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Small Nuclear Units에 의한 분산전원 및 계통연계(2)

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Small Nuclear Units and Distributed Resource interconnection(2)

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Abstract - This paper introduces a new paradigm for energy supply system in near future which produces electric and district heat cogeneration with dispersed power grid with small nuclear power units. Recently, in nuclear field, a lot of effort has been done in nuclear major countries to develop small and medium reactor for enhancement of nuclear peaceful use as like in district heating, electric power generation, seawater desalination or hydrogen generation.

Index Terms-New paradigm and prospects for energy supply system, Small and medium reactor

1. Introduction

With the introduction of diverse distributed sources (or distributed generators) of various forms, the distribution part of a power system will consist of equipment ranging from those that supply only electric power, and heat combined equipment, which supplies electric power and heat simultaneously near the load center to new complex networks. These distributed sources would have micro gas turbines, fuel cells, wind energy generators, and solar cells, etc., for small scale and would have combined cycle units, hydrogen energy, and small size nuclear reactor etc. for medium scale units. Additionally, the study on DGs whose propagation would be expected by drying up the energy source and the energy policy of country is necessary and important [1-2].

This paper presents the development and interconnection of distributed & remote cogeneration system using small reactor, which connect and support the main power distribution grid of Korea Electric Power Corporation (KEPCO). In Korea, KAERI (Korean Atomic Energy Research Institute) develops a small integral reactor, SMART-P (65 MWth), for the cogeneration of electric and seawater desalination. The results of the analysis were simulated and illustrated using the PSCAD/EMTDC tool, in which the additional power in a power system can be inserted and effected using a small reactor power generation system [3-9].

2. SMART (System-integrated Modular Advance ReacTor) [3]-[9]

In Korea, KAERI (Korea Atomic Energy Research Institute) has been developing an integral type nuclear cogeneration reactor, SMART (System-integrated Modular Advance ReacTor) since 1996 (Chang et al., 1999). Figure 1 shows the schematic diagram of SMART. Since SMART is an integral type reactor, it includes the major components such as steam generator, reactor coolant pump, and pressurizer in the reactor pressure vessel.

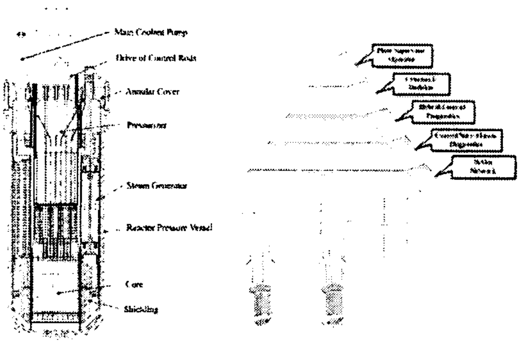

Fig. 1. Conceptual diagram of Integral Reactor, SMART

The calculation results are summarized in Table 1.

Table 1. Major System Parameters

Parameter Design Value		Calculated Value	
Reactor Power (MWt) 330		330	
Primary System			
	Core Mass Flow Rate (kg sec)	1538.48	1538.13
	Pressure	14 99	14.99
	Inlet Temperature of SG (?)	309.68	309.78
	Outlet Temperature of SG (?)	269 68	270.00
	Temperature at IC (?)	83 72	83.58
Secondary System			
	Feedwater Flow Rate (kg sec)	152 70	152.70
	Feedwater Pressure (MPa)	5 66	5.66
	Feedwater Temperature (?)	180 00	180 00
	Pressure at SG Inlet (MPa)	5 07	5 08
	Temperature at SG Inlet (?)	180.05	180.05
	Pressure at SG Outlet (MPa)	3.42	3.42
	Temperature at SG Outlet (?))	279 74	279.74
	Steam Pressure (MPa)	3 30	3 30

SMART is a modular pressurized water reactor and it is expected to be used for dual-purpose applications of seawater desalination and small-scale power generation. It has a capability to produce the fresh water of 40,000 tons per day and the electricity of 90 MW. The designed life of SMART is 60 years and the target for the operating rate is 95 % (Chang et al., 2002). Since SMART will be located relatively near the residential area, SMART should have highly enhanced safety characteristics compared with current NPPs(Nuclear Power Plants). Therefore, SMART adopts the passive safety concepts to enhance its inherent safety and to provide the promising means to remove the residual heat from the reactor core during the accident situations. The existing proven technologies are basically adopted for the SMART design. However, SMART also adopts various new and innovative design features and technologies that need to be proven through experiments and analyses. In order to verify the design and performance of SMART, SMART-P was developed and its implementation is currently in progress at KAERI (Kim et al., 2003). In a normal operation condition of SMART-P, the reactor core is designed for a thermal power of 65MW, a gas pressure in the pressurizer of 14.7steam generator primary inlet and outlet liquid temperatures of 583and 548K, respectively. As for the secondary loop, the feed water temperature is 323the steam temperature and the pressure at the outlet of the steam generator are 558and 3.45 respectively. As a code for transient thermal-hydraulic analysis of the nuclear ship reactor, RETRAN-3D/INT (Kim et al., 2001) was developed by Seoul National University based on the RETRAN-3D (Paulsen et al., 1996). It is one-dimensional system analysis code based on the homogeneous equilibrium model. In order to simulate the nuclear reactor system, RETRAN-3D/INT has special component models such as valve, pump, steam pressurizer, accumulator, and so on.

In RETRAN-3D/INT, helically coiled steam generator model, moving model, and steam-gas pressurizer model are included to simulate the unique features of integral reactor and nuclear ship reactor. The helically coiled steam generator model was verified with the natural circulation experiments for integral reactor (Kim et al., 2001) and the moving model was verified with the operation data of Mutsu that is the first Japanese nuclear ship (Kim and Park, 1996).

In addition, the steam-gas pressurizer model was verified with the pressurizer insurge experiment conducted at Massachusetts Institute of Technology (Kim, 2005). As one of the verification procedure for RETRAN-3D/INT, the steady state analysis of SMART was performed. The initial condition of the analysis comes from the normal operation condition and the calculation results were obtained by null-transient calculation for 2,000 seconds. The results show that RETRAN-3D/INT can simulate the reactor thermal hydraulic parameters appropriately.

In figure 2, the structure of KEPCO (Korea Electric Power Corporation) consists of divisions in 7 geographical areas with different geographical boundaries the Gyeongin northern area, the Gyeongin southern area, the Yeongdong area, the Jungbu area, the Yeongnam area, the Honam area, and the Jeju Island area.

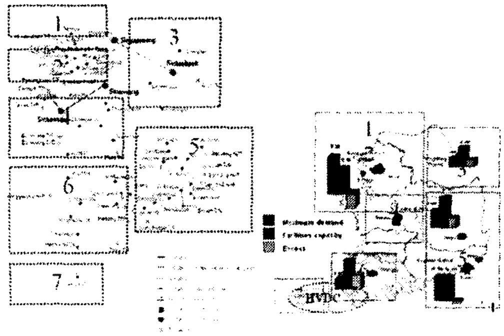

Fig. 2. Regional power system map in South Korea and Demand and facility capacity by regions

* The information in this figure was obtained from KEPCO.

3. PSCAD/EMTDC Diagram for Seven Regions in Korea [10], [11]

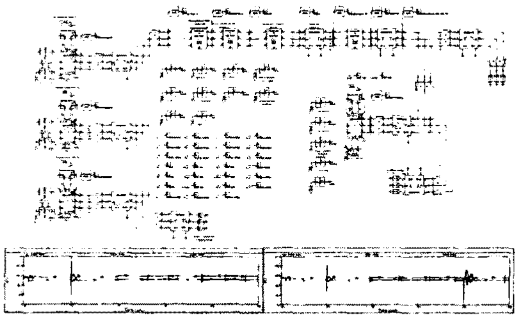

Fig. 3. PSCAD/EMTDC block diagram for the main transmission line in the Northern Gyeongin area (MG+DG)

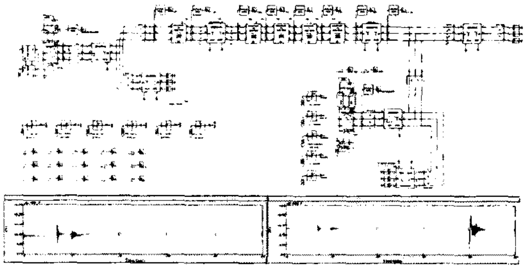

Fig. 4. PSCAD/EMTDC block diagram for the main transmission line in the Southern Gyeongin area (MG+DG)

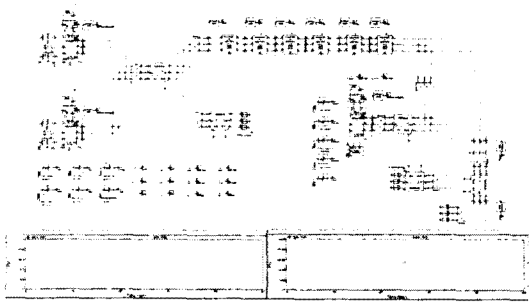

Fig. 5. PSCAD/EMTDC block diagram for the main transmission line in the Honam area (MG+DG)

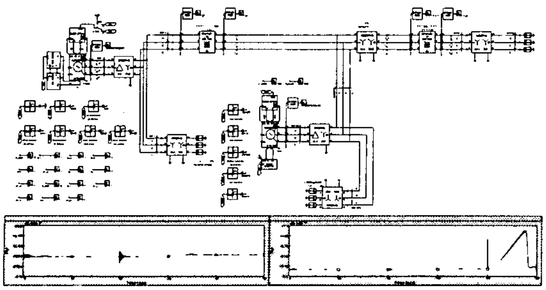

Fig. 6. PSCAD/EMTDC block diagram for the main transmission line in the Yeongnam area (MG+DG)

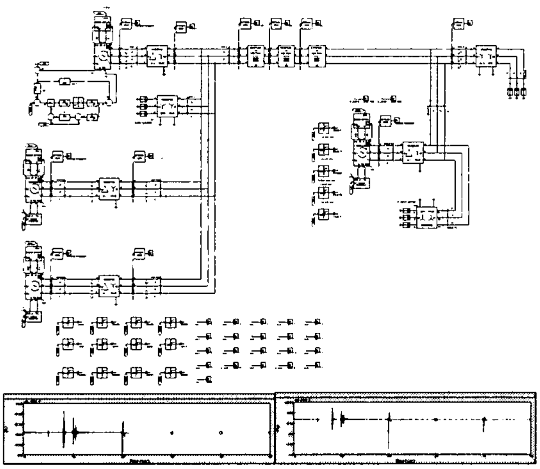

Fig. 7. PSCAD/EMTDC block diagram for the main transmission line in the Jeju Island (MG+DG)

4. Conclusions

This paper showed the insertion effects of a 20MW dispersed generator in South Korea and was given with research items as follows.

- Distributed & remote cogeneration system using small reactor, which connect and support the main power distribution grid of Korea Electric Power Corporation (KEPCO).
- Electric power and district heat cogeneration with dispersed power grid with small plants.
- Small and medium reactor for enhancement of nuclear peaceful use as like in district heating, seawater desalination or hydrogen generation.
- Small integral reactor, SMART-P(65 MWth), for the cogeneration of electric and seawater desalination.
- 345kV, 154kV and 22.9kV transmission line with interconnection for the local power systems.
- Dynamic effect of the insert in the case of dispersed generators executed on subsystems in KEPCO power system.

The results of the analysis were simulated and illustrated using the PSCAD/EMTDC tool for the effect of inserting DG for the seven subsystems in Korea.

Acknowledgment

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