A MONITORING SYSTEM FOR TPS LINAC

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Abstract

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itle of the work, publisher, and DOI Since 2014, TPS Linac system has been operating regularly. In order to keep a high stability during a long operating time, it is important to develop a monitoring system ating time, it is important to develop a monitoring setting to monitor all sub-systems' parameters, including setting values, reading values, control inputs and outputs. This system is not only recording all above mentioned paramefers, but also provides an efficient diagnosis in case of $^{\underline{\circ}}$ troubleshooting. Because the controlling system in TPS ¹ Linac is using Siemens S7-300 PLCs, Simatic WinCC is utilized to develop a historical recorder to archive operais paper attempts to show a complete solution for the inte-grated software structure and its resulting process analy-

INTRODUCTION

work TPS Linac comprises of a 90 keV thermionic gun, a 500 MHz subharmonic prebuncher (SPB), primary bunchof this er unit (PBU), final buncher unit (FBU), and three 5meter accelerating sections. The electron beam leaves the surface of the thermionic gun with 90 keV, and is accelerated to 150 MeV by three 35 MW pulse forming network (PFN) klystrons [1]. The control of TPS linac system is meter accelerating sections. The electron beam leaves the Susing S7 Siemens distributed PLCs, which are connected $\overline{\mathbf{A}}$ in an identical Ethernet. All signals of the PLC system are monitored by a general control system, which provide a $\frac{1}{2}$ real-time data for operators. This general control system, [©] which is programmed with EPICs and is using a soft IOC, S allows operators to change the setting parameters in order $\frac{5}{2}$ to optimize the linac performance. The operators can use $\stackrel{\text{def}}{\circ}$ the graphical user interface (GUI) to monitor the current $\stackrel{\text{def}}{\circ}$ status of electron source, the DT status of electron source, three RF modulators, RF distri- \succeq bution, magnets, and vacuum gate valves. 20

the Together with the distributed PLCs, the control system provides a reliable and efficient user interface for operag tors while the linac system is operating. The controlling system provides user to change setting parameters and tors while the linac system is operating. The controlling 2 monitor their reading values instantaneously. All interlock 5 signals and error messages are shown on the GUI for goperators to check the linac system and to resolve the causes. All incidents which are caused by activated inter- $\overset{\mathcal{P}}{\rightarrow}$ at top-up mode continually with an injection every 4 minutes. If an interlock is activated, it would stop the I linac system for the further checks. This may cause the termination of top-up injection process. Firstly, if the this sequences of PLC's signals, which are triggered to activate the system interlock, are recorded with time stamps, Content from

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these information can help to understand the actual causes and reduce the down time. Moreover, the increase in wear on the system is taken more seriously, because the linac system is operating 24 hours a day. Some linac output signals, such as klystron filament voltage and power dissipation energy, are becoming increasingly important. These outputs are changing slightly year by year. So it is necessary to record these outputs yearly and find out the tendency before the components are worn out completely. A commercial monitoring software, so called Simatic WinCC, can fulfil the above two requirements. It is used to monitor and record the linac operation processes. This paper presents the software structure in detail and provides an example of how to determine a PLC noise interference by using WinCC.

CONTROLLING SYSTEM LAYOUT

Simatic WinCC is a window-based software which is developed from Siemens. It is a supervisory control and data acquisition (SCADA) and human machine interface (HMI) system, which is designed for Siemens PLCs [2]. TPS linac system was delivered by Research Instruments (RI). The entire system is using Siemens' S7 PLCs as its main controlling system. This is a great compatibility of using the Simatic WinCC to monitor TPS linac system. Figure 1 shows the overview of the connection of PLCs in TPS linac. All PLCs are connected in the same local area network (LAN). All signals of the PCL system can be sent or received in this network, shown in Figure 1.

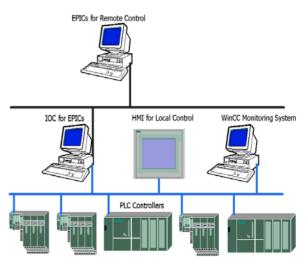


Figure 1: Overview of the connection of PLCs.

In the existing TPS linac system, all signals, including interlocks, setting parameters, and monitor values, are managed and programmed with EPICs in a soft input/output controller (IOC). The functionality of WinCC

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is much similar with the EPICs in the soft IOC. WinCC provides with a visualization system under Windows for operators to monitor Linac machine status and to trace process states and historical data (measured values, interlocks, user data) from the process database. These process data can be stored in a large storage space of computer. By obtaining the historical values from the database, it is easy to understand system performance or machine status from the statistics archived trends. The following paragraphs will describe how to implement WinCC into the TPS linac system with a new archiving function.

INSTALLATION AND SET-UP OF WINCC

WinCC is installed in a Window-based computer. A TCP/IP communication channel is established to connect to all Simatic S7 Controllers. Firstly, it is an important step to ensure a proper connection between WinCC and all PLCs. Because both PLCs and WinCC are developed by Siemens, there are not any additional drivers needed during the installation procedures. Figure 2 indicates the TCP/IP setting page in WinCC communication page. In the dialog window of Connection Parameter - TCP/IP, IP address has to be set to the destination PLC's IP. The PLC's IP can be found from the hardware configuration.

Connection Parameter - TCP/IP	Х
Connection	1
S7 Network Address	
IP Address: 192,168,1.60	
Rack Number: 0	
Slot Number: 2	
☐ Send/receive raw data block	
Connection Resource: 02	
Enter the IP address of the automation system. Example: 142.11.0.123	

Figure 2: TCP/IP setting page in WinCC.

Secondly, all interlocks, setting parameters, and monitor values have to be added into WinCC's Tag Table, shown in Figure 3, and assigned their corresponding Data Blocks (DB) names. These DB names can be found from the destination PLC's Step 7 program code. When all necessary data points are created in Tag table, they are now ready for showing real-time process values and process interrupts. Figure 4 shows linac modulator GUI display. Both setting and measured reading values are shown in the same page.

Tag Management «	Fags [LowLevelRF_CAB06]		Find	ρ.		
Tag Management	Name	Comm Deta type	Leng	th Forr Con Group	Address	Liteat
🗄 😲 Internal tags	1 ACCOLLAL_ARC	alarm Binary Tag	1	Low CABO6_DB31_LLRF	0831,0257.6	
SIMATIC ST Protocol Suite	2 ACCOL_AL_ARC	alarm Binary Tag	1	Low CABO6_DB31_LLRF	0831,0257.7	
- II MPI	3 ACCOLLARC	alarm Binary Tag	1	Low CABO6_0831_LLRF	0831,0258.0	
- PROFIBUS	4 AMPOD_SET_OPR	set: alitinary Tag	1	LOW CABOE_D833_LLRF	0833,0240.2	
Indutriel Ethernet	5 AMPOO_SET_OPR_REMOTE	set: alitinary Tag	1	Low CA806_0832_LLRF_	REMOTE 0832,064.1	
Ser R.C	6 AMPRI_AL_ESRC	alarm Binary Tag	1	Low CABO6_DB31_LLRF	0831,0254.2	
8- TCP/IP	7 AMPELAL PINEMAX	alarm Sinary Tag	1	Low CA806_0831_LLRF	0831,0254.3	
# #5 Low/aver85 C4806	8 AMPOL_MON_PWR	month Floating-point	14	Floa Low CABO6_DB31_LLRF	0831,00116	
8-#5 MOD1 CA807	9 AMPEL_MON_PWRMAX	month Floating-point	14	Floatow CA806_0831_LLRF	0631,00120	
# ## MOOT_CABOR	10 AMPOL_MON_PWRRANCE	month Floating-point	114	Fice Low CA806_D831_LLRF	0831,00124	
	11 AMPOL_SET_PWR	set: R Floating-point	ce4	Floa Low CABO6_D833_LLRF	0833,00004	
##\$ M002,CA809	12 AMPOL_SET_PWR_REMOTE	set: R Floating-point	114	Floe Low CA806_0832_LLRF_	REMOTE 0832,0032	
##\$ M002_CA810	13 AMPOL_SET_PWRMAX	set: R Floating-point	14	Floa Low CA806_D833_LLRF	0633,00108	
##\$ M009_CA811	14 AMPOL_SET_PWRRANCE	set: R Floating-point	14	Floa Low CABO6_D833_LLRF	0633,00112	
E ## MODE_CABI2	15 AMPOZ_AL_PWRMAX	alarm Binary Tag	1	LOW CASOS_DE31_LLRF	0631,0254.5	
E #\$ Vacuum_CA802	16 AMPO2_AL_SPE	alarm Binary Tag	1	Low CABO6_DB31_LLRF	0831,0254,4	
PROFIBUS (0)	17 AMPO2_MON_PWR	month Floating-point	14	Flos Low CABOS_D831_LLRF	0631,00128	
- Industrial Ethernet (II)	18 AMPER MON PWRMAX	monit Floating-point	14	Fice Low CABOS_DE31_LLAF	0631,00132	
Named Connections	19 AMPR2_MON_PWRRANGE	monit Floating-point	14	Floa Low CABO6_DB31_LLRF	0631,00136	
Soft RLC	20 AMPR2_SET_ON	set: R Binary Tag	1	Low CABO6_DB33_LLRF	0833,0240.1	
The Structure lags	21 AMPR2_SET_PWR	set: R Floating-point	114	Floa Low CABO6_DB32_LLRF	0633,00116	
and the second se	22 AMPO2_SET_PVIR_REMOTE	set: R. Floating-point	14	Floe Low CABOS_DE32_LLRF_	REMOTE 0832,0036	
-	23 AMPRO_SET_PWRMAX	set: R Floating-point	114	Fice Low CABO6_DB33_LLRF	0833,00120	
Tap Management	24 AMPRO_SET_PWRRANGE	set: R Floating-point	14	Floa Low CABOS_DB33_LLRF	0833,00124	
al marginese	25 AMPRO_AL_KLY1	alarm Binary Tag	1	LOW CABOS_DB31_LLRF	0831,0254.6	
Alarm logging	26 AMPES AL PWRMAX	alarm Binary Tag	1	Low CABOS_DB31_LLRF	0831,0254.7	
	27 AMPLO_KL_SET_PWRRANCE	set: R Floating-point	114	Floa Low CABO6_DB33_LLRF	0833,00132	
Tag Lingging	28 AMPES_MON_PWR	month Floating-point	114	Fice Low CABOE_DB31_LLRF	0831,00040	
Example	29 AMPOL_MON_PWRMAX	month Floating-point	14	Floa Low CABO6_DR31_LLRF	0631,00044	
Text Library	30 AMPER_SET_PWRMAX	set: R Floating-point	14	Floa Low CABO6_DB33_LLRF	0833,00128	
●□●欠臣了・	TI AMPON AL KLYZ H H H H GOLDS Tags	alarm Rinav Tat	1	Tow CARDS DR31 LIRE	0831.0255.0	3

Figure 3: Tag page for all monitoring and set values.

KIVETRON						-	
	HEATER	DELTA POWER SUPPLY FOR			ION HEATER	DELTA POWER	SUPPLY FOR
LI-RF-H	····· V	BIAS FOCUS1 LIAF-BPS-42 LIAF-FPS-44					FOCUS 2 FOCUS 3 N LI-RF-FPS-05 LI-RF-FPS-06
BLACK HEATING	RED HEATING	POWER OF POWER		BLACK HEATING TIME	RED HEATING TIME	LIAF-8PS-12 LIAF-FPS-1 Linit Inlu	
READY	RENOY	READY A READY		LINTIALUES	MAX MIN	NAX NON MAX NO	N HEAT MIN MAX MIN
emain Black Heating Time	Remain Red Heating Time	MONTOR W		FLAMENT VOLTIGE	37.00 25.00 v	(I) 181 00 1260 33	1200 310 1200 330
O WN O SEC	O WN O SEC	VOLTAGE 2.17 V 38.27	34,49 v 76,97 v	FILAMENT CURRENT	24.00 20.00 A		
		CURRENT 9.99 A 34.83		ION PUMP VOLTAGE	5.00 3.00 W	M 500 50 421 25	0 20 20 20 20
NONTOR FLAMENT	NONTORIONPUMP	SETTING VA	LUES	ION PUMP CURRENT	20.00 0.00 uk	WERSLIRENED	ITRANGE
		CURRENT 10.00 A 34.90	32.50 A 35.40 A	NEA FLAMENT VOLTIGE	SUREMENT RANGE	YOLTIGE () - 18 V 0 - 120	v o-120 v o-120 v
EXTER CURRENT SET VALUE	NTERLOCK	NTERLO	CK	FLAMENT CURRENT	0 - 33.00 A	0.000	
LACK 18.50 A	ALYSTRON2			ION PUMP VOLTAGE	0.00 5.00 w	(A) 0-50 × 0-50	A 0- <mark>50</mark> A 0- <mark>50</mark> A
ED 22.70 A	WOUN	· DAK IN LEARANCE · DAK IN LE	DAMAGE V DIKIN LDAMAGE	ION PUMP CURRENT	0.00 1000.00 uk		
THYRATRON	HVPS	MONITOR VALUES KLYSTRON 1	KLYSTRON 1 INTERLOCK	THYRATRON	HVPS	LINIT WLUES KLYSTRON 1	KLYSTRON 1
LI-RF-THY-01 🚺	LI-RF-HVP-01 🚺	PULSE VOLTAGE 240.97 KV	ARC NAVEGUDE KLY1	LI-RF-THY-01	LI-RF-HVP-01	NAX. MIN	MEASUREMENT RANGE
POWER	POWER	PULSE CURRENT 225.69	COLLECTOR WATER	PREHEATING TIME	LIMIT VALUES	PULSE 275.0	PULSE 0 - 300.0
READY	READY	TEMP.INLET 25.80 C	FOCUS PS WATER	3 MN	MAX	PULSE 295.0	PULSE 0 - 300.0
Remain Black, Heating Time 🛛	NONITOR HIGH VOLT WULLE	TEMP OUTLET 27.10 C	HNPS WATER	LINTVALUES	HIGH 39.00 KV	TEMPERATURE 20.0	
O MN O SEC H	ICH VOLTAGE 37.26 KV	OL TEMPEATURE 33.20 C	TANK OL LEVEL	NAX MIN FLAMENT 670 500 V		INLET(C)	BODY WTR. 0 - 100.0
MONTOR THYRATRON	SETHICH VOLT VALUE	DISSP.POWER 557.75 W	TANK OIL TEMPERATURE	RESERVOR 670 500 V	WEXSUREMENT RHNGE	OUTLET (C)	
LANENT 5.43 Y H	IGH VOLTAGE 37.07 KV	NATERFLOW 6.16 Linin END OF LINE CUPPER 0	SFG PRESSURE	CURRENT 15.00 80.00 A	HIGH VOLTAGE 50.00 W	OL 40.0	OIL 0 - 100.0
eservoir 5.93 a	OUTPUT STATUS	SUFETY INTERLOCK	PS CABINET RIVELOW	NEASUREMENT RANCE		DISSIPENSATION 3000.0	
URRENT 89.79 A	INTERLOCK	PEN FRONT DOOR ESTOP	PEN SNOKE DE IEUTOK	FLAMENT 1-10.00 V		WATER FLOW RD 50	BODY WTR 0 - 15.0
NTERLOCK	OVERLOAD	PFN BACK DOOR RF PSS1	DUNP SNITCH OPEN	RESERVOR 1 - 10.00 V		COUNT OF END	DIFLATINE
						OF LINE CLIPPER 30	

Figure 4: Graphic User Interface (GUI) for Linac Modulator.

Finally, the most benefit of using WinCC in TPS Linac system is the archive system. All important process values and interlocks can be saved in a historical format. These data can be retrieved from the database to trace the historical values at any specific time periods. Moreover, process interrupt sequences can be recorded and provide more information about system failure. The measured values and interlocks are stored in an archive hard disk; the size of which can be configured for a long archiving period. Process values are displayed via WinCC online Trend Controls, which display the data in the form of a 10th Int. Particle Accelerator Conf. ISBN: 978-3-95450-208-0

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The trend with a time stamp. Figure 5 shows the historical RF is pre-amplifier outputs at 4-mintues top-up injection. The RF amplifiers are switched on at every four minutes for injection. The sampling rate for WinCC for monitoring these parameters is at 500 ms.

In the 4th quarter of Year 2018, linac system had experienced unexpected trips in one of three modulators during the regular operation. These unexpected trips occurred, then terminated the injection process from linac. These occurred frequently without any interlock indications. When it occurred, all DC power supplies for focusing magnets in klystron 2 are switched off and on in as fast as 2 seconds. By using WinCC's archive system, the suspected PLC controlling points were selected and monitored. When the incident was occurred, all the process interrupt sequences are recorded. This shows an evidence for ease of tracing trigger points and reduce the trouble shooting time. In this case, a communication noise interference was pick up in a photoelectric converter, then caused an interruption between two PLCs. Figure 6 shows the difference archiving data in the normal operation, and the status changed when a noise interference was pick up. By comparing of these two states, it is easy to find out the interrupt sequences.

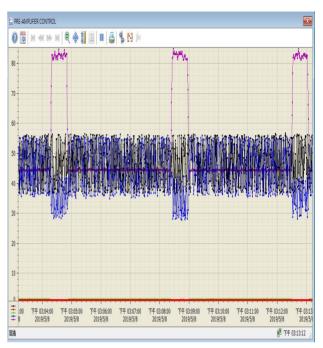


Figure 5: Historical data for RF pre-amplifier outputs at 4-mintues top-up injection.

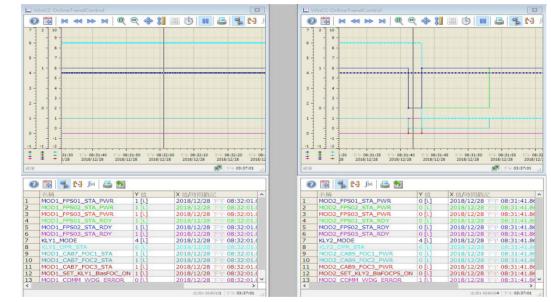


Figure 6: Archiving curves for all focusing magnet power supplies at normal operation (left) and system failure (right).

CONCLUSION

A monitoring system by using WinCC is implemented in TPS Linac successfully. All setting parameters, reading values, process sequences are recorded to provide additional information for system health check or trouble shooting.

REFERENCES

- [1] *TPS Linac Operation Manual*, Research Instruments, Jun. 2011, pp. 12-15.
- [2] https://w3.siemens.com/mcms/waterindustry/en/Documents/SIMATIC_WinCC.pdf