ภาคผนวก ก

โปรแกรม Ladder ของระบบควบคุมการจ่ายน้ำดีไอออไนซ์

DIwaterSupply

Module Type Information: FX5CPU FX5U

Step No. Instruction I/O (Device)

```
0 LD SM402
2 MOV K80
 D1
6 MOV K20
 D2
10 MOV K10
 D3
14 MOV K1000
 D454
18 MOV K1000
 D455
22 MOV K1000
 D462
26 MOV K1000
 D453
30 MOV K1000
 D458
34 MOV K50
 D456
38 MOV K50
 D459
42 MOV K5
 D461
46 MOV K10
 D4
50 MOV K10
 D5
54 MOV K10
 D6
58 LD M0
60 LD M2
62 OR M4
64 ANB
65 ANI M3
67 OUT M4
69 LD M1
71 ANI M81
73 OUT M17
75 LD M4
77 OR M17
79 ANI M81
81 OUT M21
83 LD M4
85 RST M1
87 LD M1
89 RST M4
91 LD M4
93 OR M1
95 MPS
96 AND>= D0
 D1
100 OUT M5
102 MPP
103 AND< D0
 D2
107 OUT M7
109 LD SM8000
111 AND< D0
 D3
115 OUT M6
117 LD M4
119 OR M1
121 LD M7
123 OR M20
125 ANB
126 ANI M5
128 OUT M20
130 LD M4
132 LD M8
134 OR M10
136 OR M15
138 ANI M16
140 LD M16
142 ANI T0
144 ORB
145 ANB
146 LD M1
148 LD M8
150 OR M10
152 ANB
153 ANI M9
155 ORB
156 ANI M6
158 ANI M14
160 ANI M9
162 OUT M10
164 LD M4
166 LD M11
168 OR M13
170 OR M14
172 ANI M16
174 LD M16
176 AND T0
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178 ORB
179 ANB
180 LD M1
182 LD M11
184 OR M13
186 ANB
187 ANI M12
189 ORB
190 ANI M6
192 ANI M15
194 ANI M12
196 OUT M13
198 LD M4
200 AND M16
202 MPS
203 ANI T1
205 OUT T0
D453
210 MPP
211 AND T0
213 OUT T1
D453
218 LD SM402
220 MOV K50
D100
224 MOV K500
D110
228 SET D111.0
230 SET D111.5
232 MOV K4000
D132
236 MOV K0
D133
240 MOV K50
D116
244 MOV K150
D114
248 MOV K6500
D113
252 RST D111.4
254 RST D111.6
256 LD SM402
258 ORP M19
262 ORP M1
266 RST D102
269 LDP M19
273 MUL D456
K80
D132
280 MUL D457
K80
D133
287 LD M10
289 OR M13
291 ANI M17
293 ANI M19
295 PID D100
D104
D110
D102
301 LD M4
303 LD M10
305 OR M13
307 ANB
308 MPS
309 AND SM412
311 MOV D102
D103
315 MPP
316 / D103
K80
D105
323 LD M4
325 OR M17
327 AND SM411
329 MPS
330 AND M10
332 MPS
333 AND> D108
D105
337 AND<= D108
K50
341 #NAME? K1
D108
346 MRD
347 AND< D108
D105
351 AND>= D108
K0
355 #NAME? K1
D108
360 MPP
361 AND> D107

K0
365 #NAME? D107
K1
D107
370 MPP
371 AND M13
373 MPS
374 AND> D107
D105
378 AND<= D107
K50
382 #NAME? K1
D107
387 MRD
388 AND< D107
D105
392 AND>= D107
K0
396 #NAME? K1
D107
401 MPP
402 AND> D108
K0
406 #NAME? D108
K1
D108
411 LD M4
413 LD M10
415 OR M13
417 ANB
418 OR M17
420 ANI M23
422 ANI M7
424 OUT M22
426 LD M4
428 AND M22
430 MPS
431 LDP T3
435 ORP T2
439 ANB
440 ALT M24
443 MRD
444 AND M25
446 OUT T2
D454
451 MRD
452 AND M26
454 OUT T3
K10
459 MRD
460 AND M24
462 OUT M25
464 MRD
465 ANI M24
467 OUT M26
469 MRD
470 ANDP M24
474 SFTL M27
M28
K3
K1
480 MPP
481 ANDP M28
485 RST M27
487 LD M4
489 ANI M7
491 AND M22
493 LD M28
495 LD M36
497 AND M30
499 ORB
500 OR M37
502 ANB
503 LD M17
505 AND M73
507 ORB
508 ANI M34
510 ANI M81
512 OUT M31
514 LD M4
516 ANI M7
518 AND M22
520 LD M29
522 LD M34
524 AND M28
526 ORB
527 OR M38
529 ANB
530 LD M17
532 AND M75
534 ORB
535 ANI M35
537 ANI M81

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539 OUT M32
541 LD M4
543 ANI M7
545 AND M22
547 LD M30
549 LD M35
551 AND M29
553 ORB
554 OR M39
556 ANB
557 LD M17
559 AND M77
561 ORB
562 ANI M36
564 ANI M81
566 OUT M33
568 LD M4
570 ANI M7
572 AND M22
574 MPS
575 LDF M31
579 OR M37
581 ANB
582 OUT T4
 K20
587 ANI T4
589 OUT M37
591 MRD
592 LDF M32
596 OR M38
598 ANB
599 OUT T5
 K20
604 ANI T5
606 OUT M38
608 MPP
609 LDF M33
613 OR M39
615 ANB
616 OUT T6
 K20
621 ANI T6
623 OUT M39
625 LD M4
627 ANI M7
629 LDP M22
633 ORP M30
637 ANB
638 SET M27
640 LD M4
642 ANI M7
644 LD M34
646 OR M35
648 OR M36
650 ANB
651 LD M17
653 LD M72
655 OR M71
657 ANB
658 ORB
659 OUT M71
661 LD M17
663 ANI M4
665 MPS
666 AND M73
668 OUT M74
670 MRD
671 AND M75
673 OUT M76
675 MPP
676 AND M77
678 OUT M78
680 LD M0
682 OR M1
684 MPS
685 AND< D4
 D461
689 SET M34
691 MRD
692 AND< D5
 D461
696 SET M35
698 MRD
699 AND< D6
 D461
703 SET M36
705 MRD
706 AND M34
708 OUT T16
 D454
713 MRD
714 AND T16
716 RST M34
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718 MRD
719 AND M35
721 OUT T17
D454
726 MRD
727 AND T17
729 RST M35
731 MRD
732 AND M36
734 OUT T18
D454
739 MPP
740 AND T18
742 RST M36
744 LD M4
746 ANI M43
748 ANI M44
750 MPS
751 LDP T7
755 ORP T8
759 ANB
760 ALT M40
763 MRD
764 AND M41
766 OUT T7
D455
771 MPP
772 AND M42
774 OUT T8
D455
779 LD M4
781 LD M40
783 LD M44
785 ANI M42
787 ORB
788 ANB
789 LD M17
791 LD M45
793 OR M41
795 ANB
796 ANI M84
798 ORB
799 ANI M43
801 ANI M81
803 LD M10
805 OR M13
807 ANB
808 OUT M41
810 LD M4
812 LDI M40
814 LD M43
816 ANI M41
818 ORB
819 ANB
820 LD M17
822 LD M46
824 OR M42
826 ANB
827 ANI M85
829 ORB
830 ANI M44
832 ANI M81
834 LD M10
836 OR M13
838 ANB
839 OUT M42
841 LD M4
843 AND M86
845 LD M10
847 OR M13
849 ANB
850 MPS
851 LDP T9
855 ORP T10
859 ANB
860 ALT M47
863 MRD
864 AND M48
866 OUT T9
D458
871 MPP
872 AND M49
874 OUT T10
D458
879 LD M4
881 LD M50
883 OR M48
885 OR M52
887 ANI M86
889 LD M86
891 AND M47
893 ORB
894 ANB

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895 LD M17
897 LD M50
899 OR M48
901 ANB
902 ORB
903 ANI M53
905 ANI M62
907 ANI M81
909 LD M10
911 OR M13
913 ANB
914 OUT M48
916 LD M4
918 LD M51
920 OR M49
922 OR M53
924 ANI M86
926 LD M86
928 AND M47
930 ORB
931 ANB
932 LD M17
934 LD M51
936 OR M49
938 ANB
939 ORB
940 ANI M52
942 ANI M63
944 ANI M81
946 LD M10
948 OR M13
950 ANB
951 OUT M49
953 LD SM402
955 MOV K50
 D200
959 MOV K500
 D210
963 SET D211.0
965 SET D211.5
967 MOV K4000
 D232
971 MOV K0
 D233
975 MOV K50
 D216
979 MOV K150
 D214
983 MOV K6500
 D213
987 RST D211.4
989 RST D211.6
991 LD SM402
993 ORP M54
997 ORP M17
1001 RST D202
1004 LD M48
1006 OR M49
1008 ANI M17
1010 ANI M54
1012 PID D200
 D204
 D210
 D202
1018 LD M17
1020 OR M4
1022 LD M48
1024 OR M49
1026 ANB
1027 MPS
1028 AND SM412
1030 MOV D202
 D203
1034 MPP
1035 / D203
 K80
 D205
1042 LD M4
1044 AND SM410
1046 MPS
1047 AND M48
1049 MPS
1050 AND> D208
 D205
1054 AND<= D208
 K50
1058 #NAME? K1
 D208
1063 MRD
1064 AND< D208
 D205
1068 AND>= D208
 K0
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1072 #NAME? K1
D208
1077 MPP
1078 AND> D207
K0
1082 #NAME? D207
K1
D207
1087 MPP
1088 AND M49
1090 MPS
1091 AND> D207
D205
1095 AND<= D207
K50
1099 #NAME? K1
D207
1104 MRD
1105 AND< D207
D205
1109 AND>= D207
K0
1113 #NAME? K1
D207
1118 MPP
1119 AND> D208
K0
1123 #NAME? D208
K1
D208
1128 LDP M54
1132 MUL D459
K80
D232
1139 MUL D460
K80
D233
1146 LD M4
1148 ANI M58
1150 ANI M59
1152 MPS
1153 LDP T11
1157 ORP T12
1161 ANB
1162 ALT M55
1165 MRD
1166 AND M64
1168 OUT T11
D462
1173 MPP
1174 AND M65
1176 OUT T12
K100
1181 LD M4
1183 LD M55
1185 LD M59
1187 ANI M57
1189 ORB
1190 ANB
1191 LD M17
1193 LD M60
1195 OR M64
1197 ANB
1198 ANI M82
1200 ORB
1201 ANI M58
1203 ANI M82
1205 ANI M81
1207 LD M48
1209 OR M49
1211 ANB
1212 OUT M64
1214 LD M4
1216 LDI M55
1218 LD M58
1220 ANI M56
1222 ORB
1223 ANB
1224 LD M17
1226 LD M61
1228 OR M65
1230 ANB
1231 ANI M83
1233 ORB
1234 ANI M59
1236 ANI M83
1238 ANI M81
1240 LD M48
1242 OR M49
1244 ANB
1245 OUT M65
1247 LD SM400
1249 MPS

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1250 AND C3
1252 OUT M58
1254 MPP
1255 AND C4
1257 OUT M59
1259 LD SM8000
1261 AND SM412
1263 MOV D100
 D400
1267 MOV D108
 D401
1271 MOV D104
 D402
1275 MOV D107
 D403
1279 MOV D200
 D410
1283 MOV D208
 D411
1287 MOV D204
 D412
1291 MOV D207
 D413
1295 LD SM402
1297 MOV K50
 D300
1301 MOV K500
 D310
1305 RST D311.0
1307 SET D311.5
1309 MOV K4000
 D332
1313 MOV K400
 D333
1317 MOV K50
 D316
1321 MOV K150
 D314
1325 MOV K6500
 D313
1329 LD SM402
1331 ORP M17
1335 RST D202
1338 LD M4
1340 ANI M17
1342 AND M80
1344 PID D300
 D204
 D310
 D302
1350 LD M17
1352 OR M4
1354 MPS
1355 AND SM412
1357 MOV D302
 D303
1361 MPP
1362 / D303
 K40
 D305
1369 LD M4
1371 AND SM413
1373 MPS
1374 AND M80
1376 MPS
1377 AND> D308
 D305
1381 AND<= D308
 K100
1385 #NAME? K1
 D308
1390 MPP
1391 AND< D308
 D305
1395 AND>= D308
 K0
1399 #NAME? K1
 D308
1404 MPP
1405 ADD D200
 K5
 D300
1410 LD M17
1412 OR M4
1414 MPS
1415 AND> D104
 D100
1419 OUT M79
1421 MPP
1422 OUT M80
1424 LD SM400
1426 LD M14
1428 AND M15
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1430 LD M34

1432 AND M35

1434 AND M36

1436 ORB

1437 LD M43

1439 AND M44

1441 ORB

1442 LD M53

1444 AND M52

1446 ORB

1447 LD M58

1449 AND M59

1451 ORB

1452 OR M7

1454 ANB

1455 OUT M81

1457 EN

ภาคผนวก ข

โปรแกรม GT Designer3 ของระบบควบคุมการจ่ายน้ำดีไอออไนซ์

[Screen Image / Setting]

Screen Design

Design Name	Classic-Black

Base Screen

Background Color	No

Window Screen

Background Color	No
Screen Contour	Rectangle
Window Design	Classic
Shadow	None

Base Screen1

[Base Screen Details]

Screen Name		MAIN	
Size		800X480	
Detailed Description			
Security			0
Individually set the screen design		No	
Switch Station No.		No	
Switch buffer memory unit No.		No	
Pop up alarms		Yes	
	Display Position	Bottom	

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting

Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting

Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting

[Dialog Window]

Dialog Window	Same as the project setting

[Option Selection Window]

Option Selection Window	Same as the project setting

[Object List]

Object ID	Coordinates	Device

Switch	10000	0,160		M2
	10002		64,160	M3
	10118		304,366	M68
	10119		144,366	M66
	10235	16,64		GD1
	10236	48,64		GD1
	10237	80,64		GD1
	10257		16,432	-
	10270		336,190	M14
	10271		336,128	M15
	10272		448,160	M34
	10273		544,158	M35
	10274		640,158	M36
	10275		736,240	M43
	10276		768,238	M44
	10277		752,384	M53
	10278		752,461	M52
	10279		640,366	M58
	10280		640,430	M59
	10286		304,174	-
	10287		304,110	-
	10288		400,128	-
	10289		496,128	-
	10290		592,128	-
	10291		736,144	-
	10292		560,350	-
	10293		560,416	-
	10294		720,368	-
	10295		720,446	-
Bit Lamp	10001		32,224	M21
	10004		174,222	M6
	10005		174,126	M5
	10006		304,174	M10
	10007		304,110	M13
	10016		400,126	M31
	10022		496,126	M32
	10023		592,126	M33
	10034	416,94		M31
	10035	512,94		M32
	10036	608,94		M33
	10037		416,190	M31
	10038		512,190	M32
	10039		608,190	M33
	10041		704,206	M21
	10044		736,126	M41
	10045		768,126	M42

	10056		320,238	M71
	10064		368,190	M34
	10077		464,190	M35
	10078		560,190	M36
	10097		720,366	M48
	10099		720,446	M49
	10103		560,414	M65
	10109		640,398	M65
	10110		528,414	M65
	10111		560,350	M64
	10112		640,334	M64
	10113		528,350	M64
	10147		144,382	M67
	10148		304,382	M69
	10153		352,398	M69
	10155		192,398	M67
	10157		160,304	M80
	10173	464,94		M34
	10174	560,94		M35
	10176	656,94		M36
	10190		160,430	M67
	10191		320,430	M69
	10199		224,366	M67
	10206		384,366	M69
	10232	144,64		M0
	10238	16,16		M0
	10239	80,16		M1
	10252	192,64		M20
	10264	256,16		M79
Word Lamp	10233	32,80		GD1
Numerical Display	10145		720,350	D208
	10146		720,430	D207
	10149	512,16		D104
	10254		192,174	D0
	10258		304,160	D108
	10259	304,94		D107
Numerical Input	10169		560,302	D200
	10170		160,288	D308
	10255	384,16		D100
	10281		448,302	D204
Graphical Meter	10003		160,110	D0

Base Screen2

[Base Screen Details]

Screen Name	DIW SETTING
Size	800X480

Detailed Description		SETTING AND MOMITOR PRI-MOTOR
Security		0
Individually set the screen design		No
Switch Station No.		No
Switch buffer memory unit No.		No
Pop up alarms		Yes
	Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting

Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting

Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting

[Dialog Window]

Dialog Window	Same as the project setting

[Option Selection Window]

Option Selection Window	Same as the project setting

[Object List]

	Object ID	Coordinates		Device
Switch	10001	0,0		-
	10155		272,288	-
	10156		160,176	M19
	10157		16,224	M16
	10172		496,112	M8
	10173		496,160	M9
	10179		688,112	M11
	10180		688,160	M12
	10203		16,176	M16
Bit Lamp	10162		16,128	M0
	10164	16,80		M1
	10165	400,48		M10
	10166	592,48		M13
	10169		416,112	M10
	10170		416,160	M10
	10171		416,208	M14
	10176		608,112	M13
	10177		608,160	M13
	10178		608,208	M15
Numerical Display	10007		144,112	D104

	10111		144,145	D102
	10174	464,64		D33
	10181		656,208	D107
	10186		608,256	T1
	10193		416,256	T0
	10207		480,208	D108
	10208	656,64		D53
Numerical Input	10004	144,80		D100
	10021	240,80		D113
	10024		240,112	D114
	10107		240,144	D116
	10184		96,256	D453
	10190		96,212	D456
	10191		96,231	D457
Trend Graph	10102		32,320	D400
Slider	10140	320,80		D105

Base Screen4

[Base Screen Details]

Screen Name		DIW BOOSTER PUMP
Size		800X480
Detailed Description		TO CONTROL PRESSURE SUPPLY TO PRODUCTION MACHINES
Security		0
Individually set the screen design		No
Switch Station No.		No
Switch buffer memory unit No.		No
Pop up alarms		Yes
	Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting

Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting

Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting

[Dialog Window]

Dialog Window	Same as the project setting

[Option Selection Window]

Option Selection Window	Same as the project setting

[Object List]

	Object ID	Coordinates		Device
Switch	10001	0,0		-
	10079		272,282	-
	10119		160,176	M54
	10120		16,224	M86
	10130		16,176	M86
	10136		480,112	M50
	10137		480,160	M53
	10143		688,112	M51
	10144		688,160	M52
Bit Lamp	10122		16,128	M0
	10124	16,80		M1
	10131	384,48		M48
	10132	592,48		M49
	10133		400,112	M48
	10134		400,160	M48
	10135		400,208	M53
	10140		608,112	M49
	10141		608,160	M49
	10142		608,208	M54
Numerical Display	10106		144,112	D204
	10114		144,145	D202
	10145		656,208	D207
	10147		608,256	T10
	10149		400,256	T9
	10154		464,208	D208
	10155	464,64		D73
	10157	656,64		D93
Numerical Input	10104	144,80		D200
	10108	240,80		D213
	10110		240,112	D214
	10112		240,144	D216
	10125		96,256	D458
	10127		96,212	D459
	10128		96,231	D460
Trend Graph	10070		45,298	D410
Slider	10117	320,80		D205

Base Screen6

[Base Screen Details]

Screen Name	RO WATER TANK CONTROL	
Size	800X480	
Detailed Description	SETING CONTROL LEVEL	
Security		0
Individually set the screen design	No	
Switch Station No.	No	

Switch buffer memory unit No.		No
Pop up alarms		Yes
	Display Position	Bottom

[Key Window]

Key Window Setting

Key Window Setting	Same as the project setting

Key Window/Cursor Display Setting

Key Window/Cursor Display Setting	Same as the project setting

Key Window/Cursor Movement

Key Window/Cursor Movement	Same as the project setting

[Dialog Window]

Dialog Window	Same as the project setting

[Option Selection Window]

Option Selection Window	Same as the project setting

[Object List]

	Object ID	Coordinates		Device
Switch	10000	0,0		-
	10021		16,432	M73
	10026		112,432	M75
	10031		208,432	M77
	10045		569,270	M58
	10046		569,335	M59
	10047		704,304	M60
	10048		704,336	M82
	10054	590,64		M43
	10055		592,128	M44
	10068		704,384	M61
	10069		704,416	M83
	10070	704,96		M45
	10071		704,128	M84
	10072		704,176	M46
	10073		704,208	M85
Bit Lamp	10003		64,192	M6
	10004	64,80		M5
	10012		16,320	M31
	10017		32,368	M34
	10022		112,320	M32
	10025		128,368	M35
	10027		208,320	M33
	10030		224,368	M36

	10039		477,333	M65
	10040		592,317	M65
	10041		432,333	M65
	10042		477,270	M64
	10043		592,256	M64
	10044		432,270	M64
	10051	448,64		M41
	10052		448,128	M42
	10088		256,272	M0
	10090		326,272	M1
	10092	256,64		M0
	10094	326,64		M1
	10096	656,64		M0
	10098	726,64		M1
	10100		656,272	M0
	10102		726,272	M1
Numerical Display	10005		64,128	D0
	10006	192,96		D1
	10008		192,144	D2
	10010		192,192	D3
	10015		16,288	D4
	10023		112,288	D5
	10028		208,288	D4
	10056	480,96		D7
	10058		480,160	D8
	10074		488,308	D9
	10075		488,373	D10
Numerical Input	10013		272,320	D461
	10018		272,384	D454
	10064		416,208	D455
	10066		416,432	D462
	10086		416,400	D20
Text Display	10082		473,281	C3
	10083		473,346	C4
Graphical Meter	10002	48,64		D0

Base Screen7

[Base Screen Details]

Screen Name	Setting
Size	800X480
Detailed Description	set all parameter are concern
Security	0
Individually set the screen design	No
Switch Station No.	No
Switch buffer memory unit No.	No
Pop up alarms	Yes

	Display Position	Bottom		
[Key Window]				
Key Window Setting				
Key Window Setting	Same as the project setting			
Key Window/Cursor Display Setting				
Key Window/Cursor Display Setting	Same as the project setting			
Key Window/Cursor Movement				
Key Window/Cursor Movement	Same as the project setting			
[Dialog Window]				
Dialog Window	Same as the project setting			
[Option Selection Window]				
Option Selection Window	Same as the project setting			
[Object List]				
	Object ID		Coordinates	Device
Switch	10000	0,0		-
	10070		352,416	M19
	10071		624,416	M54
Numerical Input	10005	32,96		D1
	10006		32,128	D2
	10007		32,160	D3
	10018	272,96		D100
	10022		272,144	D113
	10024		272,192	D114
	10026		272,240	D116
	10033		272,288	D453
	10036		32,224	D454
	10039		32,352	D455
	10042		272,336	D456
	10043		272,384	D457
	10049	544,96		D200
	10050		544,144	D213
	10051		544,192	D214
	10052		544,240	D216
	10054		544,288	D458
	10057		544,336	D459
	10058		544,384	D460
	10061		32,432	D462
	10072		32,272	D461

ภาคผนวก ค

บทความทางวิชาการที่ได้รับการตีพิมพ์เผยแพร่ในระหว่างการศึกษา

รายชื่อบทความทางวิชาการที่ได้รับการตีพิมพ์เผยแพร่ในระหว่างการศึกษา

Kritsasa Somsapa Natthapon Donjaroennonb, Suphatchakan Nuchkuma Uthen Leetonb (2025). COST REDUCTION OF DI WATER SUPPLY SYSTEM BY MULTIVARIABLE CONTROL WITH PLC. Proceedings of the 8 th International Symposium on Engineering and Natural Sciences, 8th ISEAN, February 03 - 05, 2025

Certificate of Presentation

International Symposium on Engineering and Natural Sciences

February 03-05, 2025 Chiang Mai, Thailand

Suranaree University of Technology

Kritsada Somsap

Has attended the conference and presented a paper entitled

Cost Reduction of DI Water Supply System by Multivariable Control with PLC

Chief Executive Committee

Tess Chao

Cost Reduction of DI Water Supply System by Multivariable Control with PLC

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Abstract

This research presents the development of an automated DI (Deionized) water distribution system for industrial applications aimed at reducing DI water production costs and ensuring efficient operation 24 hours, designed with a Programmable Logic Controller (PLC) and a Human-Machine Interface (HMI) as the primary control mechanisms, incorporating a PID-based pump control system to optimize energy usage, with testing results demonstrating that the system effectively supplies DI water according to production machinery requirements, extends the lifespan of equipment and raw materials used in DI water production, achieves a 20% reduction in production costs, and significantly decreases energy consumption of the pump system, thereby enhancing operational efficiency and sustainability in the manufacturing process.

Keywords: DI water supply, PID control. Human-Machine Interface.

1. Introduction

Deionized Water (DI water), which refers to water that has undergone ion removal through filtration processes using resin as the filtering medium, resulting in water free of residual ions with enhanced quality and high purity, is widely utilized in the electronics industry due to its exceptionally high purity, making it a preferred choice for various industrial processes where the quality and purity of water are critical.

In modern industrial settings, DI water is commonly utilized in workpiece cleaning processes using automated cleaning machines; however, the water distribution system in many factories is still controlled manually through valve adjustments to regulate water pressure and flow rate according to the cleaning machine's requirements, which often results in excessive water distribution beyond the machine's actual needs to accommodate scenarios where multiple cleaning machines operate simultaneously.

This thesis investigates and designs a DI water distribution control system utilizing PID control principles to manage pump motors and water return control valves, as well as to regulate various processes involved in DI water distribution, by applying Programmable Logic Controllers (PLC) and Human-Machine Interfaces (HMI) to enhance the efficiency of DI water supply operations while simultaneously reducing production costs. Figure 1 illustrates the schematic diagram of the DI water distribution system.

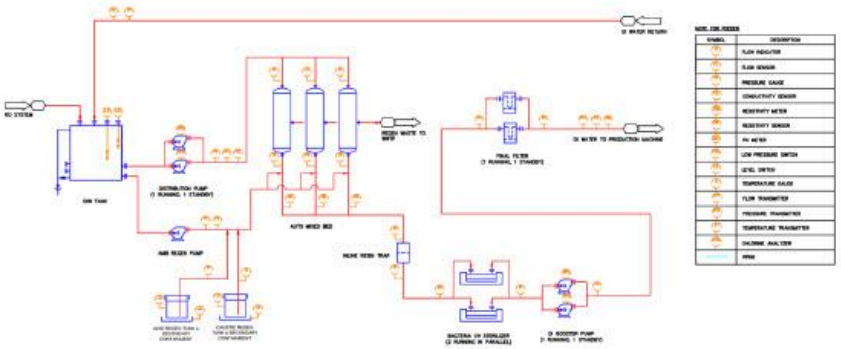


Figure 1. Schematic Diagram of the DI Water Distribution System.

2. Process and Analysis

The control design for the DI water distribution system utilizes a Programmable Logic Controller (PLC) for operational management and incorporates control interface design through an HMI (Human-Machine Interface) screen, as illustrated in Figure 2.

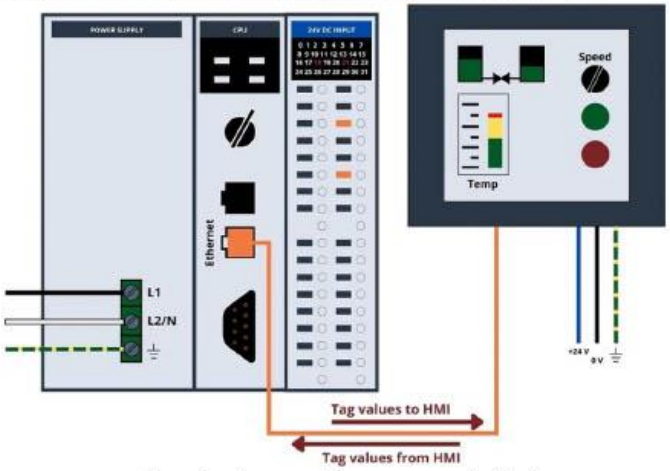


Figure 2. Schematic Diagram of the DI Water Distribution System.

The design for controlling the pump motor and the water return control valve applies PID control principles utilizing the PID function within the PLC, as shown in Figure 3.

PID control operates through a PID instruction, which requires the system to calculate the output value (MV) based on the measured value (PV). This calculation integrates the proportional (P), integral (I), and derivative (D) functions, enabling the system to achieve the target set value (SV).

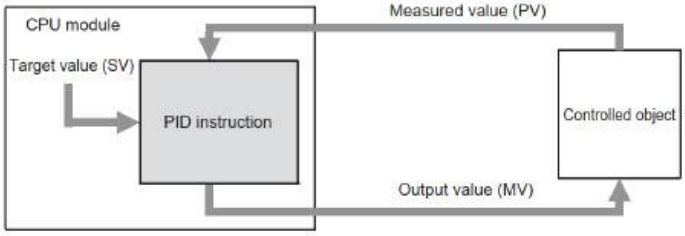


Figure 3. PID Control System.

The PID process operates as follows: when the target value (S1), the measured value s2), and the PID parameters (s3) through (s3) +6 are set and the program is executed, the calculated output value (MV) is transferred to the output (D) at every sampling interval. The sampling time is defined by (s3), and the operation is illustrated in Figure 4.

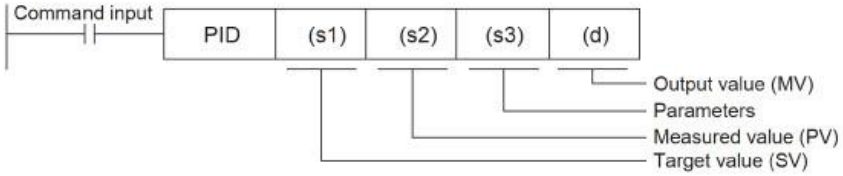


Figure 4. PID Function Instructions.

3. Research Methodology

Currently, PLCs and HMI screens are widely employed for system control in various industrial applications, representing one of the most critical techniques in industrial operations. This study presents the application of PLCs and HMI screens in managing the DI water distribution system.

The methodology focuses on the control of devices and machinery involved in the DI water distribution process, encompassing the operational control of the following equipment:

I. Develop a program to control the RO water volume and display the water volume on the HMI screen.

II. Create a program to manage the DI water pump operations based on specified water pressure using PID control, where an alternate pump automatically starts

if an alarm occurs on one pump, and stops only when a manual stop button is pressed or the pump alarm is resolved.

III. Develop a program to control the operation of the Mixed Bed Resin tanks, alternating their operations based on a set schedule; when the water conductivity exceeds the specified value, the system will automatically switch to the next Mixed Bed Resin tank and initiate the regeneration process for the depleted tank.

IV. Write a program to control the UV sterilization lamps, alternating their operation on a set schedule; if any lamp encounters a fault, the system will automatically switch to another lamp.

V. Create a program to manage the DI booster pump operations based on specified pressure levels using PID control, where an alternate pump automatically starts in case of an alarm on one pump and stops only upon a manual stop command or resolution of the pump alarm.

VI. Develop a program to control the filtration system valves, alternating their operations on a defined schedule, and automatically switching when a filter alarm occurs.

VII. Write a program to control the water return valve, which opens according to specified values and adjusts automatically when the system pressure exceeds the defined limit, ensuring the pump operates at the minimum specified level.

The control of equipment and machinery in the DI water distribution process follows the operational sequence illustrated in Figure 5.

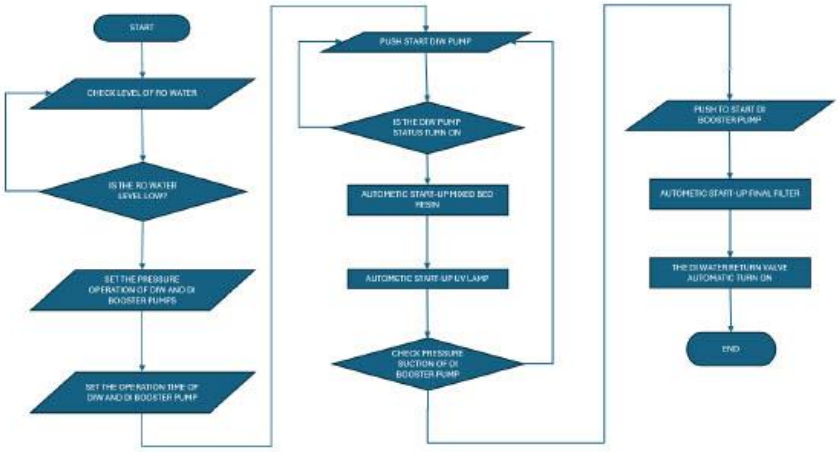


Figure 5. Steps of DI Water Distribution System Operation

4. Results

Based on the study and current data collection on the DI Water distribution system in the factory, this case study aims to propose an approach to improving the overall efficiency of the DI Water distribution control system. The researcher has simulated the DI Water distribution control program using GX Works3 and GT Designer3 to model the control processes of equipment and machinery in the DI Water distribution system, as follows:

- Control of the DIW Distribution Pump operation.
- Control of the Mixed Bed Resin Tank operation.
- Control of the UV Lamp operation for sterilization.
- Control of the DI Booster Pump operation.
- Control of the Final Filter Tank operation.

The results of the implementation are presented in Table 1.

Table1. The machinery in the DI Water distribution process

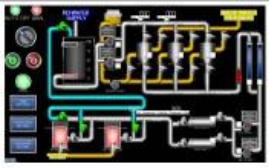
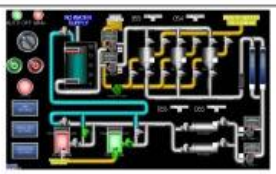
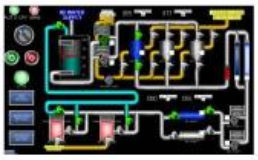
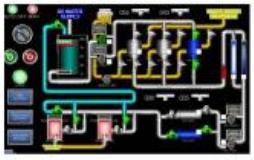
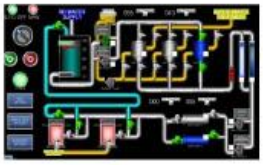
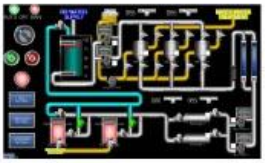
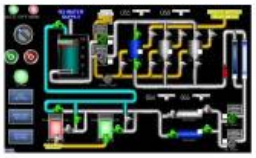
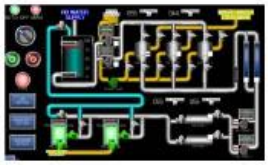
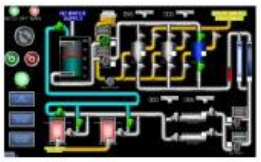
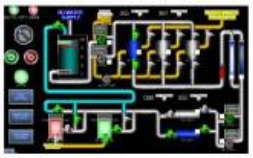
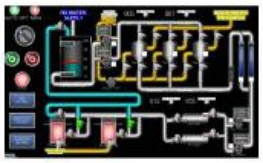
Control of the DIW Distribution Pump operation		
		
Low Water Level Detected: DIW Distribution Pump Not Operating	PID Control for Pumps	Pump Shutdown Activated When Two Alarms Are Triggered
Control of the Mixed Bed Resin Tank operation		
		
Operation of Mixed Bed Resin	Operation of Mixed Bed Resin 1	Mixed Bed Resin 1 Alarm: Next Unit Auto-Activated
Control of the UV Lamp operation for sterilization		
		
Operation of UV Sterilization Lamp	UV Sterilization Lamps 1 and 2 Alternate Operation	UV Sterilization Lamps Shutdown When Both Alarms Are Triggered

Table1. The machinery in the DI Water distribution process (continue)

<table>
<tr><td colspan="3">Control of the DI Booster Pump operation.</td></tr>
<tr><td> 
Operation of DI Booster Pump</td><td> 
PID Control of DI Booster Pump</td><td> 
DI Booster Pumps Shutdown When Both Alarms Are Triggered</td></tr>
<tr><td colspan="3">Control of the Final Filter Tank operation</td></tr>
<tr><td> 
Final Filter Tank Operation Starts with DIW Distribution Pump</td><td> 
Final Filter Tank Automatically Alternates Operation Based on Preset Time</td><td> 
If Both Final Filter Tanks Trigger Alarms, the DI Water Supply System Shuts Down</td></tr>
</table>

5. Conclusion

The simulation results of the automatic DI Water distribution control system, which applies PLC programming and HMI display, can be summarized as follows: The simulation of the automatic DI Water distribution control system functions can effectively control the operation of equipment and machinery in the DI Water distribution process. Additionally, the automated DI Water distribution system can reduce electricity consumption as the pump operation is regulated to supply water based on the actual demand of the production machinery. Furthermore, the system helps extend the lifespan of resin media used in DI Water production, as water consumption is minimized due to the optimized pump control according to production requirements. Moreover, the automated DI Water distribution control system reduces the risk of disruptions and potential impacts on production, as it can automatically switch the operation of equipment or machinery when an alarm is detected within the DI Water distribution control system.

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