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# Effective use of local and global component of neutron noise signals

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ABSTRACT

India is pursuing the design of Advanced Heavy Water Reactor (AHWR) to achieve the objective of thorium utilization with enhanced safety and economic competitiveness. AHWR is 920 MWth pressure tube type boiling water reactors with light water as coolant and heavy water as moderator. The reactor is designed to remove the core heat by two-phase natural circulation mode not only during startup, power rising or shut down cooling but also during normal full power operation. In addition, the design incorporates many passive safety features such as advanced accumulators, gravity driven cooling system for ECC and LOCA incidences respectively and passive containment cooling system for containment cooling. In many ways AHWR will be addressing stringent safety needs of the next generation nuclear reactors.

Thermal hydraulics of two-phase natural circulation reactors pose stiff challenges while establishing stable operation at all power level, establishing thermal margin, thermal hydraulics related to refueling, channel burn out caused by small break LOCA, flow instability etc. In core detectors such as SPNDs are very sensitive to perturbation to neutron flux. By the definition of 1970s, neutron flux is made of the global component generated by the reactivity noise that fluctuates in phase with the whole reactor, and the local component that originates from the axially propagating perturbations. Perturbation changes the neutron field in its neighborhood, called the local component. The paper deals about effective use of SPND signal for detecting in core thermal hydraulics during steady state operation and during reactor shut down.



## 1. Introduction

Advanced Heavy Water Reactor (AHWR) is stepping stone for the 3rd stage of India's nuclear power programme. AHWR is designed to contribute sustainable nuclear energy programme using abundant reserve of thorium. It is a vertical pressure tube type boiling water reactor with two-phase natural circulation as the mode of core heat removal under all operating conditions. The design employs many passive safety systems to address the stringent safety needs of the next generation nuclear reactor [Sinha and Kakodkar, 2006].

Two-phase natural circulation mode of heat extraction for the core poses several stiff challenges. Parallel channel instability, flow reversals during refueling, channel burn out during small break LOCA, critical heat flux margin, etc. Neutron noise is very sensitive to thermal hydraulic disturbances caused by transients. Study of neutron noise signal is known to yield robust technique to detect thermal hydraulic instabilities in real time and could facilitate taking corrective action much well in time.

As pointed out by many investigators [Ando et al., 1975; Nomura, 1975; Kostic, 1976; Kosaly, 1976; Kozma et al., 1995; Kleiss et al., 1982 and Yasumasa et al., 1975], the neutron noise in a BWR is composed of global and local components. The global component, which is observed below a few Hz (generally 1 Hz or so) in the neutron noise signal, is related to the reactivity effect caused mainly by the behavior of the steam void, which is produced in the fuel channel. On the other hand, the local component observed above a few Hz (generally 1 Hz or so) is influenced by the neutron detection process in the vicinity of the neutron detector. When the steam void moves upward and attains the vicinity of the neutron detector, the coolant density fluctuates in the vicinity of the detector and so the number of neutrons caught by the detector fluctuates. According to these processes, the propagation of the density variation influences the neutron detection process. Consequently, it is possible to determine the transit time related to the propagation of the density fluctuation. This transit time is considered to be connected with the propagation time for the steam void.

During the investigation of the perturbation propagating through the reactor, difficulty is caused by the so called global noise, which is also detected by the detector, i.e. not only is the propagating perturbation seen by the detector but also a noise; this noise can be sensed at each point of the reactor. That is to say, the detector measures a local and a global noise field simultaneously. Based on the local_/global theorem the signal measured by an in-core neutron detector can be well separated as local and a global component.

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Experimental results in PWRs and BWRs have shown that in the lower frequency range (up to about 1 Hz) reactivity noise sources are dominant in the neutron noise spectra. Beyond that range in the BWR, distinctly local noise sources are superimposed which can be related to the flow of steam voids around the detector.

In BWR the main in-core neutron noise above 1 Hz is caused by the void flow of the steam bubbles. As long as the statistical parameters of the void flow (i.e. places of void origins, times of void origins, void diameters) are sufficiently disturbed, the spectrum of the void flow related noise source should be in good agreement with the Fourier transform of the SPND detector signals.

In case of local overheating of a fuel assembly (local burnout), in a finite range, steam bubbles would be generated which produce a characteristic increase in the noise spectra of neutron detectors positioned above the burnout. Thus from the mechanism of bubble generation, a broad-band increase in the noise spectrum can be expected [Fry et al., 1984].

The results correspond to the earlier findings that the high frequency part of the spectrum is rather sensitive to the axial position in the core. The magnitude of the spectra at a given frequency increases with increasing axial position because of the increasing coolant void fraction.

The systematic change of the spectra with axial position in the core indicates a strong coupling between the local component of the noise and actual thermo-hydraulic behavior. One may speculate that the change of the flow regimes along the axis contributes significantly to observed changes in the shape of the spectra.

Glockler et al., 1995 showed that neutron noise signals contained process related dynamic information in the frequency range of 0–10 Hz. This indicates that the detectors are "alive" and capable of following the small but rapid fluctuations in the neutron flux around its static value. The statistical noise signatures characterizing the normal detectors were learned for all vertical and horizontal detectors, regular and spare detectors.

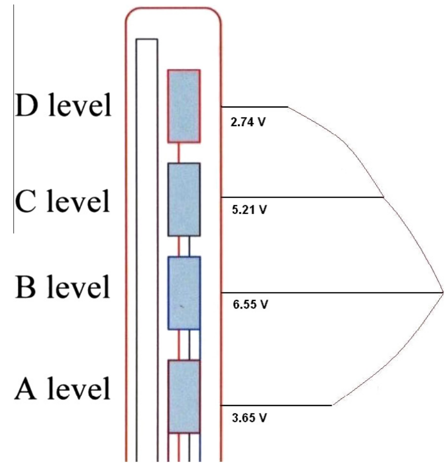


**Fig. 2.** Axial neutron flux profile.

## 2. SPND measurement in TAPS-2 reactor

Tarapur Atomic Power Station is pressure vessel type 160 MWe boiling water reactor belonging to first generation reactor design. The core map and in core instrumentation is shown in Fig. 1 along with the elevations of SPND detectors in the core.

In 24–13 grid position of the core, one string consisting of four SPNDs is installed. These are Vanadium based SPNDs. Two sets of measurements were carried out as below.

- August 2009. Plant in normal operation and one neighboring Control rod moved by one notch and restored after 1.0 min. Duration of recording 25 min.

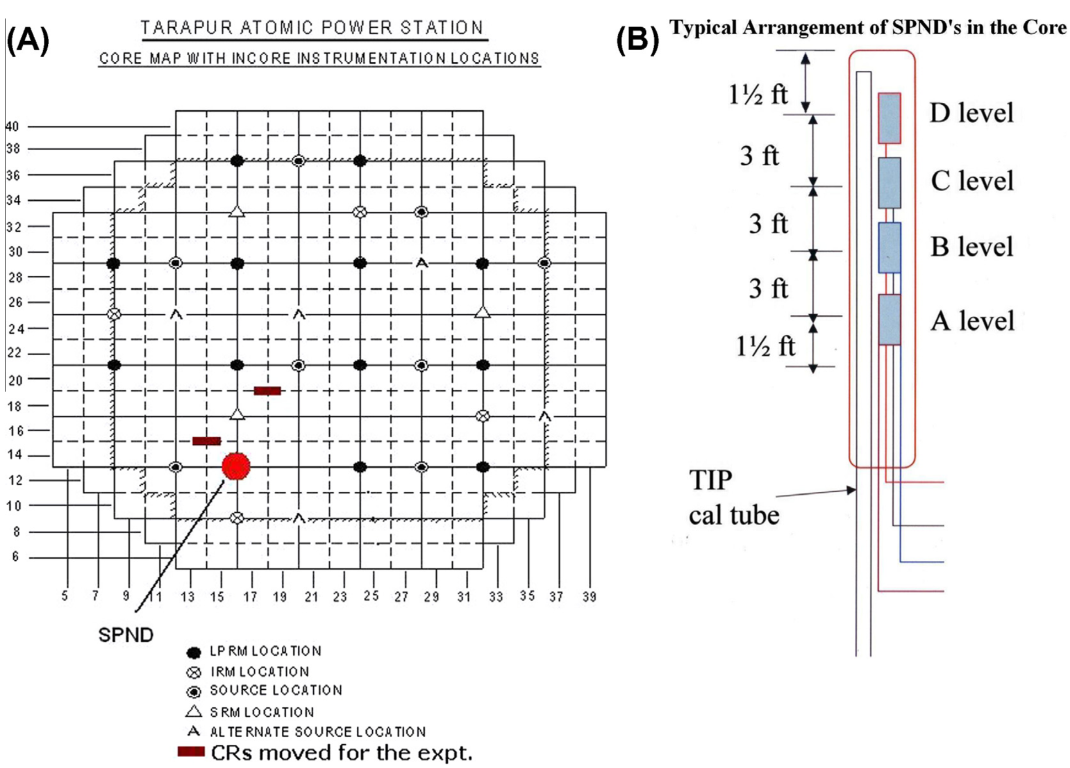


**Fig. 1.** A and B core map, in-core instrumentation and axial positions of SPND sensors in TAPS-2.