Confirmation of Accuracy of Generalized Power Series Method on Point Kinetics Equations with Feedback

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Abstract

In this paper, power series method has been developed to obtain approximate analytical solutions to point kinetics equations with feedback using generalized power series method (GPWS). The stiffness of the kinetics equations restricts the time interval to a small increment, which in turn restricts the traditional power series method (PWS) within a very small constant step size especially when the generation times are very small. The GPWS method has introduced time intervals that are much longer than time intervals used in the conventional numerical integrations like Generalized Runge- Kutta or power series methods, and it is thus useful in reducing computing time. Convergence of both the power series and the partial sums are discussed and the time step has been restricted within a circle of convergence by using the convergence conditions. Local truncation errors and some other constraints are used to produce the largest step size allowable at each step while keeping the error within a specific tolerance. The accuracy of the method is examined using five different cases of temperature reactivity feedback for step and ramp impressive reactivities with one and six groups of delayed neutrons. Supercritical (prompt and delayed) processes of a nuclear reactor with temperature feedback are discussed while inserting large and small reactivities. Results obtained by GPWS method attest the effectiveness the theoretical analysis, they demonstrate that the convergence of the iteration scheme can be controllable. The proposed method is very accurate when compared to the analytical and numerical methods.

Keywords: Point Kinetics Equations; Feedback Reactivity; Generalized Power Series Method; Step Size Control; Convergence; Numerical Solutions.

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Generalized Power Series Method with Step Size Control for Neutron Kinetics Equations

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Abstract

Based on the power series method (PWS), a generalized power series method (GPWS) has been introduced for solving the point reactor kinetics equations. The stiffness of the kinetics equations restricts the time interval to a small increment, which in turn restricts the PWS method within a very small constant step size. The traditional PWS method has been developed using a new formula that can control the time step at each step while transient proceeds. Two solvers of the PWS method using two successive orders have been used to estimate the local truncation errors. The GPWS method has employed these errors and some other constraints to produce the largest step size allowable at each step while keeping the error within a specific tolerance. The proposed method has resolved the stiffness point kinetics equations in a very simple way with step, ramp and zigzag ramp reactivities. The generalized method has turned out to represent a fast and accurate computational technique for most applications. The method is seemed to be valid for a time interval that is much longer than the time interval used in the conventional numerical integration, and is thus useful in reducing computing time. The method constitutes an easy-to-implement algorithm that provides results with high accuracy for most applications where, the reactor kinetics equations are reduced to a differential equation in a matrix form convenient for explicit power series solution. Results obtained by GPWS method: attest the power of the theoretical analysis, they demonstrate that the convergence of the iteration scheme can be accelerated, and the resulting computing time can be greatly reduced while maintaining computational accuracy. The point kinetics equations have been solved as a preliminary simple case aimed at testing the applicability of the GPWS method to solve point kinetics equations with feedback or, space kinetics problems.

Keywords: Point Kinetics Equations; Power Series Method; Step Size Control; Reactivity; Numerical Solutions; Analytical Solutions.

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Computation accuracy and efficiency of a power series analytic method for two- and three- space-dependent transient problems

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Abstract

The establishment of solutions to large-scale three-dimensional (3-D) reactor benchmark problems is needed to serve as standards for the verification of design codes and for the detailed error analysis of calculational methods. A number of partially and fully inserted control rods, represented by absorber added to certain subassemblies, cause a strong nonseparable power distribution. In addition, the existence of a very large thermal flux peak in the reflector makes this a very difficult and challenging problem to solve. PWS code has been developed to include a numerical solution for the time-dependent neutron diffusion equations for the nuclear reactor analysis. The new technique employs a new parameter (a) which can reduce the rapid increase in magnitude of the power series coefficients. These coefficients, in turn, are determined by back substitutions in the non-linear canonical diffusion equations and treating terms of the same degree to obtain a modified recurrence relation which is valid for any type of the stiff nonlinear kinetic diffusion equations. The validity of the algorithm was tested with three kinds of well-known two-group benchmark problems. The first one is the two-dimensional TWIGL seed-blanket reactor kinetics problem. The second is the two- and three-dimensional LAR BWR benchmark problem simulating a rod drop accident of a BWR core. The third is the three-dimensional LMW LRA transient problem which simulates an operational transient involving rod movements. The obtained results with the proposed PWS code are compared with those provided by other reference codes, indicating an overall agreement and excellent performance.

Keywords: Neutron diffusion equation; Analytic solution; Power series; Control rod withdrawal; Power density; Doppler feedback.

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Generalized Runge–Kutta method for two- and three-dimensional space–time diffusion equations with a variable time step

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Abstract

An extensive knowledge of the spatial power distribution is required for the design and analysis of different types of current-generation reactors, and that requires the development of more sophisticated theoretical methods. Therefore, the need to develop new methods for multidimensional transient reactor analysis still exists. The objective of this paper is to develop a computationally efficient numerical method for solving the multigroup, multidimensional, static and transient neutron diffusion kinetics equations. A generalized Runge–Kutta method has been developed for the numerical integration of the stiff space–time diffusion equations. The method is fourth-order accurate, using an embedded third-order solution to arrive at an estimate of the truncation error for automatic time step control. In addition, the A(a)-stability properties of the method are investigated. The analyses of two- and three-dimensional benchmark problems as well as static and transient problems, demonstrate that very accurate solutions can be obtained with assembly-sized spatial meshes. Preliminary numerical evaluations using two- and three-dimensional finite difference codes showed that the presented generalized Runge–Kutta method is highly accurate and efficient when compared with other optimized iterative numerical and conventional finite difference methods.

Keywords: Stiff diffusion equation; Runge-Kutta method; Numerical methods; A-Stability.

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Power series solution (PWS) of nuclear reactor dynamics with newtonian temperature feedback

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Abstract

The point reactor kinetics equations of reactor are solved analytically in the presence of delayed neutron with Newtonian feedback for different types of reactivity input using a straightforward recurrence relation of a power series. Analytical or point-function reactivity variations are introduced together with constant or time-varying reactivity compensation. Numerical evaluation is performed by the developed PWS (Power Series Solution) code, written in Visual FORTRAN for personal computers. The code solves the general non-linear kinetics problems with six groups of delayed neutron. Practical use of the method is verified through computed reactor response for representative reactivity addition functions of various types. In addition, comparison with the conventional methods confirmed the superiority of the developed power series code with different types of reactivity feedback.

Keywords: point reactor kinetics equations; Newtonian feedback; Numerical methods; Power series method.

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