IMPACT: International Journal of Research in Applied,
Natural and Social Sciences (IMPACT: IJRANSS)
ISSN (P): 2347–4580; ISSN (E): 2321–8851
Vol. 12, Issue 11, Nov 2024, 1–10

ANALYZING STABILITY AND BIFURCATION IN IMPULSIVE DIFFERENTIAL EQUATIONS TO ENHANCE MATHEMATICAL MODELS AND PREDICTIVE ACCURACY

Venkatachalapathi Uday[1] & Dr. Gautam Kumar Rajput[2]

[1]Research Scholar, Department of Mathematics, Sunrise University, Alwar, Rajasthan

[2]Associate Professor, Department of Mathematics, Sunrise University, Alwar, Rajasthan

Received: 05 Oct 2024 **Accepted: 23 Oct 2024** **Published: 09 Nov 2024**

ABSTRACT

Impulsive differential equations (IDEs) offer a robust framework for modeling systems that experience sudden changes in state at specific instants, a characteristic prevalent across various scientific and engineering domains. These equations capture the dynamics of phenomena where abrupt impulses, such as shocks, instantaneous jumps, or rapid changes in force, affect the state of a system. This paper focuses on the analysis of stability and bifurcation in IDEs to improve mathematical models and predictive accuracy, aiming to address challenges posed by non-continuous dynamics. By examining both linear and nonlinear IDE systems, we identify critical points and explore stability conditions through advanced mathematical techniques, including Lyapunov functions and the construction of Poincaré maps.

Our study delves into different types of stability, such as asymptotic and exponential stability, in the context of impulsive effects, and we derive conditions that guarantee these properties even in the presence of frequent or irregular impulses. Furthermore, we investigate bifurcation behaviors, particularly how variations in system parameters lead to structural transitions that influence stability and the overall system behavior. Through numerical simulations and case studies, we illustrate typical bifurcation scenarios in impulsive systems, including saddle-node, Hopf, and period-doubling bifurcations, and analyze their impact on predictive modeling.

The findings from this study provide insight into the underlying mechanisms driving stability and instability in impulsive systems, offering a basis for enhanced models that can predict and adapt to rapid state changes. These results have practical implications for fields requiring precise prediction of dynamic behaviors, including control systems, biological modeling, and economic forecasting. By enhancing the predictive accuracy and reliability of models incorporating impulsive dynamics, this research advances the analytical toolkit available for handling complex, real-world problems with discontinuous behaviors.