Progress in Nuclear Energy 98 (2017) 109–122

Contents lists available at ScienceDirect

Progress in Nuclear Energy

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

Response of the point-reactor telegraph kinetics to time varying reactivities

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ARTICLE INFO

Article history:
Received 29 May 2016
Received in revised form
16 December 2016
Accepted 3 March 2017
Available online 15 March 2017

ABSTRACT

The new model of the Point Reactor Kinetics (PRK) equations developed based on the Telegraph approximation of the neutron transport equation, is solved for several cases of time varying Reactivities insertions and Temperature feedback while comparing it to that of the diffusion PRK model in an infinite Thermal Homogenous Nuclear Reactor. Diffusion PRK is based on the Neutron Diffusion Equation which is a parabolic differential equation and hence it assumes an infinite velocity of propagation, while neutrons propagate with a finite velocity. By the introduction of the hyperbolic type Telegraph equation which is a more accurate representation of the neutron transport than the diffusion equation and in which neutrons propagate with a finite velocity, one could overcome this paradox that contradicts causality. The new model introduces a new parameter called the relaxation time (τ), which is not present in the diffusion approximation, and affects the neutron density calculations. Both Ramp insertions of reactivity and Sinusoidal insertions of reactivity were studied, as well as the effect of The Adiabatic Temperature feedback. The general phenomena in the solution of the new model is a Relaxation in the time response of the solution. It is found that the Telegraph model with its extra second order time derivative, will give observable different values than that of the diffusion even when we used small (τ) especially for the cases at which the neutron density changes rapidly.

1. Introduction

The system of the neutron point reactor kinetics (PRK) equations is one of the most important reduced models of nuclear engineering. They have been the subject of countless studies and applications to understand the neutron dynamics and its effects and to solve it using several methods as well as expand it to nonlinear and two energy group formulations (Nahla, 2015; Aboanber et al., 2014; Sérgio et al., 2014; Petersen et al., 2011; Nahla and Zayed, 2010) and reflected reactors (Aboanber, 2009; Aboanber and El Mhlawy, 2009). However, every PRK study was based on the neutron diffusion equation, which is considered as the correct first order approximation of the neutron transport equation. The Neutron Diffusion Equation is a differential equation of a parabolic type, and hence the neutrons described by it carry an infinite propagation velocity which in turns contradict causality principle. This can be found in details in several publications, for e.g. Weinberg and Noderer (1951), Weinberg and Wigner (1958), Meghreblian and Holmes (1960) and Beckurts and Wirtz (1964). It is also found in several recent publications, for e.g. Altahhan et al. (2016), Espinosa-Paredes and Polo-Labarrios, (2012), Heizler (2010), Olson et al. (2000), Das (1998) and Masoliver and Weiss (1994).

Another approximation to the time dependent neutron transport equation has been considered where it overcomes this infinite velocity effect. This approximation is identified as the neutron telegrapher's equation, the neutron telegraph equation or the neutron telegraphist's equation (Weinberg and Noderer, 1951; Weinberg and Wigner, 1958; Meghreblian and Holmes, 1960; Beckurts and Wirtz, 1964; Altahhan et al., 2016), and its derivation is based on the neutron transport equation and is presented in

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http://dx.doi.org/10.1016/j.pnucene.2017.03.008
0149-1970/