Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Review of Reliability Assessment of Westinghouse SSPS Using SPC by WEC

H. T. Kang, H. Y. Chung
Nuclear Engineering and Technology Institute, KHNP, Jang-Dong 25-1, Daejeon, Korea
mail:nalburushim@khnp.co.kr

1. Introduction

Westinghouse Electric Company (WEC) has accomplished the reliability assessment of Westinghouse Solid State Protection System (SSPS) in KORI #2, 3, 4, and YGN #1, 2. In their studies, it is reported that creating a cost-effective plan for improving the reliability of the SSPS and at KORI #2, 3 & 4, and YGN #1, 2 should be needed while reducing their maintenance cost [1]. In this paper, we reviewed the reliability assessment of Westinghouse SSPS analyzed in two performance standards, availability, and the maintenance expense using Statistic Process Control (SPC). As a result, it is concluded all plants have several failures reported but no effect on the system's availability, and the maintenance expense analysis did not reduce the current maintenance expense by 30%. Therefore, overall review for the reliability assessment is that a new strategy for cost-effective plan and/or upgrade approach for improving the reliability of the aging Westinghouse SSPS should be needed.

2. SSPS Overview

As SSPS perform safety related functions in the plants, SSPS is used for Reactor Trip and ESF actuation logic. SSPS consists of 2 logic trains, 2 safeguards test cabinets, a computer demux, and control board demux that are mounted in 6 separate cabinets. The logic trains perform RT and ESFAS logic and initiate demands for RT and initiation of ESFAS functions

3. SPC

SPC is defined as a procedure in which data is collected, organized, analyzed, and interpreted so that a process can be maintained at its present level of quality or improved to a higher level of quality. SPC minimizes production costs, and attain a consistency of products and services that will meet production specifications and customer expectations [2].

4. Reliability Assessment of Westinghouse SSPS

There are two metrics calculating the reliability of Westinghouse SSPS. One is availability (Y1) of the SSPS during the next 20 years after initiation of the SSPS Improvement Plan. Availability can be 100 %. Y1 is considered "bad" when it is lower than 100%. The other is total expected maintenance cost (Y2) of the SSPS. Maintenance cost can be zero in theory, but in practice it is not achievable due to regulatory requirements and technology limitations. Thus, some maintenance cost is expected. In this paper, customer's expectation is to reduce the maintenance cost by 30%. Y2 is considered "bad" when it is higher than 70% of the current maintenance cost.

4.1 Performance Standards: Availability (Y1)

Availability was calculated SSPS failures during plant operation from 2002~2006. The data for availability were obtained from KORI #2, 3, 4 and YGN #1, 2 SSPS failure history. In Table 1, "Defs" means SSPS defected, i.e., failures, and "Units" means year-base, therefore, for example, in YGN #1 there exists 3695 maxima failures opportunity for 5 years, which is "Total Opps" meaning No. of total opportunity for failure. In view of 6-sigma, the sigma level, Zst, is 4.468.

Table 1 Defect Per Million Opportunities (DPMO)

Component	Obs Defs	Obs Units	Opps per Unit	Cmplx	Adj Defs	Adj Units	Adj Total Opps	DPU	DPMO	Z.Shift	Z.ST	YTP
YGN 1	0	5	739	*	0	5	3695	0.0	187.6	1.500	5.057	0.870551**
YGN 2	1	5	739	*	1	5	3695	0.2	270.6	1.500	4.959	0.818709
KORI 2	25	5	663	*	25	5	3315	5.0	7541.5	1.500	3.930	0.006611
KORI 3	0	5	663	*	0	5	3315	0.0	209.1	1.500	5.028	0.870551**
KORI 4	0	5	663	*	0	5	3315	0.0	209.1	1.500	5.028	0.870551**

KORI #2 has several failures reported but no effect on the system's availability. KORI #3,4 have no failures during plant operations for the last 5 years. YGN #1, 2 reported a single failure for the last 5 years. Failure did not affect the system's availability. As shown in Table 1, DPMO in total, which is derived from total opportunities divided by total defect, is 1,115, which is almost zero compared with one million. So, it is concluded the availability of SSPS very high.

4.2 Performance Standards: Maintenance Cost (Y2) using SPC

Maintenance cost is calculated from two elements, SSPS periodic test cost and card replacement cost. For the purpose of the capability analysis, the assumptions for calculation are that, first, the labor cost for KHNP is estimated as $100 per hour, second, the goal is to reduce the current maintenance expense by 30%, third, the replacement card cost as $10,000, finally many of the maintenance activities occurs in every 18 months, so, recalculate the yearly based expense for these maintenance activities.

Table 2. The number of card replacement from year 2002~2011

	KORI U2	KORI U3&U4	YGN U1&U2
Average Number of Cards Replaced per year =	14.2	31	21.2
Number of Cards replaced 2002 =	8	0	20
Number of Cards replaced 2003 =	6	0	32
Number of Cards replaced 2004 =	20	0	7
Number of Cards replaced 2005 =	5	0	40
Number of Cards replaced 2006 =	32	31	7
Number of Cards replaced 2007 =	15	46	155
Number of Cards replaced 2008 =	40	54	138
Number of Cards replaced 2009 =	44	43	0
Number of Cards replaced 2010 =	46	56	0
Number of Cards replaced 2011 =	62	43	0

Table 3. SSPS Periodic Test Item and Frequency

Equipment	Activity	Frequency	Man-Hour Estimates			Installed Quantity			Plant Totals			Sub-Totals
			KORI U2	KORI U3&U4	YGN U1&U2	KORI U2	KORI U3&U4	YGN U1&U2	KORI U2	KORI U3&U4	YGN U1&U2	
Input relay	healthiness of diode installed in relay	18 M	0.2	0.2	0.05	306	612	612	61.2	122.4	30.6	214.2
Master relay	Coil resistance of relay, contact point, operating voltage,	18 M	0.5	0.5	0.05	64	128	128	32	64	6.4	102.4
Slave relay	Coil resistance of relay	18 M	0.5	0.5	0.1	146	192	192	73	96	19.2	188.2
15V Power Supply	ripple, Discharge time, No load and load test	18 M	2	4	1.4	4	8	8	8	32	11.2	51.2
48V Power Supply	ripple, Discharge time, No load and load test	18 M	2	4	1.4	4	8	8	8	32	11.2	51.2
Universal Logic Board	ICT(In Circuit Test) & ROMP test	18 M	10	4	0.5	78	156	156	780	624	78	1,482.0
Safeguards Driver Board	ICT(In Circuit Test) & ROMP test	18 M	10	4	0.5	6	12	12	60	48	6	114.0
Under Voltage Driver Board	ICT(In Circuit Test) & ROMP test	18 M	10	4	0.1	2	4	4	20	16	0.4	36.4
Isolation Board	ROMP test	18 M	0.5	1	0.5	8	16	16	4	16	8	28.0
Clock Counter Board	ROMP test	18 M	0.5	1	0.5	4	8	8	2	8	4	14.0
Decoder Board	ROMP test	18 M	0.5	1	0.1	8	16	16	4	16	1.6	21.6
Semi-Automatic Tester Board	ROMP test	18 M	0.5	1	0.1	2	4	4	1	4	0.4	5.4
Memory Board	ROMP test	18 M	0.5	1	0.1	31	62	62	15.5	62	6.2	83.7
								Plant Totals =	1,068.7	1,140.4	183.2	
								Normalized per Year =	712.5	760.3	122.1	
									$71,246.67	$76,026.67	$12,213.33	

It is ended up with 30 samples, 10 from KORI #2, 10 from KORI #3, 4, and 10 from YGN #1, 2, as shown in Table 4. 2 outliers in the data were realized to be removed for normally distributed data for the calculations. That's how data ended up with a sample size of 28. Reliability data of SSPS is not normally distributed against P-value is 0.011 as shown in Figure 1. P-value should be below 0.5 for normally distributed data. For SPC, Box-Cox transformation was made to obtain the normally distributed data.

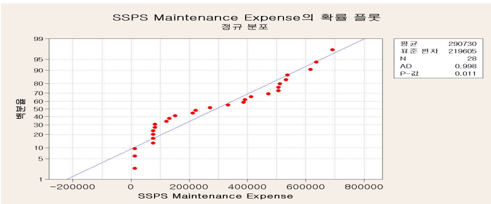

Figure 1. Verification of Normally Distribution of Reliability Data

The expected maintenance expenses are the sum of periodic test cost and card replacement cost. Table 4 shows the expected maintenance expense of SSPS.

Table 4. Expected Maintenance Expense of SSPS

	KORI 2	KORI3,4	YGN1,2
2002	151,246.6	76,026.6	212,213.3
2003	131,246.6	76,026.6	332,213.3
2004	271,246.6	76,026.6	82,213.3
2005	121,246.6	76,026.6	412,213.3
2006	391,246.6	386,026.6	82,213.3
2007	221,246.6	536,026.6	1,562,213.3*
2008	471,246.6	616,026.6	1,392,213.3*
2009	511,246.6	506,026.6	12,213.3
2010	531,246.6	636,026.6	12,213.3
2011	691,246.6	506,026.6	12,213.3

Since the goal is to reduce the current maintenance cost by 30%, the current capability was calculated without knowing the actual per hour labor cost. The average maintenance expense for SSPS is $369,828.89 for 28 sample size from Table 4. So the goal, i.e., upper standard level (USL) is $369,828.89 x 70% = $268,880.22.

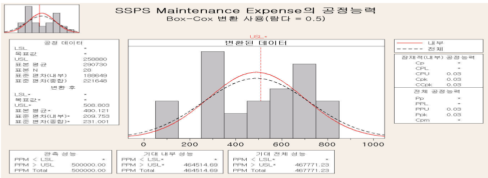

Figure 2. SSPS Maintenance Expense Process Capability in which Cpk is 0.09

As shown in Figure 2, expected total capability shows the effectiveness of the process. PPM total is 48771. In view of 6-sigma, Zst is 1.55, Cpk, process capability, is 0.09, which means current maintenance practice should be improved.

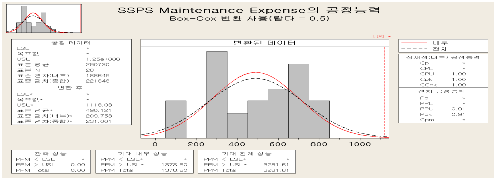

Figure 3. SSPS Maintenance Expense Process Capability in which Cpk is 1.0

Figure 3 shows, however, assumption if the current maintenance practice will have a good maintenance process capability, in which PPM total is 3281, Zst is 3.0, and Cpk is 1.0. From this view, USL should be $369,828.89 x 338% = $1,250,000. The USL is rather increased by 338% besides the goal is to reduce the maintenance expense by 70%. This means our maintenance practice has to be carefully examined such that we will have a new strategy for cost-effective plan and/or upgrade approach.

5. Conclusion

In this paper, we reviewed the reliability assessment of Westinghouse SSPS analyzed in two performance standards, availability and maintenance expense using SPC accomplished by WEC. As a result, it is concluded all plants have several failures reported but no effect on the system's availability, and the maintenance expense analysis did not reduce the current maintenance expense by 30%. Therefore, the overall review for the reliability assessment is that a new strategy for cost-effective plan and/or upgrade approach for improving the reliability of the aging Westinghouse SSPS should be needed. Based on the reliability assessment method, we will accomplish the reliability assessment of the instrumentation and control system of YGN #3, 4 at the end of this year.

REFERENCES

[1] Willam L. Miller, Mesut B. Uzman, KORI Units 2,3 & 4 and Yonggwang Units 1 &2 7300 Process Protection and Control Systems and Solid State Protection Systems Improvement Plan, WNA-AN-00032-Gen, Rev 0, 2007.
[2] Gerald M. Smith, Statistical Process Control and Quality Improvement, Fifth Edition, Prentice Hall, 2004.