8.09	W8.08	W8.07	W8.06	W8.05	W8.04	W8.03	W8.02	W8.01	W8.00

										X123					
W9.15	W9.14	W9.13	W9.12	W9.11	W9.10	W9.09	W9.08	W9.07	W9.06	W9.05	W9.04	W9.03	W9.02	W9.01	W9.00

I/O Outputs

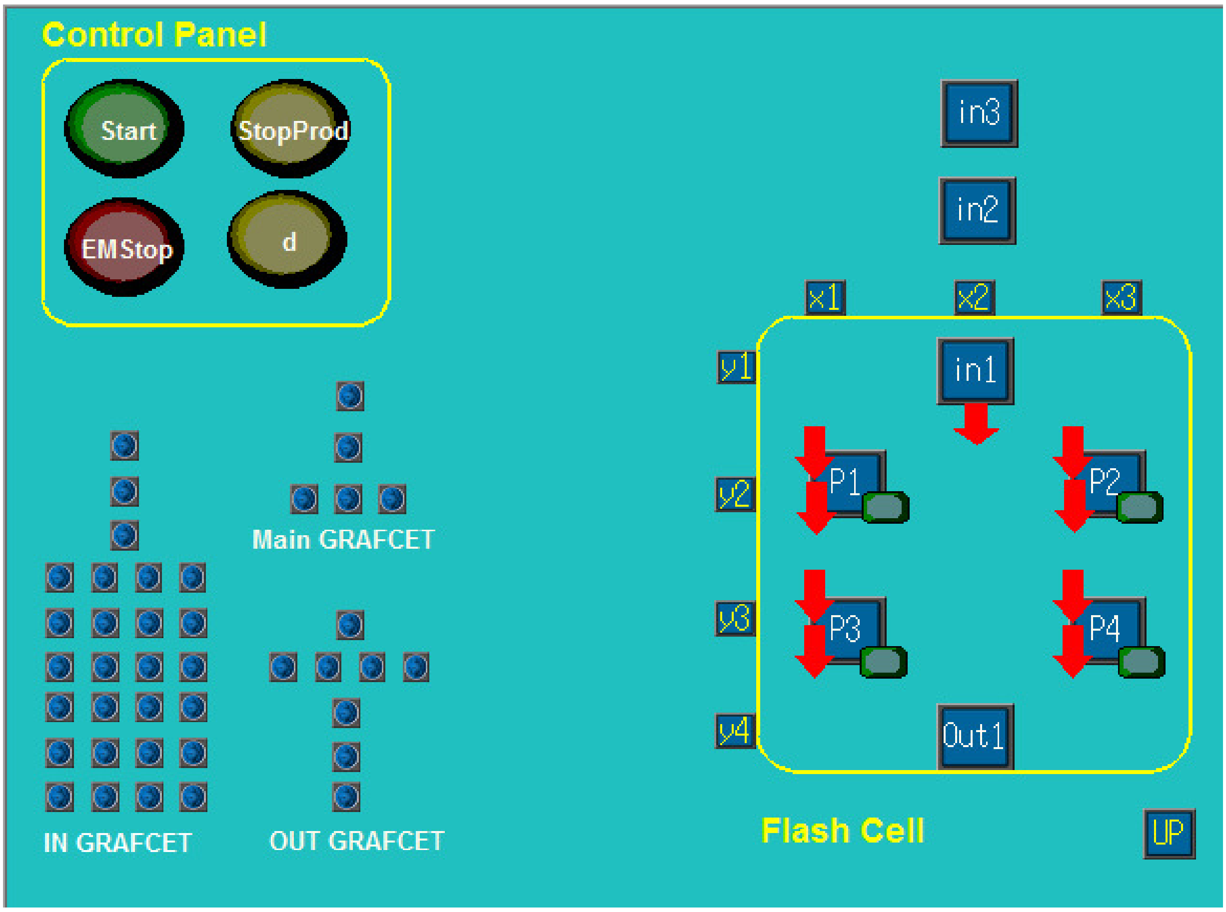
	C13	C12	ORlight	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	C0
100.15	100.14	100.13	100.12	100.11	100.10	100.09	100.08	100.07	100.06	100.05	100.04	100.03	100.02	100.01	100.00

								Reset4	Reset3	Reset2	Reset1	Flash4	Flash3	Flash2	Flash1
101.15	101.14	101.13	101.12	101.11	101.10	101.09	101.08	101.07	101.06	101.05	101.04	101.03	101.02	101.01	101.00

Cx-Designer has been used to verify the GRAFCET and the Ladder.

It is divided in 3 parts :

- Control Panel (PLC outputs)
- Flash Cell (PLC inputs)
- GRAFCET (virtual inputs), where we can see the evolution of the GRAFCET when the software is running.



7.Conclusion

All the work was crucial to better understand the difficulties of the implementation of GRAFCET, GEMMA and Ladder. It has been a very long work, much more than expected, but very important because thanks to it the concept of GEMMA is now better understood, we have done improvements in GRAFCET designing, as well in the understanding of the *Safe Automation* concept, get experience into Ladder programming, and we are now better familiar with the operation of the PLC.

Some GRAFCET and Ladder errors was detected thanks to Cx-Designer which we consider now an important tool.
It mainly helps to improve designing GRAFCET when don´t get the expected result, to detect typing translation errors from GRAFCET to Ladder that is a very long work. This process could have been optimized, some ideas have been emerging, but mainly a designing software GRAFCET could be easily developed with the function to translate GRAFCET to CTs, Xs and Outputs, as well as the I/O and Work Area addresses.

We would like to include the GEMMA part in Ladder program, but the delays did not allows it, mainly because it will be interesting to verify it.

To complete this work, an important part like verification of designing systems as UPPALL would be also very interesting to implement.