Electrical Power and Energy Systems 61 (2014) 192–196

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Modified fuzzy algorithm based safety analysis of nuclear energy for sustainable hydrogen production in climate change prevention

Tae Ho Woo *

Systemix Global Co. Ltd., 3 F, 494-48, Yonggang-dong, Mapo-Gu, Seoul 121-876, Republic of Korea

ARTICLE INFO

Article history:
Received 20 November 2012
Received in revised form 29 October 2013
Accepted 20 March 2014

Keywords:
Hydrogen
Nuclear power plants
Gas
Random number
Fuzzy set theory

ABSTRACT

The high temperature coolant of nuclear power plants (NPPs) has been investigated for the hydrogen production, which could be a major role of a green energy promotion. An accident of the high temperature gas cooled reactor (HTGR) is modeled for the stabilized hydrogen production using nuclear energy. For the clean energy resource pursuit in preventing the climate change, the hydrogen is one of very attractive energy sources. The non-operational data could be produced by the fuzzy set theory which is one of non-linear complex algorithms. So, the result can show the possibility of the event happening instead of the exact solutions. The random numbers are generated for membership numbers of the fuzzy function. The event manipulation is done by new membership numbers for the propagations. The final result is 1.0 in 8 times during 100 months. So, the frequency is 0.08, or 8% of successful long-term cooling by conduction.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

The high temperature gas cooled reactor (HTGR) has been suggested for the hydrogen production as well as the electricity generation in order to cope with the carbon dioxide matter in the aspect of global warming as climate change [1–3]. Until now, hydrogen is being used as raw materials of chemical products such as ammonia, but hardly used as an energy carrier like electricity [4]. So, the high temperature of the plant coolant can produce the hydrogen with the electricity generation. There are technical problems to be commercialized. In the case of Fort St. Vrain Generating Station, it was stopped by some problems of economic factors, which was operated from 1979 to 1989 [3]. After this time, there are no commercial HTGR and some HTGRs exist as Dragon reactor (United Kingdom), AVR reactor and THTR-300 (Germany), HTTR (Japan), and HTR-10 (China) [3]. It is expected that the hydrogen will be widely used as clean energy carrier for fuel cells to generate electricity, because hydrogen can make a major role to reduce carbon dioxide which can produce the green house effect. Therefore, the global R&D has focused on the fuel cell vehicles (FCV) and stationary power generators. There are equations for hydrogen production by chemical reactions. As for the hydrogen production technology, a thermo-chemical hydrogen production cycle so-called IS (iodine–sulphur) process has been developed step by step [4]. The reactions are decomposing water thermally into hydrogen and oxygen using heat at temperatures lower than 900 °C, which can be made by HTGR. According to the gas phase decomposition theory, the operational pressure could be maintained as lower value, although the capability of heat exchanger increases by the pressure [5].

In the historical review of the HTGR, the design was first proposed by the staff of the Power Pile Division of the Clinton Laboratories (known now as Oak Ridge National Laboratory) in 1947 [6]. The Peach Bottom reactor was the first HTGR to produce electricity with operation from 1966 through 1974 as a technology demonstrator. In addition, Fort St. Vrain Generating Station was one example of this design that operated as an HTGR from 1979 to 1989. However, the reactor was remodeled by some problems to its decommissioning due to economic factors. This was proved as the HTGR concept in the United States. In other countries, there was the Dragon reactor in the United Kingdom, AVR (Arbeitsgemeinschaft Versuchsreaktor in German) and Thorium high temperature reactor-300 (THTR-300) in Germany, the High temperature test reactor (HTTR) in Japan, and the High temperature reactor-10 (HTR-10) in China. China has constructed the 2 pebble-bed HTGRs. There are several descriptions of the HTGR. The specifications of the HTGR are in Table 1, which is a gas turbine modular helium reactor (GT-MHR) [7].

For the stable sustainable hydrogen productions, the accident assessment is investigated in the very high temperature reactor (VHTR). The fuzzy set theory is applied to the safety assessment

* Tel.: +82 2 831 8394; fax: +82 2 831 8422.
E-mail address: thw_kor@hotmail.com

http://dx.doi.org/10.1016/j.ijepes.2014.03.035
0142-0615/© 2014 Elsevier Ltd. All rights reserved.

Nomenclature

ATWS	anticipated transient without scram
AVR	Arbeitsgemeinschaft Versuchsreaktor
CFR	Code of Federal Regulation
FAA	Federal Aviation Administration
FCV	fuel cell vehicles
GT-MHR	gas turbine modular helium reactor
HTGR	high temperature gas cooled reactor
HTTR	high temperature test reactor
ICBM	Intercontinental Ballistic Missile
NPPs	nuclear power plants
NRC	Nuclear Regulatory Commission
THTR-300	Thorium high temperature reactor-300
VHTR	very high temperature reactor

in this advanced power plant of the nuclear power plants (NPPs). The conventional method is modified by the fuzzy set logic. The safety assessment has the event/fault tree concept for the analysis which has been used for the license of the plant constructions and operations. Since there are no operational data in the HTGR, non-linear algorithm like the fuzzy set theory of the artificial intelligence methods could make the quantifications. Language verification is used in the fuzzy algorithm, where the new kind of the function as the membership function incorporated with the membership number in the theory is utilized.

In the literature review, Ball studied the results of various accident scenario simulations for the two major modular HTGR variants (prismatic and pebble bed cores) are presented [8]. Sensitivity studies can help to quantify the uncertainty ranges of the predicted outcomes for variations in some of the more crucial system parameters, as well as for occurrences of equipment and/or operator failures or errors. In addition, safety demonstration tests using the HTTR will be conducted for the purpose of demonstrating inherent safety features of HTGRs as well as providing the core and plant transient data for validation of HTGR safety analysis codes [9]. Also, safety demonstration tests were conducted on the 10 MW HTR-10 to verify the inherent safety characteristics of modular HTGRs as well as to obtain the transient data of reactor core and primary cooling system for validation of HTGR safety analysis models and codes [10].

2. Method

2.1. Modeling

For the stabilized hydrogen production, the accident is modeled for the assessment, which can break the hydrogen generations. The anticipated transient without scram (ATWS) is one of important accidents in the HTGR. The safety criteria for ATWS and its parameter are shown in the 'Screening of Gas-Cooled Reactor Thermal–Hydraulic and Safety Analysis Tools and Experiment Database', I-NERI Final Project Technical Report, Korea Atomic Energy Research Institute, Korea [11]. Table 2 is the key events of ATWS. These values are used to find out the event failure frequency using the nuclear fuel. That is to say, although the 1600 °C is considered as the maximum temperature in the nuclear fuel, there is the maximum event failure frequency at T_{Fuel} = 1250 °C.

2.2. Event/fault tree analysis

Fault Tree Analysis (FTA) was created in 1962 at Bell Laboratories by H.A. Watson, which was done by a U.S. Air Force Ballistics Systems Division contract to evaluate the Minuteman I Intercontinental Ballistic Missile (ICBM) Launch Control System [12–14]. Boeing Company and Avco Corporation expanded usage of FTA to the entire Minuteman II system in 1963–1964. In 1970, the U.S. Federal Aviation Administration (FAA) published a change to 14 CFR (Code of Federal Regulation) 25.1309 airworthiness regulations for transport category aircraft in the Federal Register at 35 FR 5665.

The U.S. Nuclear Regulatory Commission (NRC) began using probabilistic risk assessment (PRA) methods including FTA in 1975 of the nuclear power industry, and significantly expanded PRA research following the 1979 incident at Three Mile Island [15]. This led to the 1981 publication of the NRC Fault Tree Handbook NUREG-0492 [16], and mandatory use of PRA under the NRC's regulatory authority.

There are successful works for nuclear power age as power reactor of the enhanced safety in which the advanced safety criteria with conservativeness as new kinds of safety measures and the consistent analysis in the fields of general nuclear energy and human health matters had been done in late 1960s [17]. In the early 1970s, the US Atomic Energy Commission started the safety of NPPs by the Reactor Safety Study 'WASH-1400' which ended in October 1975 [18].

Fig. 1 shows the conventional event/fault tree method where the event flows from left side to right side in event tree (a). The fault tree is shown in (b). The models sequences of events that need to occur in order for undesired end states to occur. A sequence of events means an accident sequence. The example of an accident sequence is a fire that leads to catastrophic consequences because mitigation systems fail to operate. A model

Table 1
Specifications of the GT-MHR.

Content	Value
Reactor power (MW_t)	600
Tin/Tout (°C)	491/850
Number of fuel blocks/pebbles	1020
Bypass flow fraction (%)	10–15
Reactor pressure (bars)	70
Power density (W/cc)	~5
Reactor mass flow rate (kg/s)	320
Effective core height (m)	7.93
Core diameter (m)	2.63 ID/4.83 OD
Reactor pressure (bars)	70

Table 2
Scenario of ATWS.

Step	Event scenario
1	Rod withdrawal and scram failure
2	Shutdown cooling system fails to start
3	Core power increases by reactivity insertion
4	Core temperature and system pressure increase
5	Power control by runback
6	Reactor trip signal and turbine trip, but, no reactor scram
7	Coastdown of primary flow
8	PCM to rapidly heatup core
9	Core power decreases by Doppler feedback, Xenon inventory increases
10	Equilibrium power level is to be decay heat
11	Long-term conduction and radiation cooling
12	Re-criticality and power oscillation

Download English Version:

https://daneshyari.com/en/article/6860303

Download Persian Version:

https://daneshyari.com/article/6860303

Daneshyari.com