Summary and Conclusions

As part of our program on R & D of ADS, we have carried out theoretical studies on the development of reactor noise methods for measuring sub-criticality of such systems. The principal difference between reactor noise in ADS and traditional reactors, as also between our approach and that followed by other authors (Pazsit and Yamane, 1998a,b; Kuang and Pazsit, 2000; Behringer and Wydler, 1999; Munoz-Cobo et al., 2001), lies in the characteristics of the external source. As elaborated in section 2.2.3 of chapter 2, there are reasons to believe that the accelerator produced neutron source cannot be assumed to be a Poisson process. An immediate consequence of this is that the commonly used approaches in traditional reactor noise theory such as the Kolmogorov forward equation and the Bartlett formula are not applicable to the study of reactor noise in ADS.

Thus, it is necessary to have a different theoretical approach to the subject. In view of this, a theory of reactor noise in ADS considering periodically pulsed source and its non-Poisson character was developed earlier by Degweker (2000, 2003). The theory has been further developed in the thesis as outlined below.

In chapter 3, we have characterized the non-Poisson source by considering exponentially correlated Gaussian statistics of the proton beam intensity. We have also treated pulses of finite widths by considering rectangular and Gaussian pulse shapes. Expressions for various noise descriptors have been obtained. In chapter 4, we have extended the theory to include the effect of delayed neutrons. The source is considered to be a periodic sequence of delta function pulses with non-Poisson character. Two cases have been considered. In one case it is
assumed that there is no correlation between different source pulses while in the other case we have considered a specific model viz. exponential correlation between the proton pulses. We have derived expressions for Rossi alpha and Feynman alpha formulae. For further extension of the theory of reactor noise in ADS to the more general case of correlated non-Poisson pulsed sources with finite pulse width including delayed neutrons, we have followed the Langevin approach in chapter 5. We have obtained the PSD of the reactor noise in ADS for the general case described above.

Experimental studies are planned (Rasheed et al., 2010) to be carried out in the upcoming Purnima sub-critical facility at BARC to study pulsed neutron and noise methods for measuring the sub-critical reactivity of ADS and to interpret the results in the light of the above theory. As a part of the planning of these experiments, we have developed a few group diffusion theory based analogue Monte Carlo code for simulating the proposed experimental set-up. The simulator incorporates delayed neutron effects and dead time effects. The development of the simulator and some results obtained are described in chapter 6.

The main conclusions of our studies are as follows.

The correlations in the source fluctuations introduce additional terms which could confuse interpretation of alpha measurements by the variance method. The variance method is likely to suffer most from the presence of other sources of fluctuations. The Rossi alpha, correlation and spectral density methods might perform better in this case. On the other hand, correlations between the numbers of neutrons emitted in different pulses give rise to extra terms. Calculation of Rossi alpha shows that if correlation times are greater than or of the order of the prompt neutron decay times, it will be difficult to use methods such as Rossi alpha. The importance of the delayed neutron contributions will be most clearly felt in those situations where the prompt and delayed time scales are not very distinct and the formulae
derived by us would serve as corrections even on prompt neutron time scales. The Langevin approach is capable of correctly describing the non-Markov process resulting from a non-Poisson source. We have shown that a complete description of the spallation neutron source is possible by treating it as a combination of an internal noise given by the Schottky prescription and another that is of external origin arising from the proton beam. With such a description, we have obtained the PSD of ADS reactor noise complete with delayed neutrons, finite pulsed width, and correlations if any between proton pulses. The simulator gives a fairly realistic picture of the kind of results that may be expected with regard to the errors and the accuracy that may be expected from actual measurements. Simulations of proposed Purnima sub-critical assemblies show that proper location of detectors gives an almost single exponential (fundamental mode) response making alpha measurements by the noise methods possible even in deeply sub-critical systems.

Further studies on the subject can be carried out along the lines given below.

If noise methods are to be used for sub-criticality measurements, experimental studies on the statistical characteristics of the proton bunches should be carried out. Since the Feynman alpha method has been studied in several experimental facilities, it would be worthwhile to look for non-Poisson behavior of the source. A study of the variation of the Feynman Y function with the degree of sub-criticality would bring out the relative contributions from the external source and from the fission source. It is also important to study the current fluctuation statistics of ion beams from accelerators, either theoretically or experimentally. Our treatment of reactor noise in ADS is limited to very low power systems and we have completely disregarded the effects of thermal hydraulic feedbacks and other noise sources which are expected to be important in an operating power reactor. It will be worthwhile to investigate these effects. Finally, development of a robust procedure for diffusion in multi-media, and which does not use numerical approximations such as finite differencing, remains