

## CONTROL SYSTEM DEVELOPMENT FOR THE TLS

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### Abstract

Control system of the 1.5 GeV Taiwan Light Source (TLS) was working near 25 years. The original control system for TLS is a proprietary design. Limited resource prevent major revised possible. Several minor upgrades during last two decade to avoid obsolete of some system components and keep up-to-date since its delivery in early 1990. These update are also necessary to support the development of the accelerator system. The control system of the new 3 GeV Taiwan Photon Source (TPS) which start service in 2016 is based upon the EPICS framework. To save resources for TLS control system maintenance and development, adopt EPICS for new developed and rejuvenated subsystems for some of the TLS control interfaces includes BPM system, insertion devices, bunch-by-bunch feedbacks, quadrupoles power supplies control, booster to storage ring transport line control, electronics instruments interface and so on. These efforts allow new devices installed, obsoleted parts replacement, add new software components and functionality. EPICS related applications developed continually accompany with the TLS control consoles environment normally. Control system allowed two kinds of control environments working together seamlessly. Strategic and efforts will summary in this report.

### INTRODUCTION

The TLS is a third generation of synchrotron light source built at the National Synchrotron Radiation Research Center (NSRRC) campus in Taiwan in early 1990's. The machine dedicated in 1993. The TLS consists of a 50 MeV electron Linac, a 1.5 GeV booster synchrotron, and a storage ring with 360 mA top-up injection. The TLS Control system is a proprietary design [1] which consists of console level workstations as operation interface and VME based intelligent local controller (ILC) to interface with subsystems. Several minor upgrades had been performed to avoid obsolete during last two decades. Hardware and software on console level workstation change several times due to evolution of fast evolution of computer technology. PC running Linux is the current configuration. Hardware and software on VME layer change several times also to avoid obsolesce of parts. Well design of the original control software structure, port to new platforms without difficult.

The EPICS (Experimental Physics and Industrial Control System) is a set of open source software toolkits used to create distributed soft real-time control systems for scientific facility such as the particle accelerators and large scientific experiments [2]. Many resources and supports are available as well as numerous applications for accelerator have been developed.

To meet user requirements, a new low emittance light source was initiated and discussed around 2005 and finally conclude the TPS of 3 GeV synchrotron light source [3, 4] which was delivered in 2015 and start to provide user service in 2016. The EPICS toolkits were chosen as control system framework for the TPS project. Due to limited resources available, it was decide to fuse the original architecture of the TLS control system with the EPICS environment and run two control environments together at the same platform rather than to convert whole control system into EPICS or use gateway to bridge two different control environments. For the new installed or rebuild subsystems runs EPICS control environment to reduce working load and use the same expertise of manpower.

In the TLS, the control console operate on the existing control system environment and fuse with the EPICS is the approach for TLS control system maintenance strategic.

### TLS CONTROL SYSTEM AT BEGINNING

The control system of the TLS is a distributed-type system and follows the concept of "Standard Model" control system for experimental physics. It's a two-level hierarchical system providing good real-time performance with a system update rate of 10 Hz. The overall architecture is simple, scalable, and easy in maintenance. Process computers and workstations at the upper -level control system provide graphical user control interfaces, data storage, the necessary computing power for machine modeling, ...etc. The VMEbus based ILC are hearts of the lower-level control system that handles real -time device access and closed loop control. The two levels are connected by Ethernet network using IEEE 802.3 standard and TCP/IP protocol. The software used on the upper-level computers includes database server, network server, simulation programs, various applications, and X-window based graphical user interfaces. Device drivers, application programs for devices control, and communication programs are the major software components on the ILC level. The central parts of the console level software and ILC layer software called as "TLS console core" and "TLS ILC core" respectively. The hardware configuration of the control system is shown in Fig. 1.

The console level computers, comprising a process computer and several workstations, handle the system-wide device control functions and provide a friendly operator interface. The process computer is a VAX 4500. The workstation consoles serves as the platform to run graphical and control applications as well as the operator control console. The X-Window and OSF/Motif systems are used to develop the friendly, dedicated graphic user interface for facility operation. A graphical editor was

developed for easy configure GUIs and link to signals channels.

The ILC is a VME-based system that includes Motorola MVME-147 CPU board and a variety of interface cards. The ILCs are field level controllers, which perform data acquisition, local closed-loop control, and monitoring equipment of various subsystems. The ILCs are connected to the hardware devices via analog and digital input/output interfaces, NI GPIB-1014 VME module interface, and serial communication interface. There are 10 ILCs in the control system dedicated to the storage ring.

The software structure is divided into several logical layers, as shown in Fig. 2. These include device access, network access, database management, graphical user interface, and applications. The purpose of software layering is to reduce the development time. Many applications run at console level computers; including the data logging and archiving, alarm checking and machine modeling programs on the process computer.

The dynamic data are updated into the database of the console computers at 10 Hz. The devices access processes run on ILC, as well as the control tasks and various input and output tasks. The pSOS+ real-time kernel provides the ILC with support for task scheduling, memory allocation, event handling, and message queuing. The pNA+ network support package provides socket network programming interface. The hardware dependent device drivers are also implemented. Downloading the database from the process computer into the ILC to form a local distributed database is under development. The network access software takes control of the data exchange between console level computers and ILCs, while the communication protocols UDP/IP and TCP/IP provide an open environment for easy expansion. The console level computers use the VAX/VMS system, and the software package is developed using high-level language. Functions of the process computer and workstations are slightly different. The process computer holds the system wide static database and maintains it. At system start-up, each workstation requests and receives a copy of the static database from the process computer. Each console computer then has all the database information necessary to process dynamic database frames received from the ILCs. The workstations are mainly used for the user interface. The process computer initiates the

The booster control system is a turnkey system provided by Scanditronix AB in 1990. The system is a VAXstation that stores the database and functions as the control console. A Multibus Crate is used as the data collector. The pre-injector control system is a PLC-based system using Simens' Simatic S5-135 PLC and is connected to Multibus crate by Ethernet. A BitBus network that connects about 20 nodes together to Multibus crate controls all booster devices. The control system are operated in stand-alone mode before the control system integration in late 1997.

The virtual instrumentation system connects IEEE-488 enable instruments by local area network via GPIB-ENET adapter [5]. Operator and machine physicist will have the flexibility to access the instruments via the control system.

This system was built on standardized networking protocols and implemented with the measurement server concept.

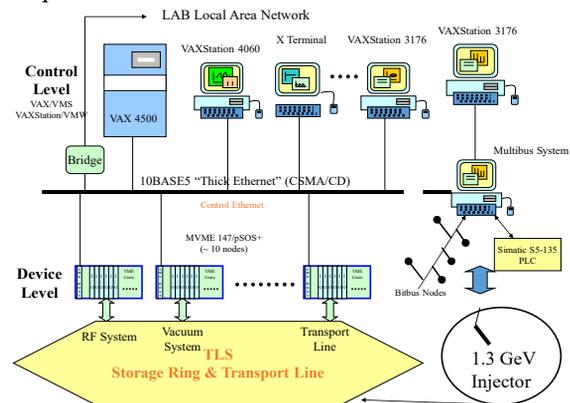


Figure 1: Hardware configuration of the control system at early stage.

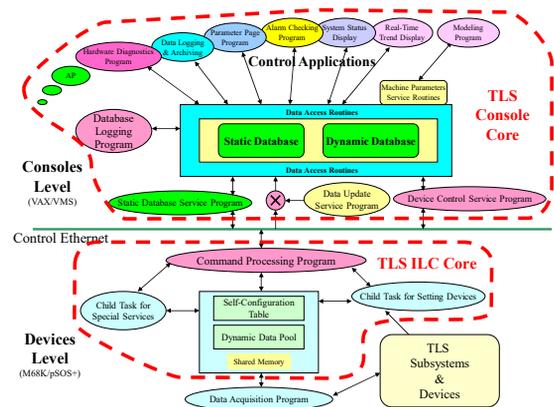


Figure 2: Block diagram of the software structure of the original TLS control system.

## EVOLUTION OF THE HARDWARE AND SOFTWARE OF THE TLS CONTROL SYSTEM

Many devices/subsystems were added to the TLS include insertion devices, 1.3 GeV to 1.5 GeV upgrade, top-up injection, un-reliable system improvement, obsolete parts replacement, orbit stabilization, bunch-by-bunch feedbacks, superconducting insertion devices, superconducting RF system, new quadrupole power supply...etc. during last two decades. The control Ethernet is updated from 10BASE5 "Thick Ethernet" (CSMA/CD), hub, then 10M/100M/1G/10G switched Ethernet gradually to keep up-to-date with the evolution of Ethernet technology. At ILC layer, M68K/pSOS+ environment have been success migrated to PowerPC/LynxOS environment start from 1998. It was taken about more than 5 years efforts to remove all M68/pSOS+ system. Combine Compact PCI (cPCI) crate running Linux, TLS ILC core and EPICS IOC were deploy since 2014. The control consoles were migrate gradually from VAX/VMS, DEC/Ultrix environment to PC/Linux environment between 2006~2010, the conversion keep original software

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structure and protocol. Control servers convert form VAX/VME to PC/Linux environment in 2009.

To minimize necessary manpower to maintenance, EPICS environment was decided for the TLS control system revise after TPS project launch around 2008. The first EPICS system of the TLS is BPM upgrade, Libera Electron was adopted for BPM upgrade, an EPICS to TLS control system gateway was implemented to simulate the role of ILC without take advantage of all functionality of BPM electronics. To bridge two kinds of control environment together using a gateway in common, but it need scarify some functionality. Since then, pros and cons of the gateway was examined. Functionality of TLS control system is less richness than EPICS. To take advantage of the EPICS environment, it was decided to fuse of TLS control system with EPICS to take full functionality of both system. Control console running EPICS and TLS control environment start from 2010. After that time, several minor upgrades of TLS subsystem were done for the purpose of maintenance by the approach of rebuild of the original subsystems which were difficulty to maintain.

## FUSION OF TLS CONTROLS WITH EPICS

No enough resources as well as no shutdown window longer enough to revise the whole TLS control system. It was decide to combine TLS controls with EPICS environment. Maintain existing TLS hardware and software as possible. For the system need revise go to new solution: support TLS control system and EPIC to avoid obsolesce and maintain difficult. There is no plan for major upgrade of the TLS control system. The TLS adopted a different method to fuse two kinds of control environment together.

The first step is combined EPICS IOC functionality with TLS ILC environment. It was decides give up ILC in VME/LynxOS combination further. New platform will same as TPS control system to save necessary resource. The concept is shown in Fig. 3. The TLS ILC core was modified as data server follow TLS control protocol and co-work with EPICS IOC. The TLS ILC core can read data from I/O device directly or by PV access the EPICS IOC. However, setting can only done by EPICS IOC to keep data consistence. An EPICS IOC is will run at the front-end controller. The ILC core access the I/O devices via the EPICS IOC which running at the same platform via TCP socket. This configuration support homogenous access from TLS console software and EPICS applications.

The hardware system of the revised system hardware as shown in Fig. 4 EPICS OPIs, EPICS Servers, and EPICS IOCs are added to the systems. Networking have been migrate to 1 G/10 G environment.

The software environment is show as in Fig.5. TLS console core and GUIs can access all devices as this original design include new cPCI based EPICS IOCs which embedded TLS ILC core. EPICS EDM pages can only access devices which support EPICS IOCs. The central database on TLS console core is used as a buffer

between the low-level tasks at ILCs and the console level applications. The application programs access equipment parameters directly from database rather than from ILC, and therefore are devices transparent. Among the many applications run on the console level computers, the data logging and archiving, alarm checking and machine modeling programs are run on the process computer, and the graphic-oriented applications such as real-time trend display, machine parameters display, and computation intensive tasks are run at the control consoles. The software at device control level include PowerPC/LynxOS based ILC and newly added EPICS IOC which run TLS ILC core to interface various subsystems and devices.

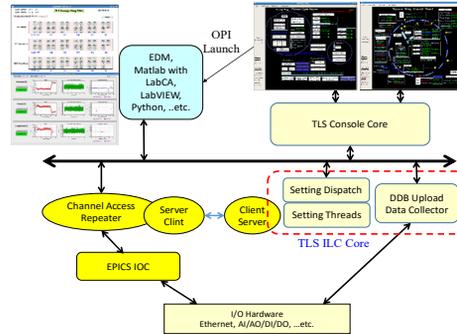


Figure 3: Concept of EPICS IOC fuse with TLS ILC core.

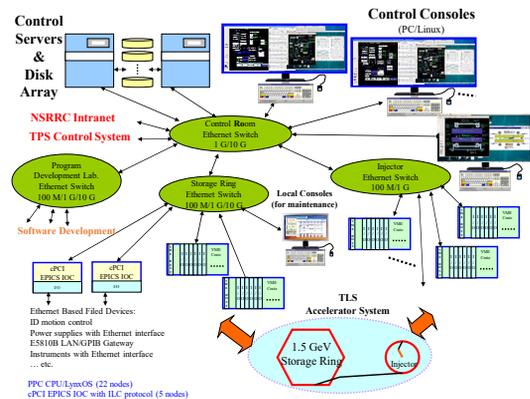


Figure 4: Hardware configuration of the present control system.

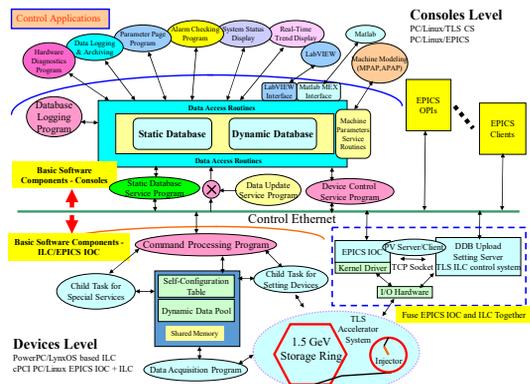


Figure 5: Software configuration of the present control system.

## SOME EPICS APPLICATIONS DELIVER TO TLS CONTROL SYSTEM

Combined two kind of user interface at the same consoles will benefit to usage. The console installed TLS console core and EICS OPI. The control page of TLS can invoke EDM page by a simple click by invoke a simple script. It provide seamless integrated GUIs and take advantage of both kinds of control system. Some of such kind applications are summary in this paragraph.

### Invoke EPICS Applications from TLS Control GUI

To easy the operation of TLS of different kind of GUIs, the EPICS EDM pages or another kind of GUIs (Matlab, Python, ...etc.) can invoke by a click to execute a simple script is current solution. Figure 6 show the look and feel of the TLS GUI with EDM and Matlab GUI at the same time. Other kind GUIs can also support by another tools.

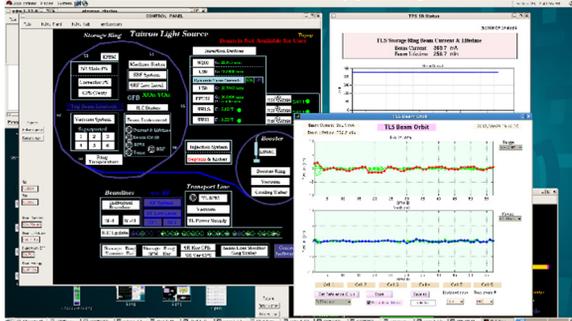


Figure 6: Typical operation interface combined several kind of GUIs.

### TLS BPM EPICS Applications

The TLS upgraded the BPM electronics for both the storage ring and the transport line and completed respectively in 2008 and 2012 [6, 7, 8]. Besides integrating into the original TLS control system, since the electronics has embedded EPICS server, it also provides GUI for display and configuration by EPICS implemented as Fig. 7. EDM and Matlab GUI were implemented to support operation of the BPM system.

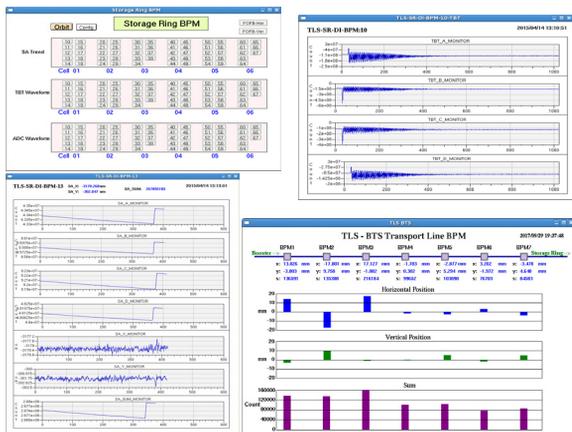


Figure 7: BPM GUI interface.

### Bunch-by-Bunch Feedback Applications

Commercial bunch-by-bunch feedback solutions iGp12 (Integrated Giga-sample Processor 12) [9, 10] is adopted to suppressed beam instabilities in TLS. The system is embedded EPICS IOC. GUIs in EDM are provide to access the devices. A simple waveforms interface implemented let the operator tell whether the bunch-by-bunch system is working properly or not. The notch due to noise suppression at the averaged bunch spectrum is used as tune monitor for routine operation and a tune EDM page is created.

### Rebuild Controls for U50 and U90 Undulators

The undulator U50 and U90 for Taiwan Light Source (TLS) was installed on March 1997 and March 1999. Control system of U50 includes a PC running MS-DOS for local control. Control system of U90 includes a VME crate which equips with PowerPC CPU module running LynxOS. Re-build control system for both undulators decided to eliminate maintenance difficult. Ethernet based motion controller was chosen to drive motor drivers. All control functionality will coordinate by the cPCI EPICS IOC. To compatible with TLS existed control environment, a TLS ILC core as server program was developed to access I/O devices PVs via the EPICS IOC by TCP/IP protocol. The user interface implemented by using EPICS EDM (Extensible Display Manager) was also created. TLS GUI and EDM control page for U90 as shown in Fig. 8, is for general operation and a detail maintenance page can show all status and adjustable PVs parameters (PID, torque limit ... etc). These upgrade lead to avoid obsolescence of the control parts, increase productivity and support on-the-fly experiments [11].

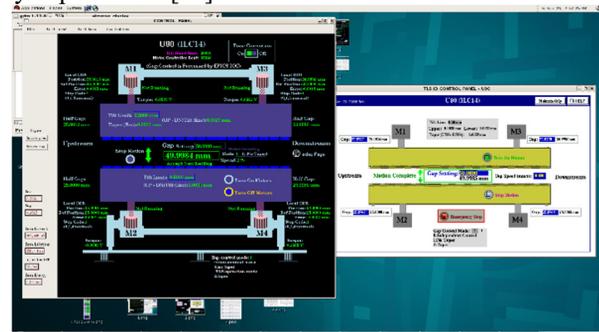


Figure 8: TLS GUI and EDM to support U90 operation.

### Remote Access of Ethernet-based Oscilloscope

Several types of oscilloscopes had been used for different purposes at the TLS control system. The DPO4000 are usually used for observing Linac-related waveforms. The DSO9000H is higher resolution oscilloscope and specially used for observing and analyzing waveforms of storage ring injection kicker current transformer in detail at every injection. One dedicated EPICS IOC was set up to implement the EPICS support, and communicates with the oscilloscope via Ethernet interface [12]. Figure 9 shows waveform related to the operation of booster synchrotron.

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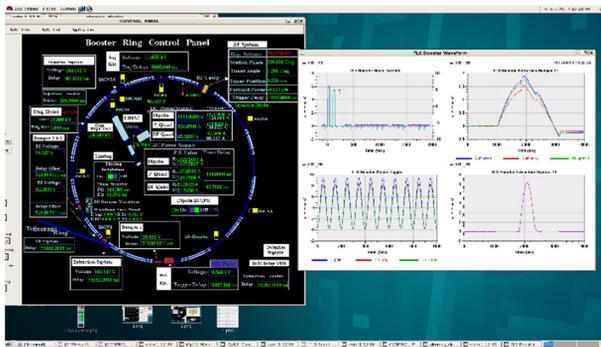


Figure 9: GUI for observing the waveforms of TLS booster synchrotron.

### Quadrupole Power Supply Replacement

Quadrupole power supply have been replace by high efficient power supply in 2015. The new cPCI controller support EPICS IOC and TLS ILC core. The system can support TLS control and EPICS environments. Figure 10 shows the TLS synoptic GUI for power supply control include dipole power supply and sextupoles, detailed devices page for quadrupole power supply can invoke related EPICS EDM page for further control functionality.

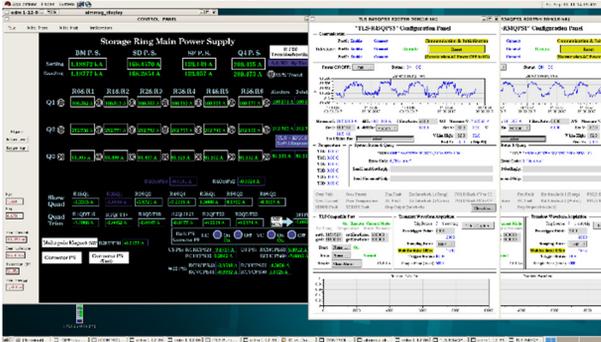


Figure 10: GUI for storage ring power supply controls. TLS GUI for synoptic control, EPICS EDM for detailed control.

### Archive EPICS PVs with the Same Format of TLS Data Archive

Besides the basic control functionalities to fuse both control environments together, the archive system is another important issue needed addressed. The archive system of TLS control system is simple; the file format is pure text including time stamp and value columns only. There are two types of archive, logged at 10 sec and 100 ms, named as slow and fast log the timestamp scales are different: minute and second. The log files are stored in directory hierarchy: yy/mm/dd/signalName.yyymmdd to support easily access by NFS clients or FTP transfer. A viewer running on Windows system may show trends of two different logs to analysis events. Supporting the viewer to access logs of EPICS PVs which belong to TLS besides the existed logs is useful. An “acquire” and a “store” program are implemented to archive EPICS PVs with the same format as TLS fast logs. The “acquire” and “store” process pair may handle up to 500 PVs at once. Because the EPICS PV names mostly include a char ‘:’ and cannot

be part of a file-name on Windows system, it is converted to ‘\_’ by the “store” program while creating then insert the name in the top of the file as description.

## SUMMARY

To take advantages of the latest hardware and software developments to deliver high performance, rich functionality, and avoid maintain difficult for obsolete components, TLS control system were revised continually by resources which were allocated for annually maintenance. To support both of the existing TLS control system and the EPICS environment, the client consoles were setup with TLS console and EPICS environment for access the upgraded subsystems via TLS control protocol and PV channel access from the dedicated IOCs combined with TLS ILC core. Various EDM pages for different purposes were created for operation at the TLS accompany with existed TLS GUIs. Do the things when it need is the current strategic for the TLS control system maintenance. Maintain the TLS system by adequate small scale upgrade approach was adopted to take advantage of latest technology and also allowed by the limited available resources.

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