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Regulatory Experience on Safety System Instrument Uncertainty of Wolsong Units

- Focused on Drift Problem -

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Abstract

This paper presents the regulatory experience gained from Wolsong Units 2,3 &4 - Special Safety System Instrumentation Uncertainty for Trip Setpoint and Allowable Values. The equipment diversity method for the defense against common mode failure was applied to the transmitters of shutdown system number 2. However the Units experienced an unexpected drift problem with which the performance did not meet the Technical Specification (Tech Spec) Surveillance Requirements (SR). Discussed are the background, status and corrective actions, regulatory positions and issues to be solved for the drift problem. It was an instrument uncertainty methodology that the designer of safety system should have shown when the drift problem occurred. For deeper understanding of the problem, we present the background of Tech Spec SR for setpoints in Korean PWR and in CANDU reactors. The Setpoint Verification Test(SVT) and Calibration Test(CT) shall be achieved by recording sufficient as-found data to determine the setpoint in terms of the measured process variables prior to any adjustment. We considered the problem using Canadian calibration and on-line monitoring practices with the as-found/ as-left method for drift surveillance. When an as-found value measured is between an Allowable Value and MAPS value in SVT and Calibration Test on a single channel, plant operation is acceptable with one affected channel, only if the other channels are checked and reviewed for further operation according to the Tech Spec. Measuring and Test Equipment (M &TE) accuracy, turn down factor of instrument accuracy, calibration interval, drift management program are introduced and discussed.

1. INTRODUCTION

In June1998, inspections for Wolsong Units 1, 2, 3 & 4 showed that the Setpoint Verification Tests (SVTs) procedure did not meet the Technical Specification (Tech Spec) surveillance requirement (SR) to confirm the Allowable value in the Tech Spec [1]. According to the Tech Spec, there are two similar setpoint monitoring tests: Channel Functional Test (CFT) performing every week for PDC trip process digital channels, and SVT for analogue channels - such as NOP trip parameter and Reactor Building High Pressure trip parameter every four week. It is focused on a bistables - an analog Alarm Units only for SDS 1 and 2 [2]. Requirements of R-8 and R-10 [3] of on-line test facility for Shutdown Systems trip SVT, which is unique for SDS 1& 2 of Wolsong Units 2,3 & 4, did not fully meet to Alarm Unit module racks in an analogue loop in Emergency Core Cooling System (ECCS) and Containment systems. In August 1999, an inspector found an unexpected drift problem, out of Allowable values in SDS 2 Steam Generator Level Transmitters (SGLTs) after only two years of operation. Not only did half the as-found values of the twelve SGLTs meet the requirement of Tech Spec, but also some were out of the analysis values.

Thus the specified calibration intervals in Tech Spec were no longer valid due to the unexpected drift problem.

1.1. Status of Drift Problems identified in Wolsong Units

In April 1997, the setpoint curves for Steam Generator Low Level (SGLL) of Setback System of Reactor Regulating System (RRS) were changed. The change of the setpoint curves for Shutdown Systems (SDS 1 &2) was implemented by the compensated calibration method for SDS 1&2 transmitters. It was a fast damping time of SDS 2 SG Level Transmitters (LTs) that made SDS 2 tripped when Load Rejection Test performed in the Commissioning Stage just after changing the setpoint curves and recalibration of SDS 1&2 SGLTs. The investigation found that the SGLTs' damping time is not sufficient to damp the instantaneous spurious level signal, because a new SGs' down-comer effect causes a sudden differential pressure change. The plant staff solved the damping time problem for SGLT with the capacitor-resistor filter. In 1998, the installation of the passive filter for SDS2 Wolsong Unit 2 was completed. The calibration frequencies for Special Safety Systems (SDS 1 &2, ECCS, Containment System) in the Tech Spec[1] were 3 years or 4 years depending on number of channels or loops of Heat Transfer System except Wolsong unit 1.

In December 1998 during the first outage of Wolsong Unit 2, the Calibration Test(CT) intervals were no longer valid in some channels so that the I & C plant staff have calibrated all the channel of SDS 1 & 2 SGLTs since then. At that time, the drift problem of some SDS 2 transmitters of Wolsong Unit 2 was not fully understood both plant staff and regulatory body because it was hard to get the calibration data sufficiently. In August 1999, for the as-found data were fully available, an extended inspection confirmed that the drift problem prevailed in Wolsong 2, 3 and 4 such as Table 1. Even if the Allowable Values for each SDS 2 transmitter in Tech Spec were not specified, the drift magnitudes were beyond the total loop error - Allowable Values in Tech Spec. The worst case was Wolsong Unit 4 SGLTs, which were out of the Allowable Values when the weekly on-power spread checks was performed for the first time after a few months' operation.

Table1. The numbers of SGLTs of SDS 2 beyond the Tech Spec Allowable values

	W 2	W 3	W4	Remarks
Outage 1998	9	-	-	12 SGLTs per Unit
Outage 1999	8	8	6 / 5	Outage/ on-power

1.2 Corrective Actions Taken

The various remedial actions [4] or trial attempts to resolve the problem on a short term basis had been formalized among utility, NSSS designers and transmitters vendors such that;

- Weekly spread checks between SDS 1&2 SGLTs
- Adjustment of the existing calibration frequencies in Tech Spec,
- Re-calculation of instrumentation uncertainty components for allowable values,
- Confirmation of the uncertainty calculation in DMs of Special Safety Systems ,
- Discussion of the definition for Minimum Allowable Performance (MAPS) and Allowable Value,

- Vendor's re-evaluation of overpressure effect or other effects in transmitters' drift
- Interim analysis of safety impact on SG trip coverage with proposed new analysis values and
- Trial modification of in-site calibration procedures to evaluate static pressure effect unique in SDS differential transmitter.

If the concerned signal out of the Allowable Value is found during the weekly in-situ spread check, the re-calibration should be performed within a week.

1.3 Regulatory Consideration of interim actions.

Inspection by KINS found that the setpoints for the SDS 2 instrumentation might allow the Wolsong units to operate outside the limiting conditions of operation specified in the safety analysis. Before the plant staff decided the final solution for them, the KINS staff had temporarily concluded that the problems should be solved in such ways that;

- The existing uncertainty calculations in DM of Special Safety System instrumentation should be replaced as practically as possible in order to meet the Tech Spec by so-called, an "uncertainty methodology" with a separate "uncertainty calculation" such as a rigorous documentation recommended by ISA S-67.04-1994[4].

2. SETPOINT SURVEILLANCE REQUIREMENTS

2.1 Tech Spec SR for setpoint in Korean PWR

In addition, the Technical Specification Surveillance Requirements (SR) for setpoints for the Westinghouse and CE Type in Korea are similar except Wolsong Units and Ulchin Units 1 & 2.. Including the Wolsong Units Tech Spec, the concept for setpoint relationship similar as shown in Figure 1.

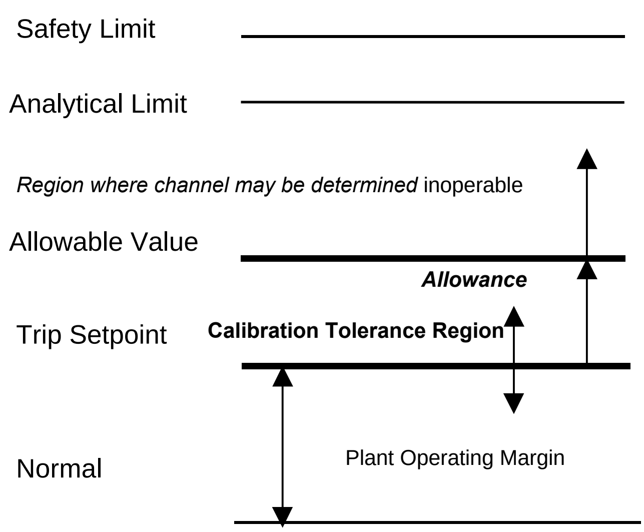

Figure 1: Nuclear safety related setpoint relationship [4, 5]

The new KORI Unit 1 setpoint study for Protection System Instrumentation has replaced the oldest one. The instrument uncertainty & setpoint methodology [6] and instrument uncertainty & setpoint calculation [7] were updated according to the latest ISA S- 67.04. The setpoint calculations for Kori Unit 1, Yongkwang Units 3,4 and Ulchin Units 3,4 are identical due to the same designer's work as follows. The Allowable Value of setpoint in Bistable, which is calculated except the measurement channel uncertainty, is checked by monthly or quarterly basis, so-called, the CFT depending on each plant's SR frequency in the PWR Tech Spec. The uncertainty calculation, for example, of Kori Unit 1 includes measurement channel(transmitter) uncertainty, I/E module uncertainties and Alarm module(i.e Bistable) uncertainties. It was utilized in the in-situ calibration procedure

2.2 Change of Tech Spec SR for setpoint in Korean CNADU

Following the Korean regulation, the designer of Wolsong Units 2,3 & 4 followed the same Tech Spec format as the existing Korean nuclear power plants did. However the Canadian plants still maintain the contents and concepts for " Operating Policies and Principles." The section of Design Manual for SDS 1 & 2 for allowance of errors and uncertainties specified the instrumentation uncertainties for each trip setpoint [2, 8]. The frequency, the method and the value for checking the setpoint of CANDU are different from that of PWR. The performance test of transmitters in CANDU in power operation is possible while that in PWR is impossible during power operation. However the test in CANDU did not verify the setpoints of analogue Alarm module – SVT - due to the difficulty to inject an accurate input signal to the transmitters till 1999. The improvement of test facilities for SDS 1 & 2 makes analogue SVT possible with a measurable accuracy.

The calibration procedure in Korean plants should be incorporated with the uncertainty methodology and setpoint calculation approved by regulatory authority. A regulatory inspection identified an example not consistent between them Thus the various remedial actions have been taken by plant staffs since then. The setpoint calculation for the Kori Units 2,3 & 4 and Yongkwang Units 1 &2 will be confirmed whether it fully comply with new Westinghouse Setpoint Methodology [9]. In conjunction with the proposal for CE and Westinghouse Improved Standard Technical Specification [10,11], the setpoint methodology will be thoroughly projected by the Korean Utility. The new standardized Tech Spec for Wolsong Units 2,3 & 4 was submitted in December 1999 and now completed;

- The calibration frequency of Special Safety Systems for every outage
- Commitment of on-power calibration test if the drift of instruments was identified during CT.

The utility projected a study of the uncertainty methodology according to both safety concern and economic necessity.

2.3. The regulatory concern for as-found and as-left techniques

The ISA S 67.04 states the setpoint maintenance or calibration techniques as agreed with Korean regulatory concerns. Formal documentation is necessary to support the investigation where a limit is exceeding, in the high or low direction as applicable as conservative to follow the Tech Spec or any design documentation such as setpoint calculation, which is specified each allowable value for each instrument or group of instrument as practical.

- Documentation of the testing and as-found data is all that is required, if as-found data indicates that no instrument adjustment is necessary,
- Documentation of the as-found and as-left data is required, if there is a need for adjustment,
- It is necessary to keep the record in order to check and evaluate the difference between the as-left value in previous CT and the as-found value before adjustment if there was or is an unexpected increased drift rate.
- Appropriate action shall be taken, if as-found data indicates that an allowable value for each instruments or instrument group as measured was exceeded,. This action shall include investigation to determine the cause of the finding, evaluation of operability, and appropriate corrective action to prevent re-occurrence.
- The improvement of setpoint test facilities for ECCS and containments System should be studied - analogue SVT with a measurable accuracy

3. Calibration Test with respect to performance

3.1. Performance Requirements for the instrument in the Standards

There are several definitions for the performance criteria for the instrument depending on purpose. The dynamic and steady state performance would be one of them. The capability in the operating environmental conditions on instrument should be considered in the performance through the environmental qualification steps as well. The minimum functional performance requirements for protection system included the followings in the IEEE 279-1971 [12]:

- System response times & system accuracies;
- Ranges (normal, abnormal, and accident conditions) of the magnitudes and rates of the change of sensed variables to be accommodated until proper conclusion of the protective action is assured

Being defined in ISA S37.1 [13], 'Error' is preferred in specifications and other specific descriptions of transducer performance. As a performance specification, 'accuracy' shall be assumed to mean 'Accuracy Rating' of the device, when used at the reference operating conditions. Accuracy Rating in the ISA S51.1 [14] includes the reproducibility - combined effects of conformity, hysteresis, dead band and repeatability error. The relationship of terms used in the CT in ISA S 51.1 is summarized as below.

- Reproducibility = Accuracy Rating + Drift
- Accuracy rating

  = Conformity (or Linearity)+ Hysteresis+ Dead-band + Repeatability

The term of the 'Measurement Accuracy' in FSAR 7 and 16 and DM of Wolsong Units 2,3 & 4 describes, "it is estimated errors applicable measurement, which is 2σ(standard deviation)". 'The Measurement Error' is interpreted the same as the total loop error or 'allowance' in the figure 1. The Measured Accuracy defined in the ISA S51.1 is typically expressed in terms of the measured variable, percent of scale length or percent of actual output reading in both side i.e. ± . The clear definition of accuracy- Turn Down Factor (TDF) should be necessary if the ratio of the full scale to upper range of output is big [4].

TDF = URL / FS

Where URL is Upper Range Limit and FS is Full Scale of output.

3.2 Calibration Standards & Drift

A drift is an inevitable phenomenon if we use an analogue instrumentation. The reproducibility for a period is a main concern for an instrument. A drift is defined in the ISA S51.1 and ISA S37.1 in the same way. Similar term, ‘the stability’ is defined in ISA S 37.1 for transducers only.

- Drift – An undesired change in output over a period time, which change is not a function of Measurand. Where, ‘Measurand’ is a physical quantity, property or condition, which is measured. The term ‘Measurand’ is preferred to ‘input’, ‘parameter to be measured’, ‘physical phenomenon’ and ‘ variable.
- Stability – The ability of transducer to retain its performance characteristic for a relatively long period of time
- Calibration [ISA S51.1], - a test during which known values of ‘Measurand’ are applied to the transducer and corresponding output reading are recorded under specified condition.

These Standards do not explicitly utilize the as-found/ as-left technique in the CT. However the reproducibility technique is interpreted as the as-found/ as-left technique. The Standard ISA S 67.04 describes methods for dealing with Calibration Tolerance in the setpoint calculation.

- If the method of CT or SVT verifies all attributes of reference accuracy or accuracy rating and the calibration tolerance is less than or equal to the accuracy rating, then the Calibration Tolerance does not need to be included in the total instrument channel uncertainty *i.e.* total loop error.

A method for verification of measured accuracy, hysteresis & dead-band and repeatability is demonstrated in ISA S 51.4. Also the Accuracy Rating of the Measurement & Test Equipment (M& TE) or the ‘reference measuring means’ is specified to be accurate less than one tenth with respect to the instrument being tested as follows.

- When the accuracy rating of the M & TE is one tenth or less than that of the instrument under test, the accuracy rating of the M & TE may be ignored.
- When the accuracy rating of the M & TE is one third or less but greater than one tenth that of the instrument under test, the accuracy rating of the M & TE shall be taken into account.

The statement M & TE accuracy rating in ISA S 51.1 is comparable to IEEE 498 standard [15]. The IEEE Standard sets forth the requirements for a calibration program to control and verify the accuracy of M & TE and Reference Standard used in the safety system of a nuclear facility. This standard is withdrawn in Branch Technical Position HICB-12 of the Standard Review Plan, but still valid review guidance [16].

- The rationale of 4: 1 higher accuracy requirement for M & TE than the instrument being calibrated is based on the IEEE Std 498 requirement.

In addition to 4: 1 higher accuracy requirement, TDF concept would be considered when TDF of MT & E is big.

3.3 Brief Historical Review of Regulation on Drift problems .

Also Drift has been one of the main topic in US Licensee Event Reports (LERs) since the first version of Regulatory Guide (RG) 1.105 published in 1975. In 1974, NRC issued a Standardized Tech Spec, which has a new concept; the Allowable Value. Exceeding the Allowable Value in a single channel was a reportable event *i.e.* LER. The Allowable Value meant an allowance for bistable module rack only at that time. In 1976, RG 1.105 Rev.1 defined a new Allowable Value allowed for a Drift. In 1983, NRC issued a revised 10CFE 50.36 'Technical Specification' [17], which did not require reporting a LER in case of a single channel inoperability except loss of completion of its function. The concerns for instrument drift are expressed in the RG1.105.

The first version of ISA S-67.04 [4] did not mention the drift relationship with 'Measurand'. The drift sometimes is assumed as a linear function of time for exploration, not for interpolation vice versa. It is not generally accepted in the US-NRC as indicated in the concerns in RG 1.105 with Generic Letter (GL) 91-04 [18] for reviewing the extended surveillance intervals. The drift issues are highlighted in the increased calibration interval related GL 91-04. The Followings are the concerns identified in the GL 91-04. It is informative to the Wolsong drift problem.

- Confirm that the instrument drift as determined by as-found/ as left calibration data has not exceeded specified limits for a calibration interval
- Confirm that the value of drift for each instrument type and application have determined with a high probability and a high degree of confidence.
- Confirm a summary of the methodology and assumptions used to determine the rate of instrument drift with time based upon historical plant calibration data.
- Confirm that the magnitude of instrument drift has been determined for a bounding calibration interval of 30 months for each instrument type and application.
- Confirm that a comparison of the projected instrument drift errors has been made with the values of drift used in the setpoint analysis.
- Confirm that the projected instrument errors caused by drift are acceptable for control of plant parameters to affect a safe shutdown.
- Confirm that all the conditions and assumptions of the setpoint and safety analysis have been checked and are appropriately reflected in the acceptance criteria of plant surveillance procedures for channel checks, channel functional tests, and channel calibrations.

Based on the survey for LERs by AMS [19], the survey confirmed the validation of existing Tech Spec Surveillance. A research [20] showed that only the heat and pressure cycling conditions resulted in any measurable degradation in limited sampled transmitters. The search of LERs [20] showed setpoint drift and calibration problems in about 5% of process instrument systems predominantly including pressure, level, and flow transmitters. In LERs' Statistics of Table 2, 10CFR 50.36 revision resulted in an 50% decrease in the number of LER from those reported in 1984. Thus fewer LER were submitted after then solely to report problems with a small number of instruments only when the safety function fails. The average failure for pressure instrumentation can be calculated 1.9 failures per US plant per year in the Table 2.

- 1.9= 1,866 LERs ÷ 100 plants ÷ 10 years

Table 2. LERs Statistic

Total LER					40,000
Pressure Sensing System Failure				6.04%	
1. Pressure Instumention Failure			4.67%		
1.1 Aged- Related		36%			
1.1.1 Drift. Calibrarion	27%				
1.1.2 Worn,Broken, Bent	22%				
1.1.3 Water Spray, Flow Bloc	19%				
1.1.4 Vibration, Fatigue	5%				
1.1.5 Errosion/ Corrosion	2%				
1.2. Personnel Error		31%			
1.2.1 Testing/ Surveillance	26%				
1.2.2 Desing Erros	20%				
1.2.3 Maitenance/ Operation	22%				
1.2.4 Intallaltion/ Fabricatio	13%				
1.2.5 Administrtive	8%				
1.2.6 Construction	2%				
1.2.7 Others/ Unknown	5%				
1.3 Other causes		33%			
2. Sensing Line Failure			1.37%		

3.4 Performance and Diversity

IAEA Code for protection system design provides the general design criteria for system & component reliability, which describes several design measures that may be used to achieve and maintain the required reliability commensurate with important of the safety functions to be performed within all three echelons of defense in depth[21] – reliability design: redundancy, diversity, independence, fail safe design and auxiliary services. The following design methods are considered for diversity design criteria in the IAEA design code [22] and IAEA Safety Guide for Protection System [23].

- Using the principle of diversity to reduce the potential for certain common cause failures can enhance the reliability of some systems.
- Diversity is applied to redundant systems or components that perform the same safety function by incorporating different attributes into the systems or components.
- Care shall be exercised to ensure that any diversity used actually achieves the desired increase in reliability in the implemented design,if diversity is applied,.

If diverse components or systems are used, there should be a reasonable assurance that such additions are of overall benefit, taking into account the disadvantages such as the extra complication in operating, maintenance and test procedures or the consequent use of equipment of lower reliability. Diversity may be of some benefit in all portions of the safety systems but generally the largest gains are achieved in particular areas as follows:

- Functional diversity by the sensing of two different variables.

- Equipment diversity offers protection against design, manufacturing and construction deficiencies as well as reducing the potential of cascading influences from other system, if carefully applied.

4. DISCUSSION OF WOLSONG DRIFT PROBLEMS

4.1 Consideration on Canadian Calibration Practices for as-found limits

The requirements of on-line test facility for CFT for the trip parameters in Programmable Digital Comparators (PDC) is specified, and SVT for the analogue trip parameters in Alarm Units becomes possible through modification of test facilities of SDS 1 & 2. However SVTs for instrumentation of ECCS and Containment System does not fully meet the Tech Spec surveillance requirements in Korea. The loop error was not specified for SVT and CT in any design documents. The drift check procedure with the as-found/ as-left technique or limiting drift value for determining further operability should have been specified in the uncertainty calculation for CT criteria and SVT. The on-line signal validation technique from transducers would be introduced for reducing the calibration efforts if they show a bad correlation. The idea for cross-calibration or signal validation technique can be found in the literatures [24] and CANDU reactors in CANADA. The on-line trip monitor computer on Darlington, Point Repreau and Gentily-2 NGS could be one of the modern cross-calibration techniques; now this monitoring facility is considering for Wolsong Units 2,3 & 4.

4.2 MAPS and Allowable Value

The Minimum Allowable Performance Standard (MAPS) are defined in the section 4.1.6 of R-8 [3] such that;

- If any component of a shutdown system is found to be inoperable, or impaired below its MAPS, that component and its associated equipment shall immediately be put in a safe condition.

This requirement is implemented in Tech Spec of the Special Safety Systems of Wolsong Units. MAPS is understandable as the analytical limits. There used to be a misunderstanding in the application for the Tech Spec definition between MAPS in CANADA-AECB R-8 [3] and the Allow Value in US-NRC Regulatory Position 4 of RG 1.105[5].

4.3. Discussion of the unexpected drift occurence

When the as-found value measured in SVT and CT exists between an Allowable Value and an analysis value, the plant operation or a transition from the Guaranteed Shutdown State is acceptable with an affected channel being declared inoperable, only if the channels be checked and reviewed for further operation according to the Tech Spec.

The Wolsong 2,3 & 4 Tech Spec already specify the Allowable Value for imitating the ACTION for declaring the inoperability. “The region where channel may be determined inoperable” in figure 1 [4] should be interpreted as Tech Spec description in the Surveillance Requirements (SR) & Limiting Conditions for Operation(LCO) and the Bases for LSSS. The plant staff should review for channel operability and put in inoperable if the drift in Allowable Value is confirmed according to the Tech Spec.The NRC Regulatory Position 4 of RG 1.105 [5] states in a same manner such that;

- The Allowable Value is the limiting value that the trip setpoint can have when tested periodically, beyond which the instrument channel is consider inoperable and corrective action must be taken in accordance with the Tech Spec.

- It should be noted that the conservative direction of as-found limits for SVT of Alarm Unit module rack and that for CT of transducer are opposite. For example, the pressure transmitter as-found limit for the High Reactor Building Pressure has a negative sign or decreasing magnitude but the alarm module rack setpoint as-found limit has a positive sign or increasing magnitude. This one-side conservatism should have been incorporated in the two independent Allowable Value in instrument uncertainty study for one transducer and connected alarm unit module rack drift.

The weekly on-power spread transmitter's signal check between SDS 1&2 SGLTs is a temporary remedial measure for monitoring the drift rate. The limit for spread check should be carefully specified because another uncertainty factors are included on an average value measured and calculated.

- The both side errors should be checked in order to decide the operability of the concerned transducers unless the recorded drift rate is constant. In this case, the total loop Allowable Values beyond the specified transducers' drift limit would be a maximum value for initiating a re-calibration. The drift rate would be another criteria for the transducers' operability.

The improvement of SVT facilities for SDS 1 & 2 have completed and that for ECCS & containments System should be studied in near future.

4.4 Regulatory Positions for Instrument Performance

The equipment diversity method for the defense against common mode failure was applied to the transmitters of shutdown system 2. They were different to SDS 1: manufacturers and measuring principles. However they had an unexpected drift problem with which the performance did not meet the Tech Spec SR. Section 7.2.1.1.3.4 of FSAR describes the reliability; SDS 1 shall have unavailability for each trip parameter of no more than 10^{-3} years per year. For design purpose, the division of allowed unavailability is as follows:

- Trip logic 1×10^{-4}
- Trip parameters 1×10^{-4}

Meeting the requirements for the reliability goal, the degradation of performance with respect to the unexpected drift of transmitters cannot be tolerated without any compensation of drift problem.

- The equipment diversity should not be justified unless the performance of components of the SDS 2 is equivalent to that of the SDS 1 or is shown within the as-found limit criteria specified by designers.

The regulatory positions for the problem was summarized as that [25];

- The existing uncertainty calculations should be confirmed with an "uncertainty methodology".
- The performance shown in environmental qualification test or drift rate should be within the as-found limit criteria in in-situ calibration procedures according to the uncertainty methodology decided,
- The equipment diversity should not be justified unless the performance of components of the SDS 2 is equivalent to that of the SDS 1 or is shown within the as-found limit criteria specified by designers.

- New facts or data of uncertainty calculation submitted by designers or by vendors in the proposed documents should be supported by environmental qualification test reports according to the relevant standards.

5. CONCLUSION

The problem of Wolsong SDS 2 transmitters was solved as disscued above such that;

- All the SDS2 transmitters of Wolsong Units 2,3 & 4 have been replacing with new one – same as SDS1.
- The CT frequencies of Special Safety System are readjusted to a every outage frequency until the new project will justify the extended frequency of CT.

Followings are issues to be solved through a research project.

- To confirms the statistical proof of using σ (standard deviation) data with weighting factor.
- Introduction of on-line monitoring techniques for validation of trip signals
- Turn-down factors of M&T E accuracies
- The qualified life of transmitters should be confirmed if the 10 year life would be extended with justification.

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