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Control of smart non-linear base-isolated structures using optimal adaptive neural network-based PID controller

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ABSTRACT: This paper aims to propose an adaptive control approach for the PID controller known as ANN-OPID controller with simultaneous use of the advantages of the classical PID controller and neural networks so that it can provide better seismic performance than the optimal PID controller tuned by the teaching–learning-based optimization (TLBO) algorithm. In this approach, the structural dynamic is estimated using a neural network block and hence the parameters of the PID controller are adjusted adaptively. The seismic performance evaluation of the proposed controller is compared with the conventional optimal PID controller for an 8-story smart base-isolated structure subjected to various near-field and far-field earthquakes. Overall, the results obtained for the studied structure subjected to six earthquakes show that the TLBO-PID controller leads to a reduction of 24% and 25% in the maximum base displacement and its root mean square (RMS), an increase of 24% and 11% in the maximum acceleration and its RMS of superstructure floors and an increase of 6% and 6% in the maximum drift and its RMS of superstructure floors. However, the proposed ANN-OPID controller approach causes a reduction of 35% and 33% in the maximum base displacement and its RMS, a reduction of 9% and 7% in the maximum superstructure acceleration and its RMS, and a reduction of 5% and 6% in the maximum drift and its RMS of superstructure floors. Consequently, the proposed ANN-OPID controller can give a simultaneous reduction of the base displacement, acceleration, and drift of superstructure floors, while the TLBO-PID controller reduces the base displacement at the cost of an increase in acceleration and drift of superstructure floors.

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1- Introduction

Seismic isolation is a practical accepted method to simultaneously reduce the acceleration and relative displacement of the structure floors. However, structures equipped with seismic isolators often experience significant deformation in near-field earthquakes [1]. Equipping base-isolated structures with active and semi-active seismic control tools is an effective solution to overcome this problem [2-3].

In the field of controlling structures against earthquakes, PID controllers have been noticed by researchers as a controller with powerful structures [4-6]. However, the setting of PID controller parameters are interdependent, and changing any of these parameters can change the effect of each of these parameters; Therefore, although this controller has only three parameters, it is not easy to find the optimal values of these parameters without the need for a systematic process for the seismic control plan of structures.

Considering the complex dynamic behavior of structures and the random nature of the ground motion, the use of adaptive control structures for seismic control of structures can be a smart choice; Therefore, in this paper, a control approach using the advantages of classical PID controller and neural networks is proposed for seismic control of structures. The proposed controller is an optimal adaptive PID controller based on a neural network known as ANN-OPID. It is implemented for an 8-story smart base-isolated structure. The seismic performance of the proposed controller in different near and far faults and earthquakes is then compared with an optimized PID controller using the TLBO algorithm named TLBO-PID.

2- The design procedure of the proposed ANN-OPID

Considering the complex seismic dynamic behavior of structures as well as the exciting many uncertainties in the nature of ground motion, using adaptive control structures can be a smart choice. The block diagram of the proposed neural network-based optimal adaptive PID controller, ANN-OPID, is shown in Figure 1. In this control strategy, the input of the PID controller block is the velocity signal of the base story of the base-isolated structure. The neural network block is used to estimate the dynamic behavior of the structure online. By using the dynamic estimation of the structural system by the neural network block, the parameters of the PID controller can be adjusted adaptively.

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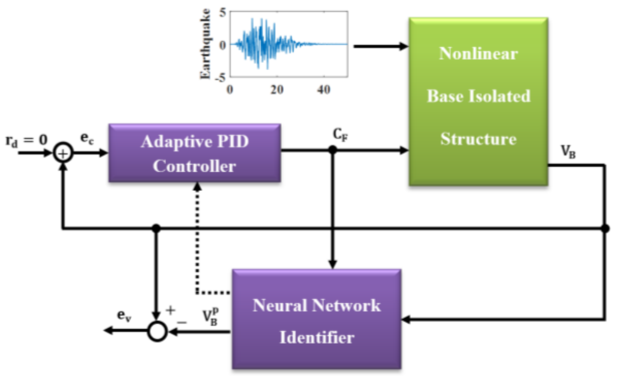

Fig. 1. Block diagram of the implementation of ANN-OPID controller

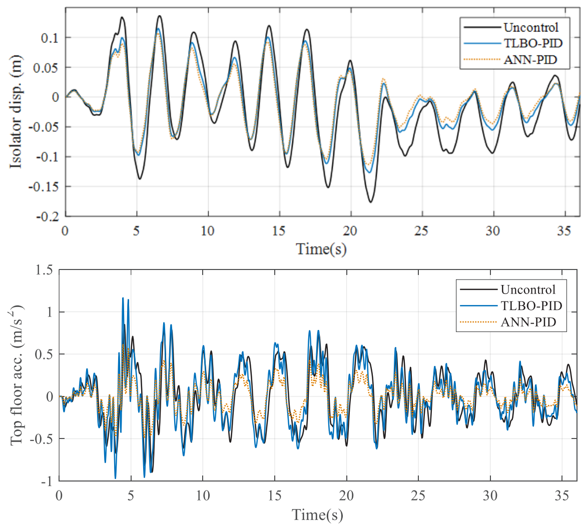

Fig. 2. Comparison of the time history of a) base displacement and b) roof acceleration under the Hachinho earthquake record

3- Results and Discussion

Numerical studies have been carried out on an 8-story base-isolated structure. The time responses of the structure in three states: uncontrolled, controlled with the TLBO-PID controller, and controlled with the proposed ANN-OPID controller were analyzed under the records of six earthquakes including Duzce, Kocaeli, El Centro, Hachinohe, Kobe, and Northridge.

For a comparison of the performance of the two controllers, during the earthquake time, the time history of the base displacement and the acceleration of the top floor during the Hachinohe earthquake as a far-field earthquake is shown in Figure 2. Similarly, the time history of base displacement and top floor acceleration during the Northridge earthquake as a near-field earthquake is shown in Figure 3.

It can be seen that although both controllers have a good performance in reducing the displacement of the isolator level in near-field and far-field earthquakes, the ANN-OPID controller shows better performance in this regard.

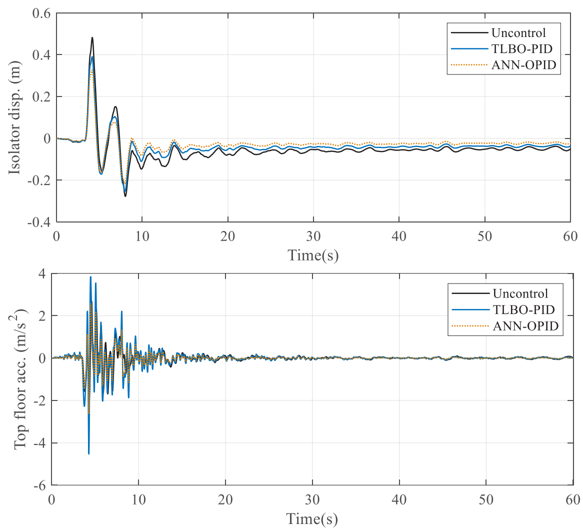

Fig. 3. Comparison of the time history of a) base displacement and b) roof acceleration under the Northridge earthquake record

4- Conclusions

To simultaneously use the advantages of classical PID controllers and neural networks, an adaptive control approach called ANN-OPID was proposed for use in smart base-isolated structures. In this approach, the dynamics of the structural system were estimated by the neural network block, and the PID controller parameters are adjusted accordingly. To evaluate the seismic performance of the proposed control approach in comparison with the TLBO-PID controller, an 8-story structure equipped with nonlinear isolators was simulated. The studied structure was subjected to six different near-field and far-field earthquakes. The results show that the TLBO-PID controller has led to a 24% and 25% reduction in the maximum displacement of the base story and its RMS, while this controller has caused a 24% and 11% increase in the maximum acceleration of the superstructure, and an increase of 6% and 6% in the maximum drift and its RMS of superstructure floors. The proposed ANN-OPID controller approach has reduced the maximum displacement of the base story and its RMS by 35% and 33% and 9% and 7% in the maximum acceleration of the superstructure floors and their RMS. It has also caused a reduction of 5% and 6% in the maximum relative displacement of the floors and its RMS; Therefore, while the reduction of the displacement of the isolator level as a result of using the TLBO-PID controller has been achieved at the expense of increasing the acceleration and relative displacement of the floors, the proposed ANN-OPID controller further reduces the displacement of the isolator level, and it has also reduced the acceleration and relative displacement of the floors.

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