Special Protection Schemes in Taiwan

Chao-Rong Chen, *Member,IEEE*, Wen-Ta Tsai, Hua-Yi Chen, Ching-Ying Lee, Hong-Wei Lan

***Abstract*--This study describes a system-wide special protection scheme (SPS) implementation, capable of averting blackouts that could otherwise result from the transient instability of N-3 contingencies in Taiwan's power system. The entire SPS installation consists of two stages. The first and second stages of the SPS prevent the transient instability that is caused by specific and all EHV N-3 contingencies separately. Actions for the second stage of the SPS combine remote load shedding with generators rejection. This SPS is controlled using a real-time system with redundancy. This is fully automatic function. These two stages of SPS have been fully implemented and the system is operational. This work elucidates all of the design and implementation processes of system-wide SPS for an isolated power system to prevent blackout. The proposed scheme provides a valuable reference for similar independent power networks. Additionally, to our knowledge, this is the first system-wide, event-based SPS implementation to prevent blackouts against all EHV N-3 contingencies in an isolated power system.**

***Index Terms*—Blackout, look-up table, N-3 Contingency, power transfer, remedial action scheme (RAS), special protection scheme (SPS).**

I. INTRODUCTION

THE special protection scheme (SPS) or special protection system (SPS), commonly referred to as a remedial action scheme (RAS), has been widely employed. For example, SPS features in optimized defense plan against bus-bar faults at some substations [1]; maximizing scheduling generation capacity [2]; preventing power congestion [3]; maintaining security at high import power transfer [4]; preventing power failure [5], and preventing generators from becoming out-of-step [6]. The most famous SPS application is the Hydro-Quebec' defense plan which is against extreme contingencies [7]. A PMU-based concept is also exploited in SPS to prevent blackout in Taiwan power system [8]. SPS is extensively adopted to improve power system performance because it is less costly and is easier to implement than such alternatives as adding transmission and generation facilities. Some power system blackouts have occurred in recent years [9-10]. Clearly, power system outage seems to be inevitable, but the probability of blackout must be reduced. This work studies efforts to avert blackouts in an isolated and intensive power system, based on the lessons learned from previous blackouts that were caused by the crashing of a 345 kV tower and huge earthquake in 1999 separately [11]. SPS used to involve local operational constraints, but this work describes the first implementation of a system-wide SPS to prevent transient instability of N-3 contingencies in an isolated system.

To improve reliability and prevent blackouts, Taiwan Power Company (TPC) began building a system-wide SPS since after the previous power outage in 1999. The system-wide SPS has two stages, as presented in Fig. 1. The first stage of the SPS is designed to prevent some specific N-3 contingencies and is controlled semi-automatically by an operator in a central dispatching control center. The second stage of the SPS is designed to prevent all N-3 contingencies and is fully automatic; it performs generator rejection and load shedding. Both of these two stages solve the problem of transient instability caused by N-3 contingencies.

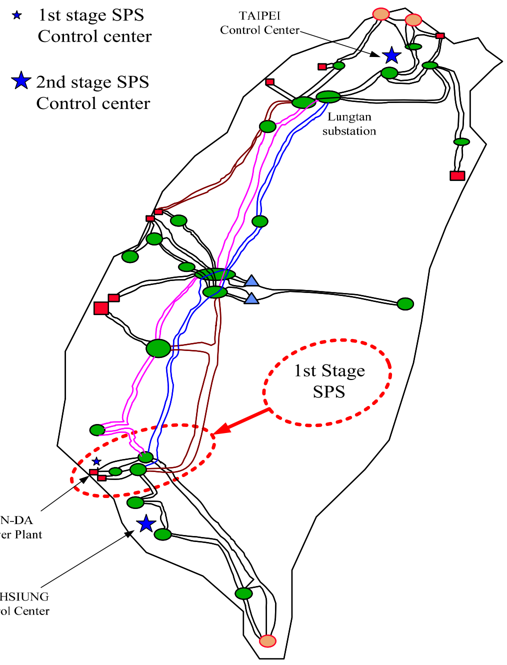

Fig. 1. Two-stage system-wide SPS of TPC.

This study describes a system-wide, event-based SPS to prevent problems of the transient instability that would cause grid blackouts in Taiwan. Bulk inter-area power transfer has been used in this system. The blackout in 1999 affected 83% of customers. The lessons learned from that event led TPC to develop a strategy for preventing blackouts. Transient instability was one of the main causes of that blackout. The defensive strategy is to install system-wide SPS with event-

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based action tables. That solves the problems of transient instability.

Power system planners apply SPS to solve one of the following conditions [6]:

1. Improve power system operation,
2. Operate power system closer to their limits,
3. Increase power transfer limit while maintaining the same level of system security,
4. In temporary installation to compensate for delays in the construction program,
5. Increase the power system security particularly towards extreme contingencies leading to system collapse.

The first and second stages of SPS address conditions 4 and 5, respectively. The third EHV transmission trunk was completed in 2002, completing also the main part of the first stage of SPS. TPC learned lessons from other large blackouts such as the Northeastern American and Italian outages in 2003 and the European blackout in 2006 [9-10]. TPC has decided to install a more reliable system-wide SPS to improve system security. The main aim is to decrease the probability of blackouts as much as possible. The second stage of the SPS has five steps -offline N-3 simulation, control system procurement, installation, testing and operation. The work of simulating the system has been outsourced to a foreign consulting company. The simulation results are called look-up tables, which provide the SPS actions of generation rejecting and load shedding in cases of transient instability. These SPS actions must be performed completed within 250 ms after fault clearance. The control system was procured following bids from a domestic manufacturer, facilitating communication among project staff as well as subsequent installation, testing, operation, and maintenance. However, this is the first experience of this particular domestic manufacturer in constricting an SPS control system. The construction period of the second stage of the SPS was from 2003 to 2006 and the total cost was about US$4 million.

II. Taiwan's Power System

The power system in Taiwan is of the island-type, intensive and isolated without any connection to another grid. It is managed by Taiwan Power Company (TPC). TPC is a vertically integrated and government-owned electrical power company. Its installation capacity is 38.6 GW and its peak load in 2007 was around 32.8 GW. The transmission system is supplied by 21 major power plants that have more than 100 generator units. They are including nuclear, coal, oil, combined-cycle, hydro and co-generation plants, representing 20%, 43%, 5%, 23%, 4% and 5%, respectively, of generation capacity. The extra high voltage level is 345 kV with a total circuit length of 3,686 km, and the high voltage transmission is 161 kV, and a total circuit length of 6,203 km. The sub-transmission voltage level is 69 kV, and the corresponding total circuit length is 6,168 km. The voltage levels of distribution network are 11 kV and 22 kV, and the corresponding total circuit length is 316,680 km [11]. The northern area is the load center and the central and southern areas are generation centers. The Taiwanese grid is characterized by large power transfer from south to north in periods of peak load, which promotes transient instability problem following large disturbances, against which the system-wide SPS measures, described herein, are implemented.

III. The First Stage Of SPS

The first stage SPS was motivated by the power outage in 1999, which was caused by the crashing of an EHV tower and led to transient instability [12]. That event caused approximately 83% of consumers from the power supply. The power outage had two main causes. One is the excess south-to-north (STN) power transfer, and the other is the delay associated with the third EHV transmission trunk. South-to-north power transfer via two EHV transmission trunks in the power outage of 1999 was large. Thereafter, TPC decided to upgrade its security and reliability by implementing the final suggestion of report on the blackout event. TPC designed a simple SPS to prevent transient instability that would otherwise be induced by particular N-3 contingencies. Figure 2 presents the first stage of the SPS that includes contingency lines and rejecting generators. When any three lines of the six lines connected to the northern grid in Fig. 2 is faulty or maintaining and the STN power transfer reaches a preset value, the SPS is triggered to reject the gas turbine generators in the Xinda power plant. This is the first stage of SPS, which protects transient instability and implements generator rejection based on an action table.

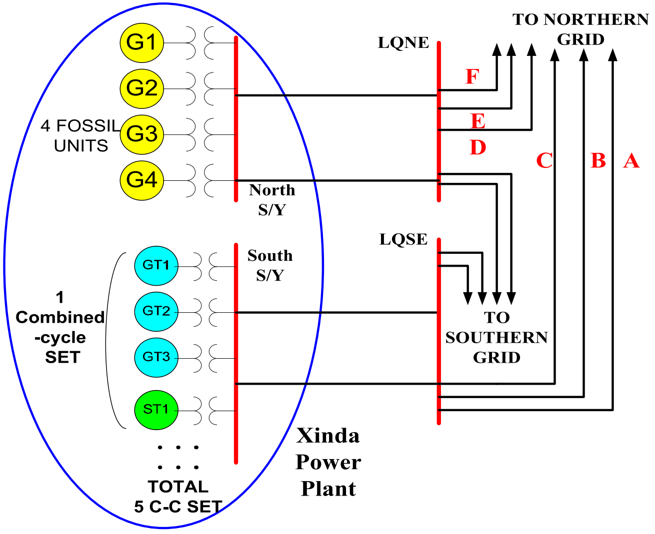


Fig. 2. Generators tripping scenario of the first stage SPS

The function is semi-automatic since the action is triggered by the system operator at the central dispatching control center. A study of the system is beginning to elucidate the nature of the vulnerability for Taiwan power system. Power system simulations include transient, small-signal and, voltage stabilities as well as frequency responses, as follows.

A. *Transient Stability*

We can obtain N-3 contingency table with the combination of line A to F on Fig. 2. Then we simulate N-3 contingencies with three phase fault as well as different STN transfers to examine transient instability. The countermeasure for instability is to reject gas turbine (GT) generators as shown in Fig. 2. Table 1 illustrates the simulation results. The division of the STN power transfer on Table 1 is 100 MW because the simulation parameter error and simple index for operators to memorize. It is not necessary to act for SPS as long as the STN transfer is below 3700 MW.

TABLE 1
ACTION TABLE INCLUDING JUDGMENT AND ACTION

Judgment (STN transfer MW)	Action (GT rejecting number)
< 3700	0
3701~3800	2
3801~3900	5
3901~4000	7
4001~4100	10
4101~4200	11
4201~4300	13
> 4301	15

B. *Small-Signal Stability*

In order to ensure other stability problems, the small signal stability and voltage stability must be checked. Generally, installing the power system stabilizer is one of the effective and economic ways to improve system damping characteristics. The simulation software is EPRI PEALS which is frequency domain algorithm. Table 2 shows the simulation results including the comparison between the normal and N-3 contingency situations.

TABLE 2
SSS COMPARISON FOR NORMAL AND N-3 CONDITIONS

	System Conditions			
	Normal		N-3	
STN Transfer (MW)	Damped Frequency (Hz)	Damping ratio (%)	Damped Frequency (Hz)	Damping ratio (%)
3800	1.2005	5.01	1.2043	3.75
3900	1.2012	5.00	1.2053	3.60
4000	1.2003	4.84	1.2063	3.40
4100	1.2004	4.68	1.2072	3.20
4200	1.1998	4.41	1.2071	3.06
4300	1.1985	4.30	1.2076	2.97
4400	1.1984	4.28	1.2082	2.92

As the STN transfer increases, however, the damping ratio decreases in both normal and N-3 contingency situations. This indicates that the greater the inter-area power transfer, the weaker the system characteristics. The damping ratio range is 4.28 % to 5.01 % and 2.92 % to 3.75 % for normal and N-3 contingency situation, respectively. The damping ratio values are valid according to the planning criteria for the Taiwan Power Company transmission system [13]. The oscillation frequencies are approximately 1.2 Hz that means the oscillation belong to inter-area mode. The STN power transfer and damping ratio reveal an inverse linear relationship. Therefore, the small signal stability is not the main constraint for this isolated power system

C. *Voltage Stability*

Heavy power transfer with long distance transmission and fault often results in voltage problem. Therefore, the relationship between the increasing STN power flow and voltage stability is examined. The EPRI VSTAB software is used for simulations. The simulation procedure is to decrease the northern area generation and increase the same quantity generation in the south by 100 MW for each step to transfer more STN power flow. The bus voltage of LQNE substation is the lowest after screening all 345 kV buses. Figure 3 shows the P-V curve of LQNE substation for both the normal and N-3 contingency conditions. To compare the results of transient stability simulation, the voltage stability has a higher operating margin. For example, Table 1 shows that the increment for the STN power flow in transient stability is about 700 MW. However, the incremental increase is also 800 MW (e.g. from 10250 MW to 11050 MW) as shown in Fig. 3. Consequently, voltage stability has a larger operating margin than transient stability. Until to this step, transient instability is still the vulnerable factor for this isolated power system.

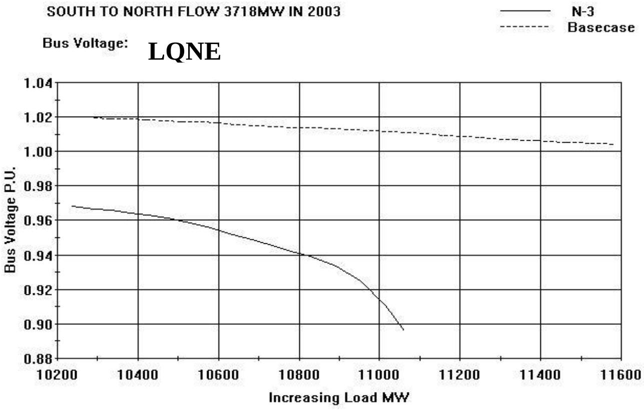


Fig. 3. The P-V curve of LQNE substation

D. *Frequency Response*

Almost every power system has been installed under-frequency load shedding (UFLS) scheme to be the last defensive line against extreme contingencies. According to the previous simulations, the transient instability is the most critical factor in TPC system so far. We have to examine the system frequency response after rejecting the maximum generators whether reaches the UFLS setting. The largest stable STN power transfer 4300 MW is used to simulate the system frequency response that total rejection generation is around 1641 MW. Figure 4 shows the simulation result that frequency swings down but is above 59.2 Hz. The 59.2 Hz is the first stage to instantaneously shed load for UFLS setting in TPC system. This illustrates the swing-down frequency does not reach the first stage setting of UFLS. Therefore, electricity service is uninterrupted even in the N-3 severe contingency. Therefore, the major operational constraint is still the transient stability problem for this isolated power system.

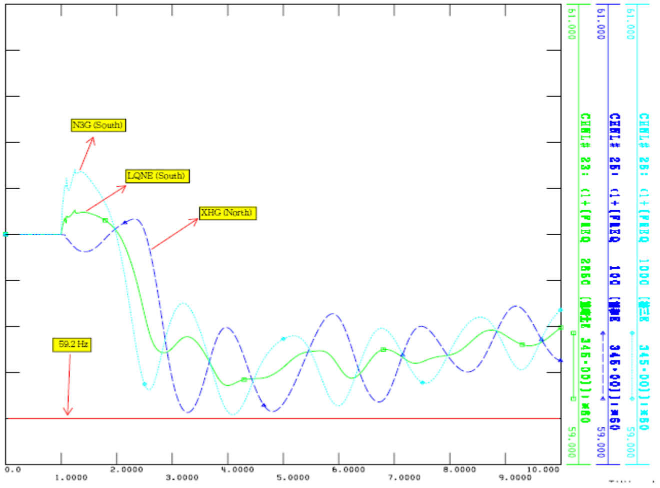


Fig. 4. Frequency swing as tripping thirteen generators

E. *First-Stage SPS Operation*

The simulation identifies transient instability as the main factor in severe contingencies of the TPC system. TPC began constructing the SPS against blackouts that are caused by instability of N-3 contingencies. Existing facilities, such as protective relays and control elements, were employed to establish the first stage of SPS, whose installation cost was low.

Fig. 5. Generators tripping control panel of the first stage SPS

TPC was completely responsible for the design and installation of the control system for the first stage of the SPS. The control system was installed in the control room of the Xinda power plant. The operator of the system control center commands the plant operator to turn on generator rejection switches when the STN transfer exceeds 3700 MW. Fortunately, the TPC system has experienced no wide-area power outage since the first stage of the SPS was completed. The fifteen on/off switches on the control system panel enable 15 generators to be tripped, as presented in Fig. 5. From Table 1, if the STN transfer exceeds 4000 MW, then the system operator commands the Xinda plant operator to turn on seven switches connected to on-line operating generators. Accordingly, these seven generators are rejected in cases of specific N-3 contingency.

IV. SECOND STAGE OF SPS

Two main reasons compelled TPC to construct a more reliable system-wide SPS. One is the importance of delays in power construction programs and the other is all of the lessons learned from the large grid blackouts. The second stage of the SPS has the following features.

1. Full-automation: real-time collection, calculation, decision-making, and action.
2. Redundancy: two sets equipment on which the control system and communication channel are based.
3. Global N-3 protection: all EHV N-3 contingencies are simulated and the critical ones are adopted to construct action tables.
4. Event-based action table: action tables elucidate countermeasures against transient instability must be updated annually.

Establishing the second stage of SPS involves the following five main tasks.

A. *Structure of Second Stage of SPS*

The second stage of the SPS comprises five parts, as presented in Fig. 6. Operational control is distributed between Taipei and Kaohsiung primary and backup energy management systems. If one of the control centers fails or breaks down, the other takes over immediately. The decision-making and action server is located at Lungtan substation.

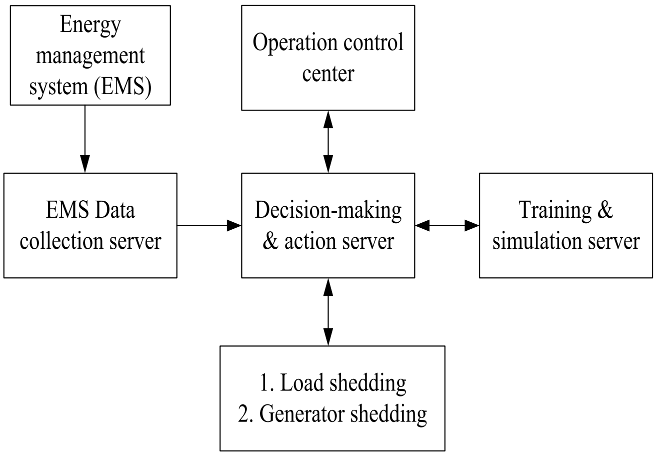
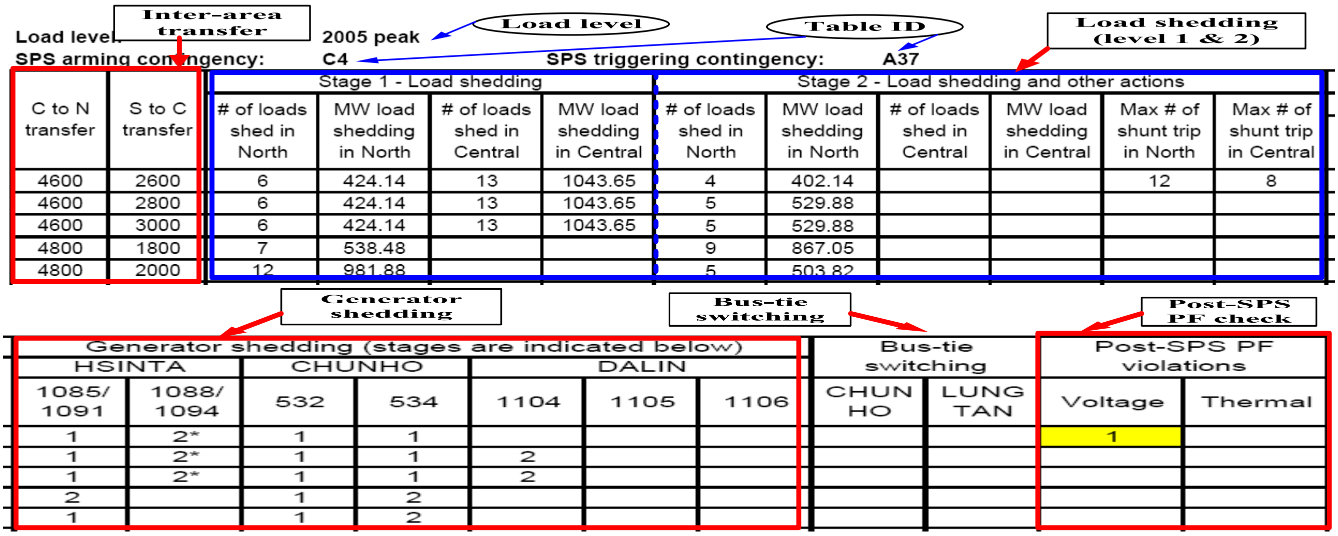


Fig. 6. Structure of the second stage SPS



Load level: 2005 peak
SPS arming contingency: C4 SPS triggering contingency: A37

C to N transfer	S to C transfer	Stage 1 - Load shedding				Stage 2 - Load shedding and other actions					
		# of loads shed in North	MW load shedding in North	# of loads shed in Central	MW load shedding in Central	# of loads shed in North	MW load shedding in North	# of loads shed in Central	MW load shedding in Central	Max # of shunt trip in North	Max # of shunt trip in Central
4600	2600	6	424.14	13	1043.65	4	402.14			12	8
4600	2800	6	424.14	13	1043.65	5	529.88				
4600	3000	6	424.14	13	1043.65	5	529.88				
4800	1800	7	538.48			9	867.05				
4800	2000	12	981.88			5	503.82				

Generator shedding (stages are indicated below)							Bus-tie switching		Post-SPS PF violations	
HSINTA		CHUNHO		DALIN						
1085/ 1091	1088/ 1094	532	534	1104	1105	1106	CHUNHO	LUNG TAN	Voltage	Thermal
1	2*	1	1						1	
1	2*	1	1	2						
1	2*	1	1	2						
2		1	2							
1		1	2							

Fig. 7. Example of look-up for 2005 peak load

It collects inter-area tie flow, substation loads, and generation data and identifies contingencies to decide whether action must be taken. It is controlled by the operation control center. If the SPS action settings must be changed, the system can firstly be simulated on the training and simulation server to determine the accuracy and the availability of the action table. Training the SPS operators is also an important task for this part. EMS sends the system load, power plant generation and EHV tie-line circuit breaker states to the EMS data collection server. In the final part (load/generator shedding) of the structure, 49 substations and three power plants, including 13 generators, can be shed and rejected. Figure 6 presents the second stage of the SPS.

B. *Requirements for System Simulation*

The design criteria of the second stage SPS is based on N-3 contingencies, which include N-1-2 and N-2-1. N-'a'-'b' contingencies mean 'a' is arming and 'b' is triggering contingencies. Different load conditions, including peak, medium and light, as well as power transfers, including south-to-central and central-to-north, are considered. The complete analysis of the system has thermal, voltage violation, small-signal and transient stability analyses. TPC adopted consultants to examine the system study because of the magnitude of the simulation and the SPS project schedule.

C. *System Simulation Consultant*

The system study was outsourced to Powertech Labs Inc. (PLI), which has extensive experience of analyzing SPS systems. The automatic processes must be considered because hundreds of thousands of cases of power must be simulated. The results of the system simulation are presented in the form of look-up tables. TPC wants to have its own the simulation technology so that it can perform its own simulations in the future. Therefore, the system simulation consultants have provided a training course and user manuals. The SPS control system procurement schedule has been postponed, and the consultants have conducted the studies of two-years (year 2005 and 2007). The final report includes the look-up tables based on thermal analysis, voltage violation, and small-signal and transient stabilities. The total cost of the two system simulations was about US$0.7 million. The task B and C are the responsibility under the authority of the system operation and planning departments of the TPC.

Figure 7 presents a look-up table for peak load in the year 2005 [14]. On the top of the table, C4 and A37 are the table identifiers, which refer to arming and triggering contingencies. The action table comprises the following five main parts.

1. Inter-area transfer: includes central to north and south to central transfers.
2. Load shedding: includes level 1 shedding for transient instability and level 2 for thermal violation. Details of the number of shed substations and the shedding area are given. Most of the load shedding substations are in the north; some are in the center of Taiwan.
3. Generator shedding: three power plants may be rejected in cases of transient instability. Two plants are in the south and one in the center.
4. Bus-tie switch: switching action for bus-tie in the two EHV substations included. One is located in the north and the other in the center.
5. Post-SPS power flow check: the power flow is re-examined after an SPS action in response to voltage and thermal violations.

D. *SPS Control System Procurement*

TPC decided to solve the problem transient instability in response to the results of the system study. According to the look-up tables, which provide the results of transient stability simulation, TPC must procure load/generator shedding equipment, control system software, and communication devices. Figure 6 presents procurement for the SPS structure. The total cost to TPC of procurement was NTD90 million (33NTD~1USD) in 2004. The installation was completed in 2006. The protective relay department was responsible for the procurement work.

E. *Operation*

The commercial operation of the second stage of the SPS is postponed because the look-up table is outmoded. TPC is a government-owned utility and so must follow government procurement regulations. Complicated procedures have delayed installation and testing, causing the second stage of the SPS to be postponed. TPC has decided to update the look-up table to the year 2010 to ensure that TPC has sufficient time to complete the additional control system procurement for the new 2010 action tables. The second stage of the SPS has been test operated. TPC is gaining operational experience of the SPS to prepare for its commercial operation. To prevent SPS malfunction, the control system and communication must be examined during the period of test operation. The test operation involves only the collection and storage of the SPS action message without load shedding or generator rejection in case of the triggering of the SPS. Figure 8 presents the second stage of the SPS located at Lungtan substation. Just SPS operational control center is conducted at the Taipei/Kaohsiung central dispatching control centers. The components in Fig. 8, from left to the right, are the training and simulation server, the EMS data collection server, the decision-making & action server and, the load/generation shedding interface.

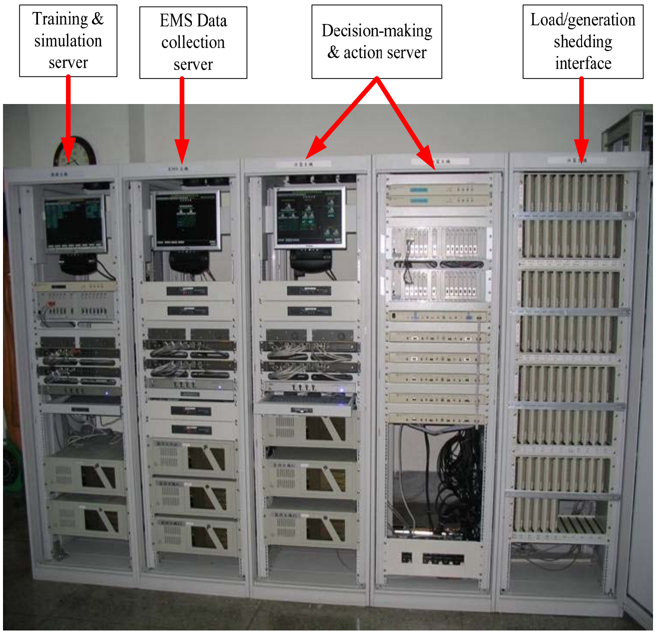


Fig. 8. The components for the second stage of SPS

V. CONCLUSION

This study describes the first system-wide SPS implementation to prevent transient instability of N-3 contingencies in an isolated power system. To reduce the power outage probability, TPC has constructed the two-stage SPS. The first stage of the SPS prevents specific N-3 contingencies and takes generator rejection measures in case of transient instability. The frequency response associated with the severest generator rejection is also simulated. The results indicate that UFLS setting is not triggered in the worst situation. Therefore, the first stage of the SPS is simple but increases reliability for electricity customers. The second stage of the SPS safeguards Taiwan’s power system from blackouts that would otherwise result from all N-3 contingencies. The SPS actions include the strategies of generation rejection and load shedding with real-time functions. The action tables must be updated periodically following a change in the grid structure. This requirement is a potential disadvantage of the system. Hence, some system studies are underway to improve SPS function by, for example, the online updating of look-up tables. The second stage of the SPS will be prepared for the updating look-up tables in the year 2010; then test operations will become formal operations. Taiwan’s power system will enter a new era of greater reliability and security with the implementation and operation of system-wide SPS.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

[1] M. El-werfelli, H. A. Haddud, and R. Dunn, "Design of an optimized defence plan for a power system," in *Proc. 2008 CIGRE*, pp. C2-209.

[2] J. Hsu, K. Cocco, T. Isham, B. Kokanos, "Use of Special Protection Systems for Major Palo Verde Network Hub Congestion Management in the U.S. Southwest," in *Proc. 2006 International Conference on Power System Technology*, pp. 1-5.

[3] J. Hsu, G. DeShazo, W. Wong, "Use of special protection systems to overcome power congestion in the Western United States," in *Proc. 2002 International Conference on Power System Technology*, pp. 1339-1343.

[4] A. Moshref, C. Henville, R. Curtis, K. Morison, L. Albassam, M. Owayedh, O. El Said, M. Ashiq, "Design of a special protection system to maintain system security at high import," in *Proc. 2003* Power Engineering Society General Meeting, pp. 311-319.

[5] S. S. Ahmed, N. C. Sarkeret, A. B. Khairuddin, M. R. B. A. Ghani, and H. Ahmad, "A Scheme for Controlled Islanding to Prevent Subsequent Blackout," *IEEE Trans. Power Systems*, vol. 18, Feb 2003, pp. 136-143.

[6] D. Karlsson, X. Waymel (edited), "System Protection Schemes in Power Networks," *prepared by CIGRE SCTF 38.02.19*, Jan. 2001.

[7] G. Trudel, S. Bernard, and G. Scott, "Hydro-Quebec's defence plan against extreme contingencies," *IEEE Trans. Power Systems*, vol. 14, pp. 958-966, Aug. 1999.

[8] Y. J. Wang, C. W. Liu, Y. H. Liu, "A PMU based special protection scheme: a case study of Taiwan power system," *International Journal of Electrical Power & Energy Systems*, vol. 27, issue 3, pp. 215-223, March 2005.

[9] G. Andersson, P. Donalek, R. Farmer, N. Hatziargyriou, I. Kamwa, P. Kundur, N. Martins, J. Paserba, P. Pourbeik, J.Sanchez-Gasca, R. Schulz, A. Stankovic, C. Taylor, V. Vittal, "Causes of the 2003 major grid blackouts in North America and Europe, and recommended means to improve system dynamic performance," *IEEE Trans. Power Systems*, vol. 20, pp. 1922 – 1928, Nov. 2005.

[10] Final Report on the disturbances of 4 November 2006, http://www.ucte.org/resources/publications/otherreports/

[11] C. H. Lee and S. C. Hsieh, "Lessons learned from the power outages on 29 July and 21 September 1999 in Taiwan," *IEE Proc.-Gener. Transm. Distrib.*, vol. 149, pp. 543-549, Sep. 2002.

[12] Taiwan Power Company, *Taiwan Power Company 2007 Annual Report*, ISSN 10214585, 2007.

[13] *Planning criteria for transmission system of Taiwan Power Company*, TPC Regulation, 2005.

[14] *Final Report – Power system analysis for SPS study*, PLI prepared for TPC, vol. Ⅱ, Nov. 2003.

VIII. BIOGRAPHIES

Chao-Rong Chen was born in Taiwan in 1961. He received his B.S., M.S., and Ph.D. degrees in Electrical Engineering from National Taiwan University in 1983, 1988, and 1991, respectively. In August of 1991, he joined National Taipei University of Technology as a faculty member, now he is presently an associate professor in the Electrical Engineering Department. From 1995 to 1996, he was a visiting scholar at the University of Washington, Seattle. At present, his research interests include power system stability, intelligent control, and energy saving.

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Hua-Yi, Chen was born in Taiwan in 1973. He received his diploma in electrical engineering from National Taipei University of Technology, Taiwan. He is an engineer in Taiwan Power Company and currently working his Ph. D degree at National Taipei University of Technology, Taiwan. His current research interest is on stability analysis of power system.

Ching-Yin Lee was born in 1957. He received his B.S.E.E. degree from National Taiwan Institute of Technology in 1983, M.S.E.E. degree from National Taiwan University in 1986 and Ph.D. from National Taiwan University of Science and Technology in 1992. Dr. Lee worked with Northern Taiwan Telecommunication from 1979 to 1986. He was an instructor from 1986 to 1991 and an associate professor from 1991 to 1998 in the Department of Electrical Engineering, National Taipei University of Technology, and since 1998, he has been a professor in the same department. He was the chairperson of the E.E. department from 1992 to 1995, a visiting scholar at the University of Taxes at Arlington from 1996 to 1997, the dean of extension education office, the dean of college of continuing and the head of secretary office from 1997 to 2001. Now, he is vice president at National Taipei University of Technology. His research interests are in power system operation, particularly in voltage stability analysis, reactive power planning, contingency analysis, power quality and electrical machinery.

Hong-Wei Lan received the B.S.E.E. degrees from National Taiwan Institute of Technology, Taipei, Taiwan, and the M.S.E.E. degree from the National Tsing Hua University, Hsinchu, Taiwan, in 1981 and 1985, respectively. From 1976 through 1978 Mr. Lan worked as an engineer in the Linkou Power Plant of the Taiwan Power Company. Since 1978, he worked as a chief dispatching engineer in the System Operations Department of the Taiwan Power Company. Mr. Lan is currently the director of the System Operation Department. His research interests are in power system dispatching and operation, particularly in system voltage control and reactive power dispatch. Mr. Lan is a Registered Professional Engineer of Taiwan, R.O.C.