DESIGN CONSIDERATION ON SEVERE ACCIDENT FOR FUTURE LWR

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Abstract

Utilities' Severe Accident Management strategies, selected based on Individual Plant Examination, are in the process of implementation for each operating plant. Activities for the next generation LWR design are going on by Utilities, NSSS vendors and Research Institutes. The proposed new designs vary from evolutionary design to revolutionary design like supercritical LWR. Discussion on the consideration of Severe Accident in the design of next generation LWR is being held to establish Industry's self-regulatory document on containment design and its performance which ABWR-IER (Improved Evolutionary Reactor) on the part of BWR and Evolutionary APWR and New PWR21 on the part of PWR are expected to comply. Conceptual design study for ABWR-IER will illustrates an example of design approach for the prevention and mitigation of Severe Accident and its impact on capital cost.

1. Severe Accident Management

NSC(Nuclear Safety Commission)of Japan issued a statement on accident management (AM) in May 1992 to urge the nuclear Utilities to prepare accident management as a self -regulatory activity. Ministry of International Trade and Industry followed by issuance of a generic letter to ask the utilities to submit plant specific Probabilistic Safety Analysis (IPE as is called in the US.) and Accident Management strategies by the end of FY1993.

The regulatory position on severe accident issues is described in the NSC statement as follows;
'Adequate level of safety for the nuclear facilities has been kept through strict regulations based on the philosophy of defense in depth at the stages of design, construction and operation. The likelihood of the occurrence of severe accident is so low in probability that from the engineering point of view it is remote from reality, and the risk associated with the occurrence of severe accident is small. Accident management , if implemented will further contribute to reduce the risk arising from operation of nuclear power plants. Thus, NSC strongly recommends licensees to voluntarily plan effective accident management.'

Upon the recommendations, Utilities submitted IPEs, Accident Management strategies and implementation plan for all 51 LWRs in operation and construction to the regulatory body (MITI) in March 1994. The reports were reviewed by both MITI and NSC. MITI issued its evaluation report in October 1994, so did NSC in November 1995, both of which confirmed that the accident management strategies reported by the utilities were technically appropriate. Utility's Accident Management program consists of the following elements (1);

- AM Procedures
- Plant modifications
- Check capability of instrumentations
- Training
- Organization

Plant modifications for Accident Management include the use of non-safety grade equipments in order to fully utilize existing plant capabilities to cope with beyond DBA situations, but considers system interface with safety system and reasonable assurance of function capability under Severe Accident condition. The proposed basic strategies are as follows (see Fig 1,2);

Generic BWR AM strategies ----- Prevention

1) Use all available makeup water driver & source to deliver water to RPV from non-safety water tanks via diesel-driven fire water pumps
2) Emergency power source connectivity to cope with Station Blackout for multi unit installation
3) Scrubbing vent to arrest TW scenario
4) Depressurization on water level signal and Alternate Rod-run-in logic to reduce ATWS / TQUX by system design

Generic BWR AM strategies ----- Mitigation

1) Ex-vessel debris cooling measures against , overheating, shell Attack , core-concrete reaction (Capability to deliver Fire-water & others to RPV/Containment/Cavity)
2) Avoid overpressure failure of containment & to allow time for containment heat removal function recovery by scrubbing vent
3) Inert entire containment & reinert after vent

Generic PWR AM strategies ----- Prevention

1) Use all available makeup water driver & source to deliver water to reactor from makeup water tank through RWSTand Alternative recirculation
2) Secondary loop cooling(Main feed water pump to cool primary loop (for ATWS, Turbine bypass system to depressurize primary loop)
3) Primary loop depressurization using relief valves in pressurizer and intact SG's to suppress coolant leakage and to utilize RHR.
4) Natural convection cooling of containment by containment cooling chiller
5) Emergency power source connectivity to cope with Station Blackout for multi unit installation
6) Alternative auxiliary component cooling

Generic PWR AM strategies ----- Mitigation

1) Firewater into the containment for debris cooling ,over-pressure protection
2) Forced depressurization of primary system
3) Igniter for Ice-condenser containment

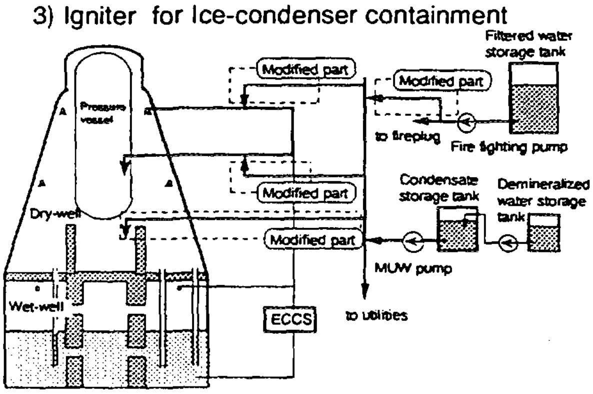

Fig. 1 Alternate water injection

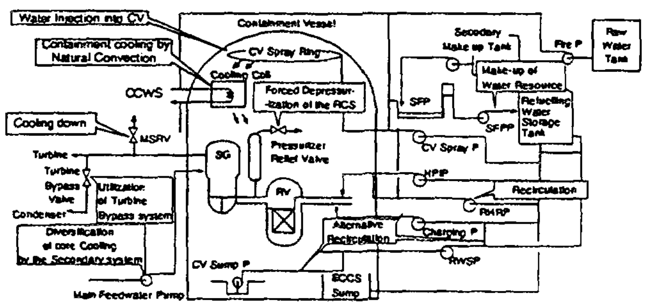

Fig.2 Typical AM Strategies and Facilities in PWR (Example)

For all LWRs, these AM strategies will be implemented by around the turn of the century. Each utility will conduct plant modifications while preparing infrastructures such as operating procedures including accident management guideline and training.

It is generally expected that future LWRs will have less complex Accident Management but nevertheless they are not free of such measures since Accident Management will provide flexibility to cope with unexpected situations.

2. ALWR Development

Various reactor concepts are proposed in Japan for future LWR. They include evolutionof ABWR, J-SBWR , RBWR(LWR breeder) on the part of BWR, andAPWR & its evolution and SPWR on the part of PWR. Supercritical LWR is a simple direct cycle LWR with elevated pressure and high thermal efficiency. This paper will focus on ABWR and its evolution as an example.

ABWR (Advanced Boiling Water Reactor)

Twin FOAK ABWRs were constructed by TEPCO. SECY-90-016 & 93-087 had been major elements for resolution in US of the capability to cope with severe accident. Japanese ABWR is essentially the same except that the fusible valve to supply water to the lower drywell is replaced by remotely operated valved to supply water from firewater tanks and that Gas turbine is not required for multiple unit installation with reliable power network. During the ABWR licensing process in US, it was analysed by GE that the critical structures would survive an ex-vessel steam explosion and that the containment can withstand pressurization by hydrogen if service level C is assumed in determining allowable stress.

ABWR-IER (Improved Evolutionary Reactor)

ABWR-IER is an evolution of ABWR and is intended to base its design on experiences of BWR operations and improvements while exploiting new and innovative design features available as technologies progress.

Pre-Phase(FY 1990) was intended to establish TEPCo's Utility Requirement (2) , which was followed by Phase I (FY 1991-92)by BWR Utilities and NSSS vendors to investigate future technologies to apply to IER.

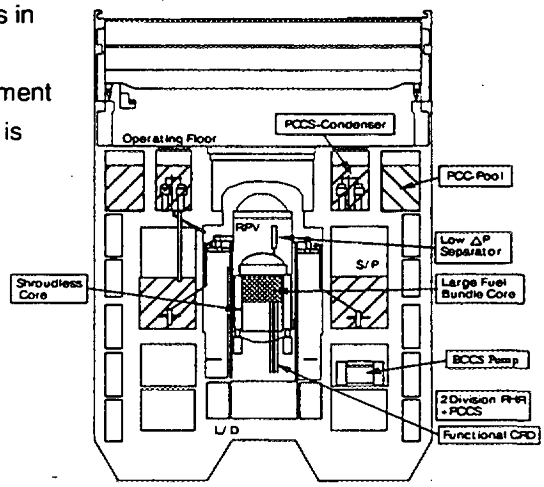

Fig 3 : ABWR-IER Concept

Phase II (FY 1993-95) was intended to establish a reference plant concept (3) with focus upon nuclear boiler and engineered safeguard systems (Fig-3). Simple economic and safety evaluations were done to confirm the compliance to the Utilities requirements. Phase III(FY 1996-98) is intended to establish entire plant concept with emphasis on economic improvement to assure competitive edge over alternative power generating sources. T & D Program is also to be planned in this stage although some selected test programs are already going on such as effect of increased number of fuel rods in a bundle on heat transfer performance.

ABWR-IER design is based on ABWR, but has several improved safety features as follows.

1) Active & passive containment heat removal systems

In addition to traditional RHR systems to serve to remove heat from Reactor pressure boundary as well as from the containment, PCCS (Passive Containment Cooling System) as is developed for SBWR is being considered for ABWR-IER to provide additional margin to remove heat from the containment by passive means.

2) Diversity in ECCS (Fig-4)

ECCS network of IER adopts the same type of three independent division system (HP & LP in each division) as ABWR, increase in diversity in working principle is considered. ARCIC (Advanced Reactor Core Isolation System utilizing steam produced by decay heat) now is equipped with its own small generator which replenish batteries with DC power for instrumentation and control in the event of station blackout. Motor-driven HPCF (High Pressure Core Flooder) and diesel-driven HDIS (High Pressure Diesel Driven Injection System) provide additional diversity.

3) Diversity in Emergency Power Supply (Fig-4)

The diversity of emergency power supply systems increases by allocating a diesel generator, an air-cooled diesel generator and a gas turbine generator for each safety division. This feature provides improved performance for station blackout sequences which probability would be dominated by common cause failure of some sort in conventional design.

4) Simplicity

Reducing complexity by reducing supporting systems such as component cooling system is expected to help simplify plant design.

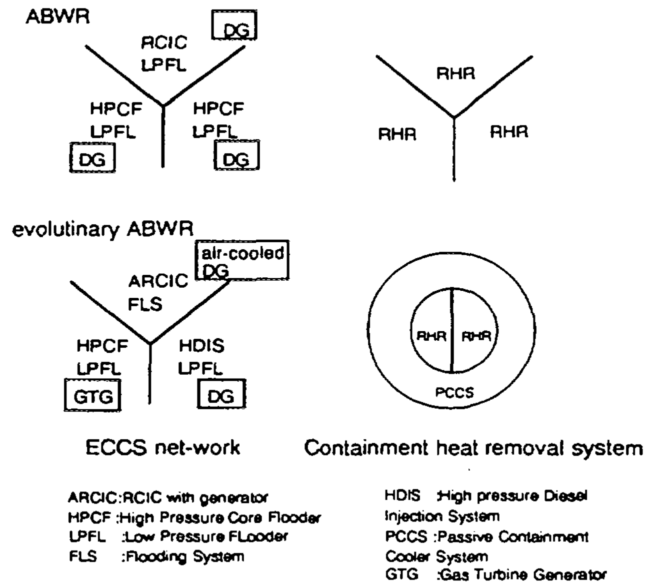

Fig 4 : ABWR & ABWR-IER ECCS/RHR

As for the mitigation of severe accident, such features as refractory material liner at the bottom part of lower dry-well, passive lower dry-well flooder, hydrogen absorber/adsorber are being discussed. In-vessel retention capability, if proved, will certainly add safety margin but will not totally eliminate measures to mitigate the consequences of severe accident.

3. Containment for future ALWRs

One aspect of design consideration for severe accident for future LWR will be severe accident mitigation especially in terms of containment design, although enhancement in prevention as discussed above for ABWR-IER will be visible in all future LWR design.

Japanese nuclear industry, with some advises from academia, is developing containment design document which will consist of performance target and design extension conditions so that appropriate design considerations on severe accident and other important issues are taken in the design of future containment In Japan. Design extension conditions are intended to provide additional margin to cope with severe accident although containment design basis itself is unchanged.

Containment performance target will probably include such targets as large release limitation, CCFP but also due consideration of identified threats to the containment as Design Extension Conditions.

The technical issues under discussion or to be discussed include;

- Hydrogen as pressurizing source for small containment
- In-vessel retention as additional margin, but not eliminate mitigation
- Debris cooling in reactor cavity
- Containment leakage characteristics
- External events

To raise some issues of concern;

<u>1) Cut-off probability</u>

The kind of scenario or phenomenon to be addressed in the containment design will certainly have limitations. One limitation arising from the imagination of designers. Another from balanced design approach, which essentially implies to what extent nuclear power should be prepared in the design for the highly unlikely events such as in-vessel steam explosion. Already certain cut-off probability has been utilized in the stage of screening of initiating events of external sources such as missile - the cut-off number hovers somewhere around 10(-7)/year.

Applying similar cut-off probability to the chain of events to eliminate certain scenario which may threaten the integrity of containment is a difficult task. Industry is discussing 10(-7)/year as such cut-off probability while requiring due consideration to every possible phenomenon in search for preventive and mitigative strategies.

2) Balanced approach

Given the decline of fossil price since mid 1980's and the deregulation of Utility business in US, Europe and Japan, the economic competition among alternative energy sources may push away nuclear power from future power market, if Utilities are much short-sighted without paying due consideration to nuclear power's importance in stable/secure energy supply and environment. *(4)*

For existing plants with advent in capital depreciation, efforts are made to preserve competitive edge by increasing availability while maintaining the same level of safety and reliability. For new installation, capital-intensive nuclear power may face difficulties if balanced approach and cost-effectiveness are not considered.

4. Conclusion

Severe Accident Management program in Japan is well under way to restrict risk arising from such highly unlikely events.Containment performance targets are being developed by Japanese industry as a self-regulatory guide with the aim of addressing severe accident issues in the design of future LWR.

Activities for the future LWR design is going on. ABWR-IER design will further reduce the likelihood of severe accident by diversity of systems & components to fulfill safety functions.

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