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THE ENERGY MANAGEMENT SYSTEM IN NSRRC

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Abstract

Taiwan has been suffering from the shortage of natural resources for more than two decades. As stated by the Energy Statistics Handbook 2019 of Taiwan, up to 97.90% of energy supply was imported from abroad. This kind of energy consumption structure is fragile relatively. Not mention to the total domestic energy consumption annual growth rate is 1.97% in twenty years. Both the semiconductor and the integrated circuit related industries, which are high energy consumers, are developed vigorously in Taiwan. All the facts cause us to face the energy problems squarely. Therefore, an energy management system (EnMS) was installed in NSRRC in 2019 to pursue a more efficient energy use. With the advantages of the Archive Viewer-a supervisory control and data acquisition system of utility in NSRRC, the data of energy use could be traced conveniently and widely. The model of energy use has been built to be reviewed periodically, furthermore, it provides us the accordance to replace the degraded equipment and alerts us if the failure occurs.

INTRODUCTION

According to the open data from Ministry of Economic Affairs of Taiwan, total electricity generation in 2019 was 274 TWh. Sources of electricity were fossil fuels 81.47%, nuclear power 11.79%, renewable energy 6.73%. The overuse of fossil fuels leads to climate change and global warming in long-term effects. The regional air pollution caused by fossil fuel power plants, such as $PM_{2.5}$, affects the health of local residents seriously. On the other hand, the nuclear-free homeland policy urges the government remains committed to phasing out nuclear power in Taiwan by 2025. All in all, the transition and conservation of energy must be taken into account by authorities under many considerations.

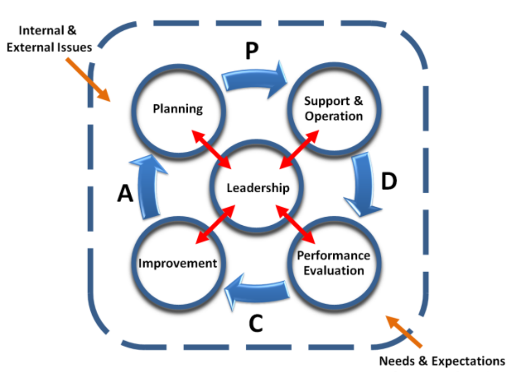

Figure 1: PDCA cycles in ISO 50001:2018 energy management system.

The energy management system (EnMS) in NSRRC is established in accordance with ISO 50001, which enables organization process necessary to continually improve energy performance. It also supports a culture of energy conservation with the commitment from leadership of NSRRC. With the assistance of the Taiwan Green Productivity Foundation, the EnMS of NSRRC has been developed with recognized energy policy and objectives, and earned the third-party certification in 2019. Therefore, we can claim the NSRRC is a synchrotron radiation facility operated with a more energy-conserved way, also known as Green Light Source.

The EnMS combines the viewpoint from stockholder and the risk management to operate the PDCA cycle. The PDCA cycle is a repetitive four-stage model for continuous improvements shown in Fig. 1. In EnMS, a leadership level representing the top management is added to direct and control the organization. The leadership level is empowered to delegate authority and any kind of support in the organization. It shows the determination of the organization. Without the full support from leadership, the system will lose substantive power to enforce the energy policy. Besides the leadership level, the EnMS is operated with common PDCA cycle, which means PLANNING energy policy at first, DOING the required processes and operations to achieve energy conservation, CHECKING the results of these energy plans and performance, and AUDITING the function of whole system finally. After the auditing, new internal and external issues must be taken into system and start another cycle again.

ARCHIVE VIEWER SYSTEM

The Archive Viewer system is a highly complicated system with hybrid SCADA systems which was proposed by Tsai et al. in 2007 [1]. It provides a platform to share and exchange recording data from different supporting systems, such as vacuum, magnet, RF, cryogenic, power supply, safety, and utility and so on. The data are collected by exchanging servers first, and then are stored in a central storage area network (SAN) via fiber network. The data from different systems can be displayed in one chart, so as to debug the system more easily. Figure 2 shows the latest version of network architecture of the Archive Viewer system in NSRRC. The new Archiver Viewer system provides better protocol integration, such as dynamic data exchange (DDE), OLE process control (OPC), PSP, EPICS, Modbus etc. [2]. Data from different systems can be reviewed in real-time or historical form on the union platform by enterprise Ethernet. With the help of the whole area WiFi within NSRRC and the remote desktop apps on smart phones or pads, sending

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commands to some authorized utility systems becomes easily. The big data base is very helpful to build up the energy tracking model and EnPIs, as well as to establish the long term EnB.

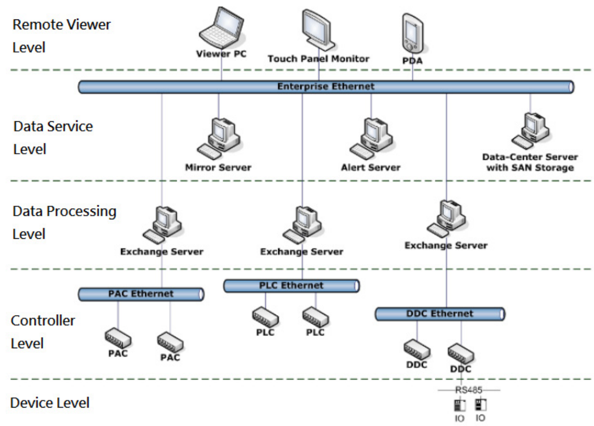

Figure 2: Network architecture of the Archive Viewer system.

ENERGY TRACING

Some survey on energy usage, such as energy tracing must be done before the implementation of EnMS [3]. Two synchrotron radiation accelerators are operated on two separate electric grids in NSRRC, and thus the declaration on annual energy use is done according two electricity supply numbers.

By analyzing the data from Archive Viewer, the electric energy consumption of individual equipment in NSRRC rankings 2020 is listed as Table 1. It shows that the majority of electric energy consumption is consumed to operate the chillers of chilled water system. Therefore, the action plans for energy saving originate from conservation for cooling systems, like air handling unit or process cooling water system. Obviously, the first priority to be replaced or retired is the TLS chillers for its more than thirty-year usage. The magnet and the radio frequency systems consume the most portion of the rest electricity. In a summary, the downtime and uptime of the chillers and the accelerator related facilities dominate the behavior of energy consumption in NSRRC.

There is one another factor affecting the electric usage in NSRRC, which is air temperature. As we mentioned above, the most of electricity usage is for the operation of chillers. NSRRC is located in subtropical climate region, and the monthly average temperatures distribute from 10 to 30 degree Celsius. As shown in Fig. 3, more than 35% of total electricity used in NSRRC during 2020 is used to operate the chilled water system. The chilled water system consists of two major parts; one is the cooling system for air conditioning, the other is for de-ionized water system which used to cooling accelerator facilities. Both increase the energy consumption with the air temperature rise. After analyzing the electricity usage and air temperature data, it is concluded that the behavior of electricity consumption can be classified into on/off mode and air temperature-related mode.

Table 1: Energy Consumption of Individual Equipment or System Rankings 2020

Designation	Power Consumption (kW/unit)	Year of Use (yr.)	Consumption Ratio (%)
TPS Chiller	651	9	22.01
TLS Chiller	**385**	**32**	**21.69**
TPS Magnet System	880	7	13.86
TLS Magnet System	**681**	**32**	**10.72**
TPS Ring RF System	530	7	8.34
TPS Heat Pump	200	8	6.76
TPS Cryo. Compressor	166	7	5.23
TPS Air Compressor	151	7	3.4
TLS Ring RF System	**200**	**32**	**3.15**
TPS Cooling Tower	110	9	2.48
TPS BR RF System	150	7	2.36

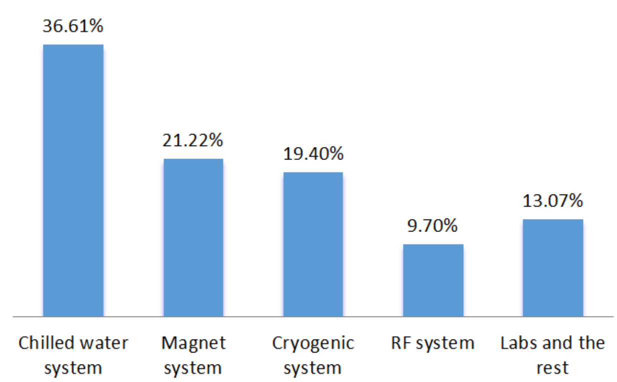

Figure 3: Energy usage percentage of different system in NSRRC 2020.

ENERGY BASELINE

As mentioned before, electricity of NSRRC comes from two supplier meters with separate electricity supply numbers. Therefore, two energy consumption models have been built to describe energy baselines of TLS and TPS. Refer to the light source schedule in 2020, each day is labeled as U/S or M, which stands for user operation and machine study, or shutdown and maintenance. The difference of energy consumptions between normal

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operation and machine study mode is negligible compared to shutdown mode. Excluding those unexpected beam trip data, the relation between daily electric power and average air temperature of TPS is shown as Fig. 4. E_{on} represents the average consumed power daily when TPS is on, while E_{off} represents the power when TPS is off. It is observed that the difference of electric power between TPS on and off is approximately 2400 kW. The correlation between electric power usage and air temperature when TPS is on is stronger than TPS is shutdown.

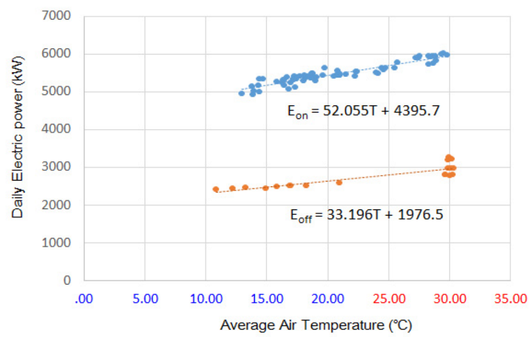

Figure 4: Relation between daily electric power and average air temperature in TPS 2020.

The correlation in TLS is similar, but only slight difference exists. The slopes of fitting curves of TLS are both smaller than TPS, and the difference of electric power between TLS on and off is approximately 1900 kW. The formulae of fitting curves are as follows:

For TPS

$$E_{on} = 52.055T + 4395.7$$
$$E_{off} = 33.196T + 1976.5$$

For TLS

$$E_{on} = 16.334T + 3853.3$$
$$E_{off} = 30.983T + 1946.5$$

The energy model can be described by these energy baselines originating from operation data of 2020. The estimation by models and real usage are as shown in Table 2. The monthly average temperature and average power were calculated from daily records in the first season of 2021. The operation status of light source was confirmed by beam current. U/S stands for machine operation, while M represents light source shutdown.

The data from January to March 2021 show that there are fewer errors between estimation and real usage in TPS case. The model of TLS seems over estimate very much in March, however, the TPS model underestimate the usage. It seems that TPS was operated with less efficient way than last year; however, some factors must be taken into consideration together. Because of the water shortage in the first half of 2021 in Taiwan, some strategies had been applied to reduce water usage, including shutting down older chillers and cooling towers. These measures not only reduce the waste of water resource, but also obtain more efficient electricity use. The water usage during January to May 2021 is 19.1% less than the same period last year. On the other hand, the overall electric usage in NSRRC is 2%~7% less than estimation as shown as Table 3.

Table 2: The Estimation Value by 2020 Model and Real Usage

	T Avg. (℃)	Mode U+S	Mode M	Power Avg. (kW)	Usage Est. (kWh)	Usage Real (kWh)	Error
TLS							
Jan	14.37	12	19	2707.03	2,283,563	2,014,030	13.38%
Feb	17.15	0	28	2200.87	1,689,512	1,478,981	14.23%
Mar	18.55	27	4	3026.95	3,005,831	2,252,049	33.47%
TPS							
Jan	14.37	25	6	4560.56	3,439,546	3,393,057	1.37%
Feb	17.15	18	10	4452.61	2,895,602	2,992,155	-3.23%
Mar	18.55	31	0	5695.92	3,988,822	4,237,767	-5.87%

Table 3: Total Error of Energy Model in First Season 2021

NSRRC	Total Est. Usage (kWh)	Total Real Usage (kWh)	Error
Jan	5,723,109	5,407,087	5.84%
Feb	4,585,114	4,471,137	2.55%
Mar	6,994,653	6,489,817	7.78%

CONCLUSION

In this article, the method of developing energy usage models in NSRRC is proposed. The errors between model estimation and real case are reliable if there is no significant load added. The energy efficiency in NSRRC will improve continually with the aid of energy management system.

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