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Conceptual design of emergency communication system to cope with severe accidents in NPPs and its performance evaluation

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ABSTRACT

The Fukushima accident induced by the great earthquake and tsunami reveals the vulnerability of I&C System. In the severe environment, the normal I&C system did not work properly and results in false information about the internal situation in NPP. Eventually the accident was not properly handled at the early stage. Therefore advanced emergency response system using a wireless channel is necessary to cope with the severe accident. In this paper, we introduce the ERS consisting of the HMS and MCS the ECS linking the HMS with MCS and the performance requirement of the ECS is analyzed. The ECS satisfying the requirement is designed conceptually and the performance of the ECS is evaluated through analysis and simulator. To secure a reliable and diverse configuration, the ECS is configured as the dual system which consists of the terrestrial communication and satellite communication. The terrestrial communication system is designed based on the IEEE 802.11. Analyzed performance results prove that the performance requirement can be sufficiently achieved. But if the scalability of data capacity is considered later, use of the advanced 802.11 standard such as 802.11n and multiple signal paths between the HMS and MCS are necessary. In the satellite communication system, the FDMA is used in the status link and the DSSS is used in the control link. The network supporting various data rates is designed and the communication link budget is analyzed considering the link availability of 99%. The designed satellite communication system can secure the link margin of 1.3 – 15.7 dB.

1. Introduction

Recently the station blackout accident induced by the great earthquake and tsunami occurred at the Fukushima Daiichi plant in Japan. This result in the loss of emergency cooling system then a hydrogen explosion occurred within the containment buildings. The plants had begun releasing substantial amount of radioactive materials (The National Diet of Japan, 2012; Tokyo Electric Power Company, 2012; EPRI, 2012; IAEA, 2011).

In view of I&C system, one reason that the accident was not controlled at the early stage is that the critical parameters such as a reactor water level was not monitored exactly. Most of I&C equipment were not working or malfunctioned due to the power blackout and accident damage. Although an emergency response facility is placed near the plants (U.S. NRC, 1981), it was impossible to utilize this facility because the region including this facility within 30 km radius of the site had been evacuation. These situations related to Fukushima accident clearly show the necessity of the novel concept about emergency response system to cope with the severe accident. The ERS we are going to design conceptually

Abbreviations: A/D, analog/digital; BER, bit error rate; BPSK, binary phase shift keying; BSS, Basic Service Set; BW, band width; C/N, carrier to noise ratio; CCW, component cooling water; CCWS, CCW system; CTMT, containment; DSSS, Direct Sequence Spread Spectrum; DTED, digital terrain elevation data; ECS, emergency communication system; EIRP, effective iso-tropically radiated power; EMP, electromagnetic pulse; ERS, emergency response system; FDMA, Frequency Division Multiple Access; FEC, forward error correction; FWS, feed water system; HMS, hardened monitoring system; Hx, heat exchanger; I&C, instrumentation and control; I/C, instrumentation parameters/control parameters; ISM, industry science and medical; LOS, line of sight; MCR, main control room; MCS, mobile control station; MODEM, modulator and demodulator; MSSS, main stream supply system; NPP, nuclear power plant; PER, packet error rate; PORV, pilot operated relief valve; PSV, pressurizer safety valve; PWR, pressurized light-water reactor; PZR, Pressurizer; QAM, quadrature amplitude modulation; QPSK, quadrature phase shift keying; RCP, reactor coolant pump; RCS, reactor coolant system; RHR, residual heat removal; RHRS, RHR system; RHX, RHR heat exchanger; RWST, refueling water storage tank; SG, steam generator; SIS, safety injection system; SNR, signal to noise ratio; SRRC, square root raised cosine; VCT, volume control tank; WLAN, wireless local area network; WR, wireless repeater.

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Table 1
Monitoring and control parameters.

System	I/C	A/D	Critical parameters	Quantity
CTMT	I	A	CTMT humidity	1
	I	A	CTMT pressure	1
	I	A	CTMT radiation	1
	I	A	CTMT temperature	1
	I	A	H2 concentration	1
	I	A	CTMT sump level	1
CCWS	I	A	CCWS temperature	1
	C	D	CCW pump	1
SIS	I	A	Accumulator pressure	1
RCS	I	A	Core outlet temperature	1
	I	A	Reactor vessel water level	1
	I	A	Sub-cooled temperature margin	1
	I	A	PZR pressure (wide/narrow)	2
	I	A	# level (wide/narrow)	2
	I	A	PZR pressure relief tank pressure/temperature	2
	I	A	Hotleg 1–3 temperature	3
	I	A	Coldleg 1–3 temperature	3
	I	A	Temperature average 1–3	3
	I	A	Delta temperature 1–3	3
	I	A	RCS flow 1–3	3
	I	A	PZR spray Flow	1
	I	D	RCP 1–3 status	3
MSSS	I	A	SG 1–3 pressure	3
	I	A	Steam flow 1–3	3
	I	D	SG PORV 1–3 position	3
	I	D	SG PSV 1–3 position	3
FWS	I	A	SG 1–3 level (Wide/Narrow)	6
	I	A	Feed flow 1–3	3
RHRS	I	A	Return temperature/flow	2
	I	A	RWST level	1
	I	A	RHR Hx bypass flow	1
	I	A	RHR Hx discharge flow	1
	C	D	Valves	10
	C	D	CTMT spray pump	1
	C	D	RHR pump	1
	C	D	Charging pump #1–#3	3
	I	A	RHX outlet temperature	1
	I	A	Boron concentration	1
	I	A	Charging outlet temperature	1
	I	A	Charging flow	1
	I	A	Makeup water tank discharging flow	1
	I	A	Batch flow	1
	I	A	Letdown Hx outlet flow/temperature/pressure	3
	I	A	VCT pressure/level	2
	C	D	Valves	20
	C	D	Makeup pump #1–#2	2

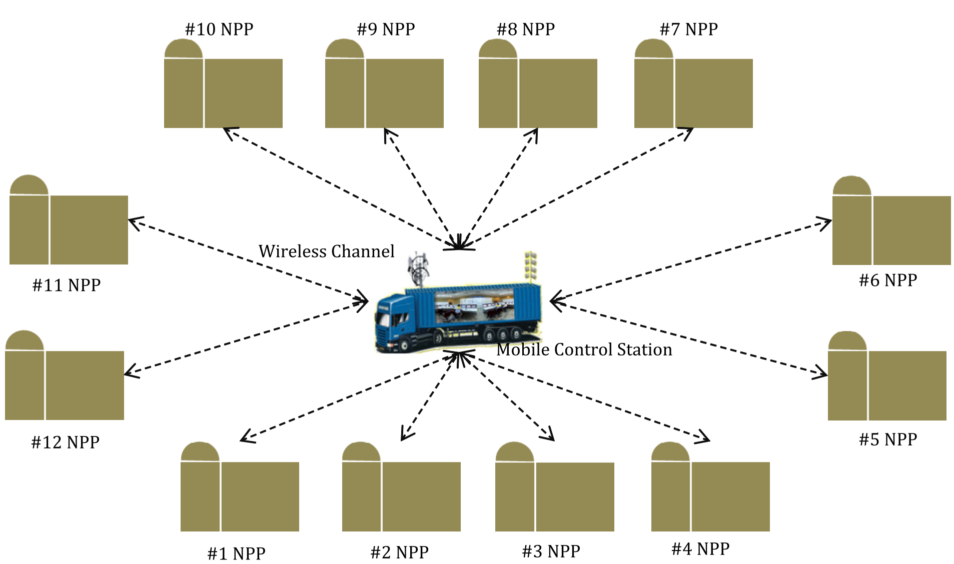

Fig. 1. Network configuration for ECS.