DONALD C. COOK NUCLEAR PLANT UNITS 1 & 2
SUMMARY REPORT FOR SYSTEM POWER QUALITY EVALUATION
REACTOR PROTECTION AND CONTROL SYSTEM REPLACEMENT PROJECT
REPORT NUMBER 2985-HEI-06, REV. 0

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1.0 PURPOSE

The purpose of this evaluation is to determine the impact of the Reactor Protection System (RPS) and Reactor Control System (RCS) hardware replacement project on the existing Class 1E Control Room Instrument Distribution (CRID) power supplies for the subject instrumentation and equipment. The existing RPS equipment is being replaced with an upgraded Foxboro "SPEC-200" system. The existing RCS equipment is being replaced with an upgraded Taylor "MOD-30" system. This evaluation will assess the impact of the following issues related to the power supply for the subject equipment replacement:

1) Adequacy of existing power supplies for replacement RPS and RCS equipment.

2) Inverter loading effects due to the RPS and RCS equipment replacement.

3) Inverter system aging evaluation.

4) Potential effects of the replacement RPS and RCS equipment on the power quality.

5) Summary of any necessary changes to accommodate the RPS and RCS equipment replacement.

2.0 SCOPE

The scope of this evaluation includes the CRID distribution panels, the CRID static inverter systems, the Isolimiter regulating transformers, the new Foxboro RPS equipment, the new Taylor RCS equipment, and the associated normal and alternate power feeds. The following is a summary of the issues addressed by this evaluation:

1) Analysis of existing power supplied for adequacy; i.e., Are the design operating limits of the existing CRID components compatible with the design operating limits of the new RPS and RCS hardware?

2) Inverter loading effects due to equipment replacement; i.e., What are the effects on normal (steady-state) and transient (inrush) loadings on the CRID inverters due to the RPS and RCS hardware replacements?

3) Inverter system aging evaluation; i.e., What aging analyses were performed to determine the qualified life of the inverter system and components?

4) Potential effects on the power quality due to the replacement equipment; i.e., What are the possible effects on waveform distortion, harmonic content and voltage regulation of the CRID system supply voltage and current due to the RPS and RCS hardware replacements?

5) Summary of design activities underway to address the remaining concerns; i.e., What CRID system upgrades are in progress due to the RPS and RCS hardware replacements?

3.0 INTRODUCTION

The D. C. Cook Units 1 and 2 Class 1E vital AC power supplies for the Reactor Protection System (RPS) and Reactor Control System (RCS) instrumentation consist of four separate distribution cabinets normally energized by four independent Class 1E static inverters. The four static inverters, manufactured by Solidstate Controls, Inc. (SCI), are identical units rated at 7.5 kVA, 118 VAC, 1ϕ nominal output. Each inverter supplies power to a dedicated 18 circuit 120 VAC 1ϕ distribution panel. The four independent inverter/distribution panel combinations are referred to as Control Room Instrument Distribution (CRID) cabinets I, II, III, and IV. Each CRID cabinet supplies power to an independent channel of RPS instrumentation and one of the four RCS hardware groups.

Each CRID cabinet can be powered from one of three independent power sources:

1) a 250 VDC Class 1E distribution cabinet feed; or
2) a 600 VAC/120 VAC regulating transformer powered from a Class 1E AC source; or
3) a 120/208 VAC non-Class 1E distribution panel feed.

Each of these three sources is described in more detail below.

CRID Cabinet I and II inverters are normally powered by a 250 VDC nominal feed from Class 1E DC distribution cabinet "MCCD" Circuits 11 and 12, respectively. CRID Cabinet III and IV inverters are normally powered by a 250 VDC nominal feed from Class 1E DC distribution cabinet "MCAB" Circuits 11 and 12, respectively. The two DC distribution cabinets are connected to independent Class 1E 250 VDC buses; each aligned to two battery chargers and one battery bank. The two full capacity battery chargers are operated with one charger in a normal active mode and the second charger in a standby mode. The battery chargers have a nominal float voltage setting of 260 VDC, a nominal equalizing voltage setting of 280 VDC, and are powered by 600 VAC feeds from Class 1E motor control centers (MCCs). The battery bank is a central power station-type design, utilizing 116 cells, and is sized to provide power to DC loads for the range of normal and emergency conditions including loss of normal station power and station blackout. This is the primary power source for the CRID cabinets, and the only Technical Specification controlled source.

3.0 INTRODUCTION (Continued)

Each CRID cabinet inverter has a dedicated alternate AC feed via independent regulating transformers. These transformers, manufactured by SCI and referred to as "Isolimiters", are single phase units nominally rated at 10 kVA with a 600 VAC primary winding and a 120 VAC secondary winding. The Isolimiters have a rated output of 83.3 Amperes. Each of the four Isolimiter units is powered by an independent 600 VAC feed from one of four independent Class 1E MCCs. The Isolimiters are operated in a standby mode, and are designed to power the CRID distribution panels via either an automatic static transfer switch or a manually-activated bypass switch.

The four CRID distribution panels may be powered by alternate 120/208 VAC feeds from Control Room Power AC Distribution Cabinet #3 (CRP-3). Panel CRP-3 is normally powered from plant Normal Lighting Distribution Cabinet "ABIE", and can be powered from an emergency feed from a Standby Lighting Cabinet. CRID panels I, II, III and IV are fed by CRP-3 branch circuits #9, #10, #13, and #14, respectively. The AC feeds from CRP-3 are normally open and are connected via mechanically interlocked circuit breakers in each CRID distribution panel. The CRP-3 AC feeds to the CRID cabinets are utilized only during maintenance activities when a static inverter and associated static transfer switch must be removed from service (References 4.7, 4.10, 4.11, 4.13).

4.0 REFERENCES

4.1 "Mild Environment Aging Analysis Report for 7.5 kVA Static Inverter for Solidstate Controls, Incorporated for Use in Donald C. Cook Nuclear Power Plant"; Wyle Laboratories Report No. 47612-01; January 03, 1985.

4.2 7.5 kVA Inverter Model SV25075/TS075NBA/TS075MB Instruction and Operating Manual; Solidstate Controls, Inc.; March 13, 1985.

4.3 7.5 kVA Static Inverter Test Report; Solidstate Controls, Inc. Test Report No. 23733-1; June 05, 1985.

4.4 7.5 kVA Static Inverter (CRID) Procurement Specification; Donald C. Cook Nuclear Plant Specification No. DCCEE-198-QCN; August 17, 1984.

4.5 10 kVA Isolimiter Model ISL12100 Instruction and Operating Manual; Solidstate Controls, Inc.; January 07, 1984.

4.6 "Donald C. Cook Nuclear Plant Control Room Instrumentation Rated Ambient Temperature Limits"; AEP Memorandum from G. P. Gurnow & J. D. Markham to H. W. Young; May 07, 1990.

4.7 "120/208V AC Control Room Instrument Distribution Cabinets "CRID-I" thru "CRID-IV" - Engineered Safety System"; AEP Drawing 1-12050-12; August 10, 1992.

4.8 "120/208V AC Main and Stand-By Lighting and Misc. Power System One-Line Diagram"; AEP Drawing 1-12099-0; September 23, 1991.

4.9 "120/208V AC Control Room Power Cabinets "CRP-1" thru "CRP-3" - 120/208V AC Rod Position Indication System"; AEP Drawing 1-12052-18; June 10, 1992.

4.10 "120/208V AC Main and Stand-By Lighting and Misc. Power System One-Line Diagram"; AEP Drawing 2-12099-0; September 23, 1991.

4.11 "120/208V AC Main and Stand-By Lighting and Misc. Power System One-Line Diagram"; AEP Drawing 12-12098-1; June 22, 1991.

4.12 "120/208V AC Control Room Power Cabinets "CCRP-1" thru "CCRP-3" - 120/208V AC Computer Power Supply System"; AEP Drawing 1-12051-21; January 15, 1992.

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4.14 "AC and DC Distribution CCV-CD Wiring Diagram; Sheet No. 1"; AEP Drawing 2-92089-44; October 14, 1991.

4.15 "AC and DC Distribution CCV-AB Wiring Diagram; Sheet No. 2"; AEP Drawing 2-92090-49; October 14, 1991.

4.16 "15V DC Multinest Power Supply - 2ARPS05 Series, Style A"; The Foxboro Company Bulletin 2AR-103; August, 1990.

4.17 "75V DC Multiloop Power Supplies - Part Numbers P0300CQ and PF100AX"; The Foxboro Company Bulletin 018-180; May, 1985.

4.18 Donald C. Cook Units 1 and 2 Final Safety Analysis Report (FSAR) Chapters 7 and 8.

4.19 "Power Distribution Drawing - Protection Set I, Rack 1"; The Foxboro Company Drawing No. 92F12687-PWR-2101 Revision 0; August, 1992.

4.20 "Power Distribution Drawing - Protection Set I, Rack 2"; The Foxboro Company Drawing No. 92F12687-PWR-2102 Revision 0; August, 1992.

4.21 "Power Distribution Drawing - Protection Set I, Rack 1"; The Foxboro Company Drawing No. 92F12687-PWR-2103 Revision 0; August, 1992.

4.22 "Power Distribution Drawing - Protection Set I, Rack 2"; The Foxboro Company Drawing No. 92F12687-PWR-2104 Revision 0; August, 1992.

4.23 "CRID Loadings", B. Sotos, AEPSC telecopy to K. Melson, Hurst Engineering, Inc.; 10/28/92.

4.24 "Reactor Protection Channel I "RPC I" Cab I Wiring Diagram"; AEP Drawing No. PS1-92431-1; June 16, 1988.

4.25 "Terminal Block Wiring Diagram Rack 1 - D. C. Cook Nuclear Power Plant Unit 1 & 2 Reactor Protection System"; The Foxboro Company Drawing No. 0-20375-PW-1; January 22, 1971.

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4.26 "Instruction Manual for Regulated Power Supplies - LMS-6000 Series"; Lambda Electronics Manual No. IM-LMS-6000.

4.27 "Instruction Manual for Regulated Power Supplies - LMS-9000 Series"; Lambda Electronics Manual No. IM-LMS-9000.

4.28 "Instruction Manual for Regulated Power Supplies - LRS-57 Series"; Lambda Electronics Manual No. IM-LRS-57.

4.29 "Failure of Power Bus Indicating Light Results in Reactor Trip Due to Partial Loss of Power Bus"; D. C. Cook Nuclear Plant Unit 1 Licensee Event Report (LER) 88-011; November 16, 1988.

4.30 "Reactor Protection System Actuation Due to Malfunction of Control Room Instrument Distribution Inverter", D. C. Cook Nuclear Plant Unit 2 Licensee Event Report (LER) 89-014; September 13, 1989.

4.31 D. C. Cook Unit 2 Problem Report (PR) 86-014; October 13, 1986.

4.32 D. C. Cook Unit 1 Problem Report (PR) 87-139; February 23, 1987.

4.33 D. C. Cook Unit 1 Problem Report (PR) 88-044; February 01, 1988.

4.34 D. C. Cook Unit 2 Problem Report (PR) 88-673; September 20, 1988.

4.35 D. C. Cook Unit 1 Problem Report (PR) 88-750; October 19, 1988.

4.36 D. C. Cook Unit 1 Problem Report (PR) 89-720; June 03, 1989.

4.37 D. C. Cook Unit 2 Problem Report (PR) 89-946; August 14, 1989.

4.38 D. C. Cook Unit 2 Problem Report (PR) 89-1355; December 16, 1989.

4.39 D. C. Cook Unit 2 Problem Report (PR) 90-1006; August 07, 1990.

4.40 D. C. Cook Unit 1 Problem Report (PR) 90-1041; August 13, 1990.

4.0 REFERENCES (Continued)

4.41 "Advantages of Ferroresonant Inverters"; James J. Yearsin, Development Engineering Supervisor: Solidstate Controls, Inc.

4.42 "New Current Sensing Scheme for Static Transfer Switches"; James J. Yearsin, Development Engineering Supervisor: Solidstate Controls, Inc.

4.43 "CRID Inverter Performance Review"; AEPSC Memorandum from R.C. Steele to M.F. Boyle; #RFC-12-2985; November 12, 1992.

5.0 EVALUATION

5.1 INVERTER LOADING EVALUATION

The purpose of this evaluation is to determine the effect of the RPS and RCS equipment replacement on the steady-state and transient power loadings of the CRID inverters. This evaluation utilizes actual steady-state current measurements on the existing RPS and RCS equipment and CRID inverters, anticipated steady-state current values for the replacement RPS and RCS equipment, and design maximum inrush values for the replacement RPS and RCS power supplies.

Each of the replacement RPS protection set channels consists of two to four separate equipment racks. RPS Channels I and II utilize four rack assemblies each; RPS Channel III utilizes three rack assemblies; and RPS Channel IV utilizes two rack assemblies. The power supplies utilized are Foxboro Model N-2ARPS05-A6 ±15 VDC and Foxboro Model P0300CQ +75VDC supply. The former power supply provides DC power to the RPS process control electronics, and has a nameplate power consumption of 550 VA. The latter power supply provides DC power to the 10-50 mA transmitters, and has a nameplate power consumption of 260 VA. Each RPS channel utilizes a design which provides one extra power supply of each voltage class than is required to provide equipment power. The channels with four rack assemblies utilize four of the ±15 VDC supplies and three of the +75 VDC supplies (References 4.16, 4.17, 4.19, 4.20, 4.21, 4.22).

Each of the replacement RCS control groups is assembled from a series of rack units, with two to four racks utilized for each RCS control group. The first rack of each group contains two redundant Lambda Model LRS-57 diode-auctioneered 24 VDC power supplies with a nameplate power consumption of 1050 W each. The last rack of each channel contains two redundant Lambda Model LMS-9000 diode-auctioneered power supplies adjusted to 80 VDC output with a nameplate power consumption of 1100 W. The former power supply provides power to the RCS process control electronics, and the latter power supply provides power to the 10-50 mA transmitters associated with the RCS (References 4.25, 4.27, 4.28).

In accordance with D. C. Cook design practices, the inrush current of the equipment associated with each RPS group is limited by design specification to a value of 50 amperes maximum. Preliminary testing has revealed that the Foxboro protection group inrush values would exceed the 50 ampere limit in the configuration proposed by the vendor. The Taylor control group inrush values are acceptable as designed.

5.1 INVERTER LOADING EVALUATION (Continued)

The following is a tabulation of the power feed information associated with the four CRID distribution cabinets (References 4.2, 4.7, 4.9, 4.13):

	CRID I	CRID II	CRID III	CRID IV
250 VDC INVERTER FEED	MCCD Circuit 11	MCCD Circuit 12	MCAB Circuit 11	MCAB Circuit 12
600 VAC ISOLIMITER FEED	MCC 1-EZC-C Cubicle 5AR	MCC 1-EZC-D Cubicle 1AL	MCC 1-EZC-A Cubicle 5AR	MCC 1-EZC-B Cubicle 1AL
120 VAC CRID DIST. PANEL FEED	CRP-3 Circuit 9	CRP-3 Circuit 10	CRP-3 Circuit 13	CRP-3 Circuit 14
120 VAC ISOLIMITER FEED TO STS	Inverter CB-4	Inverter CB-4	Inverter CB-4	Inverter CB-4
118 VAC INVERTER FEED TO STS	Inverter CB-2	Inverter CB-2	Inverter CB-2	Inverter CB-2
120 VAC CRID PANEL FEED TO RPS EQUIPMENT	CRID Dist Panel Circuit 3	CRID Dist Panel Circuit 3	CRID Dist Panel Circuit 3	CRID Dist Panel Circuit 3
120 VAC CRID PANEL FEED TO RCS EQUIPMENT	CRID Dist Panel Circuit 4	CRID Dist Panel Circuit 4	CRID Dist Panel Circuit 4	CRID Dist Panel Circuit 4

Note: Unit 2 power feeds are correspondingly numbered.

The power consumption of each existing and replacement RPS and RCS process control instrument rack has been determined by empirical measurement of the present equipment installed at D.C. Cook and by estimation for the replacement equipment (Reference 4.23). The power consumption measurements include design specified maximum peak inrush values as well as calculated steady-state values, and assume all loads are at equivalent power factor. These measurements are tabulated on the following page.

5.1 INVERTER LOADING EVALUATION (Continued)

	CRID I	CRID II	CRID III	CRID IV
(1) PRESENT INVERTER SS LOAD (A)	26	32	26	26
(2) PRESENT INVERTER SS LOAD (%)	41.27	50.79	41.27	41.27
(3) PRESENT RPS SS LOAD (A)	9.4	10.4	5.9	4.0
(4) PRESENT RCS SS LOAD (A)	6.4	6.1	3.6	7.8
(5) EXPECTED RPS SS LOAD (A)	9	10	8	5
(6) EXPECTED RCS SS LOAD (A)	12	11	8	15
(7) NET CRID SS LOAD CHANGE (A) (5+6)-(3+4)	5.20	4.50	6.50	8.20
(8) EXPECTED INVERTER SS LOAD (A) (1+7)	31.20	36.50	32.50	34.20
(9) EXPECTED INVERTER SS LOAD (%)	49.52	57.94	51.59	54.29
(10) RPS & RCS MAXIMUM INRUSH (A)	50	50	50	50
(11) EXPECTED INVERTER TRANSIENT LOAD (A) ((10/√2)+8-6) (RCS Loaded Last)	54.56	60.86	59.86	54.56
(12) EXPECTED INVERTER TRANSIENT LOAD (A) ((10/√2)+8-5) (RPS Loaded Last)	57.56	61.86	59.86	64.56

The tabulation demonstrates that the inverter steady state loadings increase from a maximum present nominal load of 50.79% to a maximum expected nominal load of 57.94%. The anticipated loading values are well within the design rating of the inverter and should present no problem for steady state CRID system operation.

The expected RCS equipment steady state currents for CRID I and CRID IV and the expected RPS equipment steady state current for CRID I meet or exceed 80% of the nominal 15 A branch circuit breaker ratings in D. C. Cook Unit 1 (Unit 2 CRID panels utilize 20 A branch circuit breakers). We plan to replace these 15 A breakers with 20 A breakers to prevent nuisance tripping. Branch circuit power cables for these two circuits are adequate as installed.

The power supplies being provided for the replacement RPS equipment have demonstrated inrush values in the 70 ampere range. Foxboro is presently considering design options to limit the inrush to the 50 ampere peak value specified. The inrush issue is expected to be resolved for the Foxboro RPS equipment by utilization of a current limiting circuit. The power supplies being provided for the replacement RCS equipment already incorporate current limiting circuits for startup to limit inrush to acceptable values. The steady state loading of both the RPS and RCS power supplies has been demonstrated to meet the design specification requirements.

Based on the 50 ampere specified maximum inrush, the worst case transient inverter loading is well below the 120% full load rms current limit setpoint, and the 300% peak current limit setpoint, of the inverter static transfer switch (References 4.2, 4.42). The duration of the inrush current also has substantial significance. As noted in Section 5.3 of this evaluation, the static transfer switch will not actuate for loads which exceed the setpoint for less than ¼ cycle. Thus, if the inrush peak falls below the transfer switch setpoint within 4 ms, the potential for a nuisance transfer to the alternate source is minimized.

5.2 INVERTER SYSTEM AGING EVALUATION

The purpose of this evaluation is to discuss aging analyses and qualified life of the inverter system components.

The mild environment aging analysis described in Reference 4.1 was performed at a maximum assumed ambient temperature of 50°C. Heat rise values have been added to the aging temperatures of the applicable safety-related inverter components. It was determined that the SCI 7.5 kVA inverter is age-insensitive over its 40 year qualified life, with the exception of two component types:

1) The nylon strain relief bushing protecting wiring entering the inverter housing.

2) The various electrolytic capacitors utilized in the inverter circuitry.

The SCI inverter test program, described in Reference 4.3, includes inverter temperature measurements after continuous full load operation of 100 hours duration at a nominal ambient temperature of 40°C. None of the age-sensitive components determined by the Reference 4.1 analyses reached the 50°C design temperature, and no age-sensitive components failed during the test. The CRID inverter systems are installed in an Auxiliary Building location provided with safety-related HVAC systems which maintain the normal area ambient temperature below 40°C. These HVAC systems are sized to accommodate the heat dissipation resulting from rated inverter loading.

The D. C. Cook CRID inverter systems manufactured by SCI were installed in 1985 as a part of a general vital AC system upgrade. Part of the justification for this upgrade was sizing of the SCI inverters to accommodate future load growth (such as the subject RPS and RCS equipment replacement) and reduction of the CRID system operating equipment temperatures. The inverter current increases due to the RPS and RCS equipment replacements result in loadings well within the design operating limits of the SCI inverter units. Therefore, the inverter operating temperatures are expected to be significantly less than the design basis temperatures utilized in the aging analysis of Reference 4.1 and the design testing program reported in Reference 4.3. The inverter maintenance instructions of Reference 4.2 include specific criteria for inspection and replacement of age-sensitive components. These guidelines were determined by the component manufacturer recommendations and the aging analysis recommendations of Reference 4.1.

On the basis of the information presented above, the CRID inverter loading increases resulting from the RPS and RCS equipment replacements are considered to have already been enveloped by the design qualified life of the CRID inverter system.

5.3 POWER QUALITY EVALUATION

The purpose of this evaluation is to analyze the adequacy of the existing CRID power system design operating limits with the design operating limits of the new RPS and RCS equipment. This evaluation is performed by review and comparison of the operating specifications, characteristics and histories of the existing CRID components with the operating specifications of the new RPS and RCS equipment.

A general description of the CRID power system configuration and alternate power sources is provided in Section 3.0 of this report. The following is a description of the operation of the CRID power distribution system.

The CRID cabinets are normally powered via the nominal 250 VDC feed to the static inverter inputs. The operation of each 250 VDC bus is supported by full capacity battery chargers, which carry the normal steady state bus loads. The battery bank associated with each DC bus will maintain that bus in an operable state in the event of a battery charger malfunction. Should a loss of normal station power occur, the batteries are sized to maintain the DC buses in a operable condition until the battery chargers are re-energized via the Class 1E emergency diesel generators.

The DC buses are the preferred power source for the CRID system during normal plant operation, loss of normal station power and postulated station accident conditions. Should a failure of the static inverter or its associated DC bus occur, the CRID distribution panel would be automatically energized by the Isolimiter regulating transformer via the static transfer switch. The CRID distribution panel can be manually realigned to either the Isolimiter via the manual transfer switch, or by the CRP-3 panel feed via the mechanically interlocked CRID distribution panel breaker (Reference 4.18).

Each CRID inverter is supplied with a static transfer switch (STS) which is designed to provide an automatic transfer to an alternate power source in the event of inverter malfunction or a downstream fault condition. The STS provides a virtual zero time transfer for any of the following conditions:

1) Degradation of the inverter square wave output waveform

2) Degradation of the ferroresonant filter sinusoidal output waveform

3) A downstream bus or branch circuit fault condition

4) A downstream sustained overload condition exceeding the maximum current output capacity by a fixed percentage

The primary purpose of the STS is to provide automatic transfer of the CRID distribution loads to a reliable regulated backup supply in the event of an inverter output failure. The secondary purpose of the STS is to provide increased fault "ride-through" capability in the event of a CRID load fault. The STS assembly can initiate a transfer by either of two methods (Reference 4.2, 4.42):

1) A steady-state level detector senses a full-wave rectified (averaged) inverter output over a 2 millisecond (ms) interval. If the inverter output exceeds the designated setpoint for 2 ms, a 2 ms timing circuit is initiated and the automatic transfer will be completed within ¼ cycle. If the inverter output drops below the setpoint during the 2 ms timing interval, the timer will reset and no transfer will occur. The steady state level detector is set at 120% of rated inverter output and protects the inverter against overload conditions. This is a factory setting which is adjustable from 100% to 150% of full load.

2) A peak level detector, which is calibrated to initiate automatic transfer within 1 μs. The peak level detector serves to protect the inverter from downstream fault conditions, and is adjustable in a range from 300% to 375%.

Following a STS automatic transfer, the STS is designed to automatically transfer back from the alternate source to the preferred source, should the condition that initiated the original transfer clear. This has been designed as a one shot transfer to assure adequate surveillance of the STS, and requires manual reset operated by a plant operator.

The load may also be manually transferred from the inverter to the alternate source, or from the alternate source to the inverter, via the STS. However, should a manual transfer from the alternate source to the inverter be performed while an abnormal condition exists, the STS is designed to automatically transfer back to the alternate source (Reference 4.2).

The following is a discussion of the history of the performance of the CRID power system at D. C. Cook Units 1 and 2. This history is developed utilizing past Licensee Event Reports (LERs) and Problem Reports (PRs). The D. C. Cook Unit 1 history includes one applicable LER and five applicable PRs. The D. C. Cook Unit 2 history includes one applicable LER and five applicable PRs. The following is a brief summary of each LER and PR.

1) LER 88-011/PR 88-750: This event occurred in D. C. Cook Unit 1 on October 19, 1988. An indicating light and socket for the Train B SSPS power indication shorted out, causing loss of power to the SSPS bay. The loss of power caused dropout of a relay monitoring RCP #11 breaker position. The 1/4 coincidence logic associated with loss of RCP flow above 50% reactor power resulted in a reactor trip.

The CRID I inverter transferred from its normal to alternate power supply, which is the expected action of the transfer switch during a downstream fault. The CRID II inverter had a momentary abnormal condition alarm, attributed to low voltage during starting of the auxiliary DC lube oil pumps. The incident was attributed to the isolated electrical failure of the SSPS light socket assembly, and did not involve the CRID inverter or associated hardware, which performed per design (References 4.29, 4.35).

2) LER 8-014/PR 89-946: This event occurred in D. C. Cook Unit 2 on August 14, 1989. The control power fuse for Nuclear Instrumentation channel N-44 opened, and the CRID IV inverter STS transferred from its normal to alternate power source. Operations personnel attempted to manually transfer the CRID IV system back to its preferred source. The system transferred on the second manual attempt, and a reactor trip subsequently occurred.

The incident was attributed to the random mechanical failure of one of the CRID IV static transfer switch SCRs. Failure of the SCR allowed sufficient voltage for transfers to occur, but insufficient CRID system operating voltages, which resulted in an undervoltage condition on the CRID IV distribution system. The reactor trip was attributed to the dropout of the breaker position indication monitoring relay for RCP #24. The 1/4 coincidence logic associated with loss of RCP flow above 50% reactor power resulted in the reactor trip. This is the only recorded failure of a STS. The CRID inverter functioned as designed throughout the event sequence (References 4.30, 4.37).

3) PR 86-014: This event occurred in D. C. Cook Unit 2 on October 13, 1986. The CRID II inverter transferred from its normal source to the alternate source due to an undetermined cause. The inverter was transferred back to the normal source without incident (Reference 4.31).

4) PR 87-139: This event occurred in D. C. Cook Unit 1 on February 23, 1987. A design review determined that the CRID inverter cubicle ventilation supply fans were not interlocked to shut down upon actuation of the CO_2 fire suppression system. This condition could have resulted in dilution of the CO_2 concentrations, thus impairing the ability to extinguish a smoldering fire. The supply fan interlock was subsequently added to the Unit 1 design (Reference 4.32).

5) PR 88-044: This event occurred in D. C. Cook Unit 1 on February 01, 1988. The CRID I inverter transferred from its normal source to the alternate source due to a personnel error during calibration of a Boric Acid Storage Tank temperature transmitter. The technician inadvertently lifted and grounded a lead connected to the CRID 120 VAC supply. The incident was subsequently utilized as "lessons learned" training for plant maintenance technicians (Reference 4.33).

6) PR 88-673: This event occurred in D. C. Cook Unit 2 on September 20, 1988. The CRID IV inverter transferred from its normal source to the alternate source due to an undetermined cause. The inverter was transferred back to the normal source without incident (Reference 4.34).

7) PR 89-720: This event occurred in D. C. Cook Unit 1 on June 03, 1989. The CRID I inverter transferred from its normal source to the alternate source due to a personnel error during re-installation of a flow transmitter in the Boric Acid Storage Tank room. The transmitter power leads were incorrectly terminated and resulted in inadvertent grounding of the CRID power supply. The wiring terminations were corrected and the CRID I inverter transferred back to its normal source without incident (Reference 4.36).

8) PR 89-1355: This event occurred in D. C. Cook Unit 2 on December 16, 1989. The CRID III inverter transferred from its normal source to the alternate source during troubleshooting activities on a sample flow gauge. An electrical jumper wire detached from a loose terminal crimp and momentarily grounded the CRID power supply. The jumper wire was properly re-terminated and the CRID transferred back to the normal source without further incident (Reference 4.38).

9) PR 90-1006: This event occurred in D. C. Cook Unit 2 on August 07, 1990. A terminal block normally attached to the alternate source input breaker for the CRID I static transfer switch was found detached from its mounting surface. No abnormal system operation occurred, and the terminal block was subsequently re-glued to the breaker case by the inverter vendor (Reference 4.39).

10) PR 90-1041: This event occurred in D. C. Cook Unit 1 on August 13, 1990. A terminal block normally attached to the alternate source input breaker for the CRID I static transfer switch was found detached from its mounting surface. No abnormal system operation occurred, and the terminal block was subsequently re-glued to the breaker case by the inverter vendor (Reference 4.40).

The LER and PR review reveals only one significant component failure associated with the CRID inverter system, which was the static transfer switch SCR failure. This incident was attributed to a random mechanical failure of the SCR gate lead connection. The majority of the events associated with the CRID system involve inadvertent transfers from the normal power source to the alternate source. These events were typically the result of relatively minor short circuits in the equipment or circuits fed from the CRID cabinets. These events demonstrate the inherent current limiting of the CRID inverter design.

The following is a tabulation of the applicable input and output specifications of the 120 VAC vital power system components (References 4.2, 4.4, 4.5, 4.16, 4.17, 4.27, 4.28):

SOURCE COMPONENT	OUTPUT SPECIFICATIONS
CRID INVERTER (SCI Model SV25075)	Voltage: 118 VAC +2, -3% Frequency: 60 Hz ± 0.5 Hz Power: 7.5 kVA Power Factor: 0.8 - 1.0
ISOLIMITER (SCI Model ISL12100)	Voltage: 120 VAC ± 2% 2 - 2.5% taps above & below Frequency: 60 Hz, 1φ Power: 10 kVA Current: 83.3 Amperes maximum
LOAD COMPONENT	**INPUT SPECIFICATIONS**
RPS ±15 VDC POWER SUPPLY (Foxboro Model N-2ARPS05-A6)	Voltage: 120 VAC +10%/-15% Frequency: 60 Hz +3/-13 Hz Power: 550 VA
RPS +75 VDC POWER SUPPLY (Foxboro Model P0300CQ)	Voltage: 120 VAC +10%/-15% Frequency: 60 Hz ± 0.5 Hz Power: 260 VA
RCS +24 VDC POWER SUPPLY (Lambda Model LRS-57)	Voltage: 85 VAC - 132 VAC Frequency: 47 Hz - 63 Hz Power: 1050 W
RCS +80 VDC POWER SUPPLY (Lambda Model LMS-9000)	Voltage: 95 VAC - 132 VAC Frequency: 47 Hz - 63 Hz Power: 1100 W

It is noted that no equipment incompatibility is apparent from a comparison of the applicable operating specifications.

The CRID inverter test report (Reference 4.3) includes test data measuring the output harmonic content of the static inverter. Test data was recorded for two different test cases:

1) 40°C ambient, 260 VDC input, 100% load, 0.802 PF
2) Normal ambient, 280 VDC input, 100% load (no PF specified)

Harmonic measurements included individual measurements of the 3rd, 5th, 7th, 9th, 11th and 13th harmonics, and a calculated overall harmonic content. The maximum overall harmonic content was 3.04% for Case 1 and 3.83% for Case 2. These values appear reasonable, as the inverter circuitry initially generates a square wave output, which will have a high harmonic content, and then uses a wave-shaping circuit to convert the square wave output to a sinusoidal waveform.

The CRID inverter output provides a regulated 118 VAC +2, -3%, which equates to a normal operating voltage range of 114.46 VAC - 120.36 VAC (Reference 4.2). The CRID Isolimiter output provides a regulated 120 VAC ± 2%, which equates to a normal operating voltage range of 117.60 VAC - 122.4 VAC (Reference 4.5). Both of these operating ranges are well within the design input specifications of the replacement RPS and RCS equipment power supplies. The CRID system components are properly designed to meet these voltage regulation criteria during normal power production, loss of normal station power and postulated accident modes of operation. The CRID inverter input voltage range of 210 - 290 VDC envelops the maximum DC battery charger equalize voltage setting and the minimum design DC battery operating voltage at the end of discharge cycle. On this basis, the RPS and RCS equipment replacements will not appreciably impact the voltage regulation of the CRID system.

The input power specification requirements for the replacement Foxboro RPS power supplies and the replacement Taylor/Lambda RCS power supplies are provided in the previous tabulation. The quality of the input power provided by the CRID system is well within the specified limits of the replacement RPS and RCS power supplies. It is noted that the CRID distribution system is contained within the confines of the plant structures, and thus is inherently less susceptible to RFI pickup from external sources, EMI pickup from high voltage sources (such as switchyard voltages), and transient overvoltages due to lightning strikes. The voltage regulation capabilities of the SCI inverters and Isolimiters during input surge testing, as documented in References 4.2, 4.3, 4.5 and 4.41, demonstrate the ability of the CRID system power supplies to provide a regulated instrumentation-quality power source for the associated CRID system loads.

5.3 POWER QUALITY EVALUATION (Continued)

The CRID inverters provide a regulated output voltage of 118 VAC +2, -3% to a load that is characteristically made up of instrument power supplies and solenoid valves. Power supply inrush accounts for the principal transient initiators on the system. Taking into account the inverter voltage specification (118 VAC +2, -3%) and the voltage drop between the inverter and the distribution panel, the minimum voltage will be 109.4 VAC at 100% load, and approximately 108 VAC at 120% load. The maximum voltage at the distribution panel will be 120.36 VAC, corresponding to the condition where the inverters are unloaded.

On the basis of the preceding discussions, it is concluded that the existing CRID system produces a high quality regulated 120 VAC output which is more than adequate to meet the input power requirements of the replacement RPS and RCS equipment.

5.4 POTENTIAL EFFECTS ON POWER SYSTEM QUALITY

The purpose of this evaluation is to determine the potential effects on the power quality due to the replacement RPS and RCS equipment. Specific topics addressed include possible effects on voltage and current waveform distortion, harmonic content and voltage regulation of the CRID system supply voltage due to the replacement equipment. This is a qualitative evaluation utilizing engineering judgement to determine the impacts of the possible effects.

The primary source of distortion on the CRID power system resulting from the RPS and RCS equipment replacement would be from the DC power supplies provided with the replacement equipment. Power supplies may appear as a non-linear load with a substantially distorted waveform to the CRID power system. Switching DC power supplies are generally the source of such phenomena.

The RPS equipment replacement utilizes Foxboro DC power supplies which are of the series-regulated (±15 VDC supply) and ferroresonant (+75 VDC supply) type (References 4.16, 4.17). Series-regulated power supplies use a series transistor in the output, with a sensing circuit which monitors and adjusts the output voltage. These supplies generally have excellent line and load regulation, very little ripple, and are typically highly reliable. Ferroresonant power supplies use a resonant inductive-capacitive circuit in the output which resonates at line frequency, thus saturating the transformer core for a portion of each input power cycle. These supplies are typically highly reliable but have only moderate load regulation ability, and are normally used in applications where precise voltage regulation is not a necessity and input frequency is relatively constant. The ferroresonant supplies require tuning and produce a clipped and rectified AC waveform output.

The RCS equipment replacement utilizes Lambda DC power supplies which are of the switching type (References 4.26, 4.27. 4.28). Switching power supplies also utilize a series transistor output, but in this case the transistor is rapidly turned off and on, resulting in a chopped DC waveform typically in the 20 kHz range. The chopped DC is converted to high frequency AC via a transformer, then rectified by a bridge rectifier circuit. These power supplies can produce a highly non-linear waveform with a high crest factor or high relative peak currents. High harmonic currents and common mode noise can also be encountered when utilizing switching power supplies. These factors can potentially affect the operation of an inverter static transfer switch. The information of References 4.41 and 4.42 provide a detailed discussion of the SCI transfer switch circuitry design which accommodates such possibilities.

5.4 POTENTIAL EFFECTS ON POWER SYSTEM QUALITY (Continued)

The SCI ferroresonant inverter design provides excellent support for the subject non-linear loads. The inverter magnetics and active third harmonic filter are intentionally oversized to accommodate this type of application. The 7.5 kVA-rated has magnetics that can support a continuous rating of 7.5 kW. The third harmonic filter, while not specifically rated, has proven capable of supporting very large load current harmonics without sustaining significant waveform distortion or derating the inverter. Conversations with SCI personnel alluded to previous tests conducted with Foxboro equipment. The SCI 7.5 kVA inverter design had been applied to a load consisting substantially of Foxboro power supplies, presumably of similar if not identical design to those utilized by the subject RPS equipment upgrade. This test revealed no indication of operational limitations of the subject inverter. Additional investigation with Foxboro is in progress to determine the relevance of this test data to the subject RPS equipment upgrade.

AEPSC has conducted independent load tests, utilizing the non-linear Lambda switching power supplies, powered from 0.5 kVA and 2.7 kVA inverters of ferroresonant design. In both load tests, the current waveforms were essentially identical to those observed when the power supplies were powered from the normal building lighting cabinet feeds. The voltage waveforms were not significantly different from that observed with the power supplies powered from the normal building lighting cabinet feeds.

The power supplies associated with the RPS and RCS equipment upgrades normally have relatively large inrush characteristics, which has prompted discussions with SCI regarding design features of the inverter which accommodate inrush.

The SCI inverter accommodates inrush by providing a circuit that discriminates between inrush current and fault current, as noted in Section 5.3 of this evaluation. This circuitry delays the normal sustained current limiter for approximately ½ cycle, and substitutes a limiter that senses currents in the order of 300% peak, which operates in less than ¼ cycle. The peak value is 300% in peak amperes, based on the inverter rating in rms amperes with the sustained current limiter set at 120% of full load rms, and increases linearly with the sustained current limiter setting. Field testing of the SCI inverters has demonstrated that power supply inrush seldom, if ever, exceeds the peak current limit in actual applications. This is attributed to the combined effects of the power supply charging characteristics and the inverter magnetics characteristics.

5.4 POTENTIAL EFFECTS ON POWER SYSTEM QUALITY (Continued)

Review of the test data noted above determined that peak current detection does not present a significant concern for unnecessary static switch transfers on power supply energization. However, the sustained nature of the power supply energization transient could result in operation of the inverter's sustained current limit circuitry. Per D. C. Cook design methodology, inverter sustained current limit results in STS transfer of the CRID distribution loads to the alternate source supplied by the Isolimiter regulating transformer. This transfer operation is perfectly normal for this inverter design and does not create a challenge for the inverter or STS circuitry. However, the D. C. Cook plant design, which intentionally guards against STS failure, utilizes a design feature to limit the number of automatic transfers between the inverter and Isolimiter. Once the STS has transferred, plant operator action is required to reset the transfer permissive and allow future automatic transfers. Inadvertent inverter transfer on CRID load energization is considered a nuisance to be avoided, if possible, for human factors considerations.

The Lambda power supplies utilized by the replacement RCS equipment utilize automatic inrush current limiting circuits incorporated into the power supply design. Thus, inverter current limiting will not occur upon RCS equipment energization. The Foxboro power supplies utilized by the replacement RPS equipment do not utilize internal current limiting, and have demonstrated peak inrush values in excess of the specified 50 ampere maximum. As noted in Section 5.1 of this evaluation, investigations are in progress to limit the Foxboro power supply inrush values to within the design specification, and thus minimize the potential for inverter current limiting on RPS equipment energization.

6.0 SUMMARY AND CONCLUSIONS

This evaluation has assessed the impact of the Reactor Protection System (RPS) and Reactor Control System (RCS) hardware replacement project on the existing Class 1E Control Room Instrument Distribution (CRID) power supplies. This evaluation has evaluated the adequacy of existing power supplies, effects on inverter loading, inverter system aging, and potential effects on power quality. All equipment design parameters considered by this review are or will be maintained within the bounds of the applicable design specifications and acceptance criteria.

In conclusion, the CRID power system is considered adequate to provide the input power requirements for the replacement RPS and RCS equipment with minor impact on the existing system design and operation. The one outstanding item which is presently being factored into the detailed design is the limitation of power supply inrush values for the new RPS power supplies to acceptable levels to minimize the potential for nuisance actuation of the inverter static transfer switch.

7.0 APPROVALS

Prepared By — Date: 11/18/92

Reviewed By — Date: 11/18/92

Approved By — Date: 11/20/92