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An Intelligent Solution to Fractional Order Controller Tuning Problem Using Whale Optimization Method

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***Abstract*— In this paper, design and implementation of various fractional order controllers designed using an artificial intelligence based modern meta-heuristic optimization algorithm has been demonstrated for solving a real world control problem of the magnetic levitation system (Maglev). fractional order calculus (FOC) plays a significant role in control theory, offering several advantages in modeling and controlling complex systems. FOC has gained a lot of research interest as a state-of-the-art control system design procedure. Basically fractional order controllers are a sub-application of FOC which provide accurate modelling, enhanced system performance, better stability and improved robustness compared to traditional integer order controllers. Therefore this study is concentrated on design and comparative analysis of fractional order (FO) lead, lag-lead and PID controllers based on a newly developed optimization algorithm known as Whale Optimization Algorithm (WOA). The objective function for controller parameter optimization is formulated using a standard error based performance metric namely integral square error (ISE). The simulation analysis signifies that the optimum performance is exhibited by the proposed FOPID controller.**

Keywords*— *Fractional order lead controller, FOPID controller, whale optimization, ISE performance index, maglev system control

I. INTRODUCTION

With the recent advances in modern engineering and technology, magnetic levitation technology [1] has been emerging as an important area of scientific interest. Magnetic levitation system (Maglev) finds its applications in various aspects of human civilization like in transportation: high speed Maglev trains [2], in industry: contactless active magnetic bearings [3], electromagnetic aircraft launch system, magnetically levitated wind turbines so on and so forth. Due to its wide area of application, electromagnetic levitation system has successfully attracted a great deal of attention of scientists and researchers all around the globe over the past few decades.

The term "magnetic levitation technique" essentially describes a mechanism in which any ferromagnetic substance can be levitated and suspended in mid-air without any discernible mechanical or physical support through the use of electromagnetic forces. So, it is quite obvious that the dynamical characteristic of the Maglev is intrinsically unstable and highly non-linear [4]. Due to these reasons the control and stabilization of Maglev has become a critical and challenging task which is continuously motivating control engineers to implement various control strategies to improve stability and dynamic performance.

An extensive literature survey has been carried out in this regard to demonstrate various control techniques that are implemented in Maglev systems. As in classical control approach cascaded lead-lag controller, lead-PI controller and PID controllers are mostly designed [5]. As reported in [6]; two control loops comprising of outer position control (lead controller) loop and inner current control (PI controller) loop can provide simultaneous stabilization and performance improvement. For obtaining large-gap control, authors have successfully implemented a piecewise linear control scheme [7] which is relatively simple and easy to implement. A piecewise linear controller can effectively handle a non-linear system operating at different equilibrium points.

As far as practical and industrial control problem is concerned, there are several nonlinear control methods reported in the literature. Sliding mode control [8], H_2 and H_∞ control [9], feedback linearizing techniques [10] are the few examples of non-linear control strategies. A non-linear model is developed and validated in [11], and then feedback linearizing technique is used to control the ball position. In some other works input-output, input-state and exact linearizing techniques are used to develop non-linear controllers.

Since the domain of artificial intelligence (AI) and soft computing techniques are rapidly evolving, design of sophisticated feedback control mechanism utilizing nature inspired or societal phenomenon based optimization algorithms [12] is now become a popular practice among the researchers and engineers around the world. Online parameter of Fuzzy PID controller for traction control of Maglev train has been extensively investigated in [13]. Optimized precise position control of magnetic levitation system with an application of adaptive resonant technology is proposed in [14]. PSO optimization based [15] controller design for Maglev is also demonstrated. In [16] controller tuning methodology using Grey Wolf Optimization (GWO) is provided. Further works have been carried out to demonstrate

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