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A Review of Smart Structures Vibration Control Strategies

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Abstract— *The expert system and artificial intelligence are still important modern technologies. A structure can modify its behavior under dynamic stresses by using active controls. The term "intelligent" or "smart" structures refers to these self-modifying structures. The structural engineering discipline may experience a revolution thanks to smart structure technologies. Particularly for huge structures, It is anticipated to have major effects. Effects with regard to the avoidance of fatalities and damage to the structure and its contents, particularly with regard to huge buildings that have thousands of elements. An efficient control algorithm to establish the magnitude of the actual forces to be applied to the construction is one of the most critical components in the successful use of smart active control technology. An overview of the primary active control approaches for the reduction of vibration in intelligent mechanical and civil structures that are subject to external dynamic loads is provided in this study. Different control algorithms' benefits and drawbacks are examined. Finally, recent advances in the study of control algorithms are highlighted, including the use of multiparadigm strategies, decentralized control, deep learning techniques applied to neural networks design of controls for sustainability, and a merging of the domains of vibration control and structural health monitoring.*

Index Terms— *Vibration control, Smart structures, Magneto-rheological damper, Control system, Dynamic Models, Control algorithm.*

I. INTRODUCTION

Skyscraper demand has gone up significantly all around the world. Advances in technology and material engineering allow for new design concepts in developing higher and safer buildings, such as skyscrapers, airport towers, and bridges, which provide structural engineers and researchers with significant problems. The impacts of wind and earthquakes on these buildings are unquestionably the most crucial challenges among the numerous complex technical problems involved in the design. The most difficult aspect to do is to ensure that both the serviceability and safety (strength) requirements are properly examined and met in the design[1]. Structures may be damaged as a result of the resulting vibration, and their performance may be insufficient. The induced vibration can be very uncomfortable if not fatal, Structures experience resonance as a result of earthquakes, winds, or other external forces. When the force frequency (earthquakes, winds, or any external force) is very close to the natural frequency, resonance develops, resulting in huge amplitude levels and vibrations. Shifting the external forcing frequency or changing the natural frequency of the structure itself are two options for avoiding resonance. As a result, structural designers have long recognized vibration control of structural systems as an important technical competitive factor in order to improve structural integrity and performance[2]. With the development of new smart materials such as Piezoelectric materials: Piezoelectric materials generate an electric charge in response to mechanical stress. When used in a vibration control system, these materials can convert the vibration energy into electrical energy [3], construction methods, and efficient elevators, the fabrication of towering structures remains

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competitive today. The building name, year of completion, height, and number of stories of the current tallest buildings in the world as mentioned in the articles[4] are included in Table I. These structures are vulnerable to lateral forces such as earthquakes and wind. See *Fig.1* Skyscraper structural design must therefore include a structural vibration control plan and vibration mitigation.

FIG. 1. EARTHQUAKE EFFECT ON TALL BUILDING[4].

The fundamental principle behind the control of vibration is to apply vibrations to a dynamic system's linear or nonlinear parameters in order to change the system's attributes in the intended manner and make the system is unaffected by brief motions and outside disturbances[5][6]. Depending on how often multi-hazard excitation occurs structure reacts differently to external disturbances such as wind, which resembles force-type loading, and earthquakes, which resemble displacement-type loading.

TABLE I. CURRENTLY, THE WORLD'S HIGHEST STRUCTURE [4]

Building name	Completed year	Height (m)	No. of stories
Petronas Tower 1 and Petronas Tower 2	1998	452	88
Taipei 101	2004	508	101
Shanghai World Financial Center	2008	492	101
International Commerce Center	2010	484	108
Burj Khalifa	2010	828	167
Makkah Royal Clock Tower Hotel	2012	601	120

This work was organized as follows. The second section presents a general review of the subject of vibration control in structures, clarification and explanation of the different mechanisms and methods used in vibration control, and the general details of each method and the mechanism of its use. In the third section of the work, a general definition of a Magneto-rheological damper is presented. The fourth section explains and reviews the literature related to the Dampers' Parametric Dynamic Models and how to apply each case and the special equations for each case. The dampers' control techniques are

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presented in the fifth section. In the sixth section, the authors' opinion was expressed about the future work that can be applied through the literary article, while the last section included the general conclusions of the literary article.

II. VIBRATION CONTROL OF STRUCTURE

1. Passive Control Systems

The most prevalent structural control mechanisms are passive control systems, as the one shown in *Fig. 2*. Passive systems are used to disperse the vibrational energy. Equipment for energy dissipation and earthquake isolation primarily falls within this category [8].

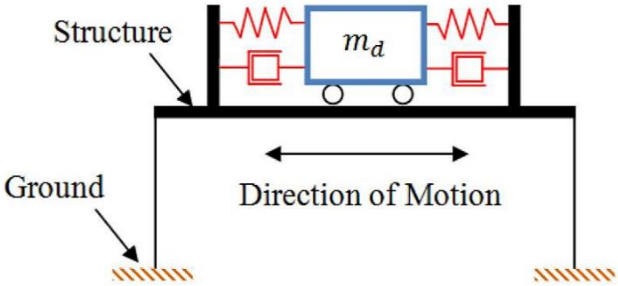

FIG. 2. SCHEMATIC OF A PASSIVE CONTROL SYSTEM[8].

The system's ability to provide a bigger damping force as the structural reaction grew was previously seen as its cleverness. Its benefits include its simple design and assembly as well as the absence of any external energy source during excitation[11].

2. Semi-Active Control Systems

Semi-active control systems are a type of active control system that needs less external energy than traditional active control systems. As seen in *Fig. 3*, semi-active control devices are frequently considered as controlled passive devices [2]. The behavior of the damper is governed by the acquired data on the building's excitation and reaction. Sensors, a control computer, control actuators, and a passive damping device are all included in this system, as well as a modest power supply. It's worth noting that the semi-active system can not control everything because it is restricted by the capability of the installed passive devices[12].

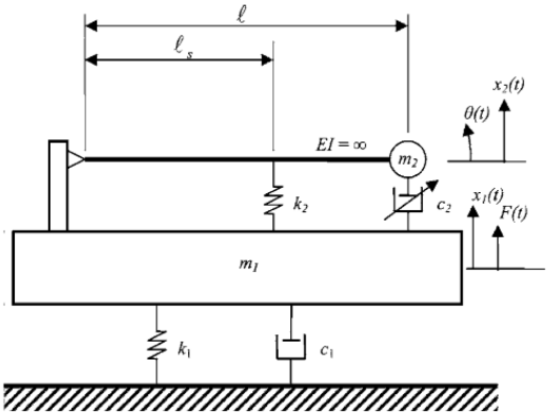

FIG. 3. SEMI-ACTIVE PENDULUM TMD SYSTEM USING A MAGNETO-RHEOLOGICAL DAMPER [11].

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3. Active Control Systems

An active control device makes use of control actuators that use an external power source to deliver predetermined forces to the building. These forces, as shown in *Fig. 4*, can be utilized to change the structure's energy balance. In an active feedback control system, the signals that are sent to the control actuators depend on how the system reacts as determined by physical sensors (for example, optical, mechanical, electrical, and chemical) [13].

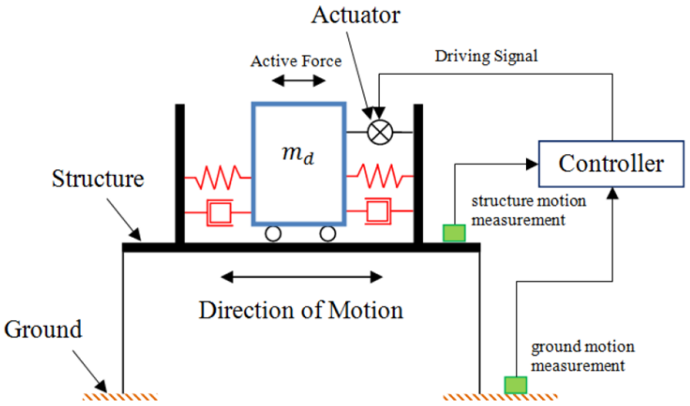

FIG. 4. SCHEMATIC OF AN ACTIVE CONTROL SYSTEM [12].

4. Hybrid Control Systems

Passive, active, and semi-active information from a hybrid control system is delivered in parallel or in series. This system has emerged as a viable choice since it offers the benefits of passive, active, and semi-active control systems. The passive component aids in reducing structural reaction and maintaining performance standards that are reasonable for the structure. The active component is utilized to adjust and modify the reaction. Therefore, hybrid control devices are successful in defending structures exposed to a variety of stimuli with varied intensities and frequency ranges, as demonstrated in *Fig. 5* [14].

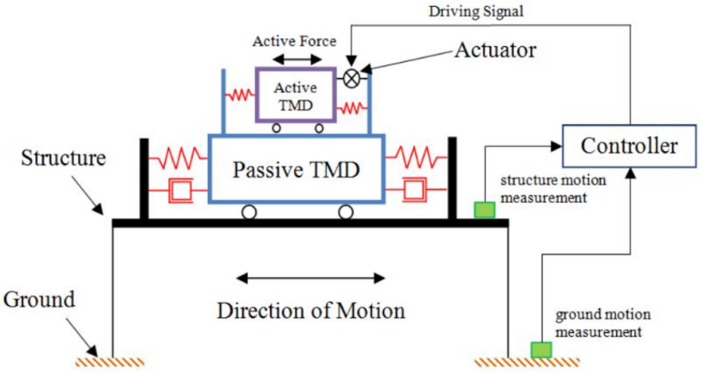

FIG. 5. SCHEMATIC OF A HYBRID ACTIVE TUNED MASS DAMPER [13].

5. Smart Control Systems

In order to withstand external dynamic forces like earthquakes, wind, or collisions, a smart structure uses sensors to assess its dynamic loading environment and dynamically adapts to that environment in real-time. A smart framework is created with an estimated number of strategies that will be actively regulated. Each part has a sensor, a feedback control device, and an actuator. Along the degrees of freedom, the sensor will stack the displacements that it measures. After the feedback

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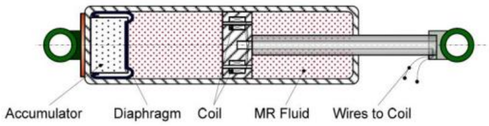
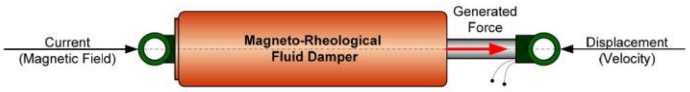
control system determines that the uncontrolled reaction has been appropriately corrected, the actuator will then apply the requisite force.[15].

III. MAGNETO-RHEOLOGICAL DAMPER (M.R. DAMPER)

The magnetorheological damper was chosen to provide the actuator device because it offers the optimum balance between the required power and flexibility to continue to provide protection even when the device is not activated. Its typical components include a piston, magnetic coils, an accumulator, a bearing, a seal, and an M.R. damper reservoir filled with magnetic resonance fluid[16]. Orifices in the piston head enable MR fluid to pass from the high-pressure area to the low-pressure area as the piston rod enters the housing with this damper as shown in *Fig. 6*.



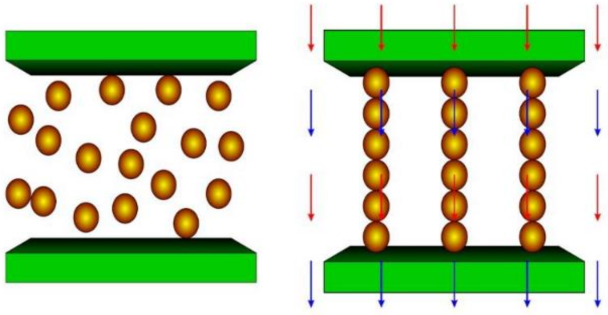
(a) Hardware structure



(b) Working principle

FIG. 6. MAGNETO-RHEOLOGICAL DAMPER [15].

The accumulator has three purposes: (1) to soften the force of the piston rod by adding the housing by accommodating volume changes; (2) to accommodate the fluid's thermal expansion; and (3) to prevent cavitation magnetic resonance fluid piston motion. The properties of the M.R. Damper are modified by the magnetic field that the magnetic coils print in the activation zones. As a result, the physical parameters of the magnetic resonance damper are controlled by the input current value for the magnetic coils; the maximum force delivered by an M.R. damper depends on the features of (a) the M.R. fluid used, (b) the fluid's flow pattern, and (c) the damper's size [15]. Fluids or soft materials that display varied mechanical properties when subjected to magnetic fields are known as magnetorheological dampers. By adjusting the external magnetic field, the particles in conventional M.R. dampers acquire a dipole movement aligned with the field, ensuring the suspension's stability and increased rigidity of the material. This procedure gives the ability to manage vibration, so it offers quick reactions, strong damping, and continuous range adjustment[17][18], as shown in *Fig. 7*.



(a) Without Magnetic Field (b)With Magnetic Field

FIG. 7. M.R. OPERATING A DAMPER (A) MAGNETIC FIELD-FREE (B) HAVING A MAGNETIC FIELD [16].

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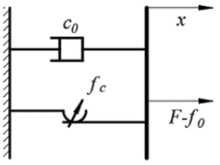
IV. THE DAMPERS' PARAMETRIC DYNAMIC MODELS

In a generalized model, the modeled damper is viewed as a theoretical shock absorber constructed of optimum mechanical components whose characteristics depend on both pertinent experimental results and boundary conditions. The Bingham model has been the current parametrized dynamic model[19], the adapted Bingham model[20], the models by Bouc-Wen, the model of phenomenology[21], and the bi-viscous hysteretic model[22].

1. Bingham's Model

It can explain the energy dissipation in the dampers and the force-displacement properties of the MR damper. However, It does not show how the damping force and speed are related., particularly in the low-speed zone, nor does it depict the relationship between the direction's velocity and displacement[19].

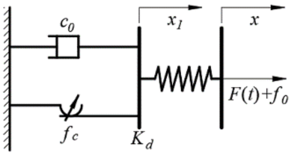


$$F = f_c \operatorname{sgn}(v) + c_0 v + f_0 \tag{1}$$

where F is the damping force generated by the MR damper, v is the velocity of the damper, f_c sgn(v) is the sign function of v, C_0 is the damping coefficient, and f_0 is the offset force. The sign function of v is a function that returns the sign of v, which is either -1, 0, or 1, depending on whether v is negative, zero, or positive, respectively.

2. Bingham's Model, as Modified

Even when the field of magnetic intensity is changeable, most of the MR dampers' dynamic characteristics may still be adequately described, but additional parameters must be measured [19].

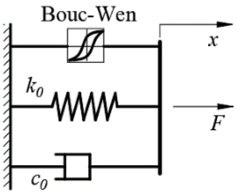


$$\begin{aligned} F &= c_0 \dot{x}_1 + f_c(E)\operatorname{sgn}(\dot{x}_1) - f_0 \\ &= k_d(x - x_1) - f_0 \end{aligned} \tag{2}$$

Where k_d is the stiffness of spring effected by the dumping force for the MR dumper.

3. The Bouc–Wen Model

An MR damper's properties of force based on its displacement and its velocity are well described., yet, The yield zone is resistant to roll-off., When the operating signals and simple velocities are the reverses of the acceleration indicator[23].



$$\begin{aligned} F &= c_0 \dot{x} + k_0(x - x_0) + \alpha z \\ \dot{z} &= -\gamma |\dot{x}||z||z|^{n-1} - \beta \dot{x} |z|^n + A\dot{x} \end{aligned} \tag{3}$$

where x is the displacement of the system, c_0 is the damping ratio, β is the shape parameter, and γ is the hysteretic parameter. A is the external excitation force applied to the system.

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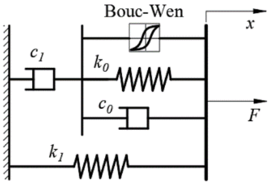
4. The Adapted Bouc-Wen Design

A prototype is compatible with the actual experimentation result and does a good job of describing the nonlinear properties of the dampers and the indifferent velocity areas, Nevertheless, more characteristics must be identified by measurement[21].

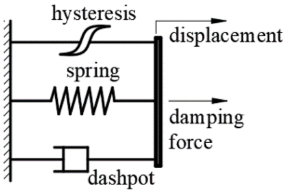


$$F = c_1\dot{y} + k_1(x_1 - x_0)$$
$$\dot{y} = \frac{1}{c_0 + c_1}\left[\alpha z + c_0\dot{x} + k_0(x - y)\right] \qquad (4)$$
$$\dot{z} = -\gamma\left|\dot{x} - \dot{y}\right|\left|z\right|^{n-1} z - \beta(\dot{x} - \dot{y})\left|z\right|^{n} + A(\dot{x} - \dot{y})$$

The adapted Bouc-Wen model provides a more accurate representation of the hysteresis behavior of a system under different operating conditions. It can be used to design systems that exhibit specific performance characteristics under different temperature and aging conditions. The adapted Bouc-Wen model has been used in a variety of applications, including the design of smart structures, vibration control of buildings, and the analysis of fatigue in materials.

5. Model Based on the Hyperbolic Tangent Function

Rate-dependent, as well as rate-independent examples of Terfenol-magnetic D's hysteresis, can be adequately modeled [22].



$$F = c\dot{x} + kx + \alpha z + f_0$$
$$z = \tanh(\beta(\dot{x} + \delta sign(x)) \qquad (5)$$

where F is the damping force, and , β is a parameter that represents the slope of the hyperbolic tangent function and δ is the hysteretic parameter.

V. THE MR DAMPERS' CONTROL TECHNIQUES

The mathematical representations of the MR dampers are essentially some descriptions of the damping force that occurs when the particular dampers operate by the relevant operating state of the MR damper. Three basic components, called the contained sensors, controllers, and actuators, make up the MR damping system. The controller is in charge of receiving data from the sensor, and processing It does this by applying the built-in control algorithm, transmitting the analysis results to the actuators, and allowing the MR damper to regulate the output of the damping force. The MR damping control's main components are control methods and control algorithms[24].

1. Traditional Control Techniques

The term "Traditional Control Techniques" designates a group of techniques for modifying a target system's damping coefficient based on different kinds of displacement, such as:-

A. Damping Control Method Using Skyhooks

When force generators' semi-active vibration control method was being investigated, Karnopp et al. [20] presented the primary idea of the Skyhook damping control, a damping control method, which was to modify the coefficient of damping. In a Skyhook algorithm, the damping coefficient [25] is defined by:-

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$$c = \begin{Bmatrix} c_{d\,\mathrm{max}} \rightarrow c_s > c_{d\,\mathrm{max}} z^{\cdot}(z^{\cdot} - q^{\cdot}) \geq 0 \\ c_s z^2 - q^{\cdot} \rightarrow c_s < c_{d\,\mathrm{max}} z^{\cdot}(z^{\cdot} - q^{\cdot}) \geq 0 \\ c_{d\,\mathrm{min}} z^{\cdot}(z^{\cdot} - q^{\cdot}) \end{Bmatrix} \tag{6}$$

where c and cs are the required and real damping coefficient within the shock absorber, respectively, z and q are the vertical suspension position and the road profile, and cd max and cd min are design variables of the partially active shock absorbers. When the device's body's absolute velocity was going the same way in this semi-actively regulated dampening as the relative speed with low-velocity feedback, the damper could work with an analogous coefficient of damping. If not, The damper was unable to be working and the vibration could not be minimized. Due to the car's relatively simple mechanism, technology has been employed to reduce vibrations in the body. Additionally, a discernible increase in Comfort suspension has been noticed [24].

B. The Method of Passive Control

A steady current is applied to the damping control system by the controls of the MR dampers passively. The passive control strategy has two modes: passive-off controller, where the Zero continuous current exists., and passive-on controller, The value of the constant value of current is at its maximum[26]. Applications of the passive control approach typically include low-requirement vibration reduction features, as in the case of stay cables and building structures, which have both been reported to be subject to vibration control in challenging environments[27].

2. Active Structural Control Techniques

Through an external control force, the structural control mechanism aims to lessen vibration and improve the building's lateral integrity caused by earthquakes or strong winds [28]. To decrease structural vibration in an active control system, it is crucial to building one controller that can transmit the right control signal to the control devices. The control approach should be easy to implement, reliable, fault-tolerant, and not necessarily ideal[29].

2.1. Linear and Nonlinear Control of Building Structures

PID Control: Numerous studies have been undertaken on the proportional-integral-derivative (PID), especially for systems that just have one or two degrees of freedom (DOF). Because of the complexity of the control algorithm for multivariable systems, they are not suited for applications like vibration management of Multy dgree of freedom MDOF flexible structures. A simulation was run for a straightforward proportional controller, which was found to be ineffectual for strong earthquake excitation but capable of reducing building displacement for wind excitation [30]. Two PD controllers were employed in[31] to manage two actuators put in place on the first and last floors. The command law is described as:

$$u(t) = K_p \left[e(t) + K_d \frac{dt(t)}{dt} \right] \tag{7}$$

where e(t) is the position error, K_p and K_d are the proportional constant and derivatives time, respectively.

***H_∞*Control:** The method is one of the most utilized a robust linear control systems for controlling structural shaking This method is excellent for multy input multy output MIMO-type structural control systems since it is sensitive to disturbances and parametric fluctuations[32] A new discrete-time robust H2/H control technique was introduced by Li and Adeli[33] where, as opposed to the frequency

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domain, the uncertainty of the structural parameters are considered. They employ a quadratic performance index that allows for the active control of large-scale, complex systems. A ten-story frame with an active tuned mass dumper ATMD system and an active bracing system (ABS) for a three-story frame are both subjected to the new control algorithm.

Optimal Control: The ensuing algebraic Riccati and Lyapunov matrix equations offer the best nonlinear controller, which is a polynomial of any order. This is because these equations take into account the structural states., and the best control law are solved to get the control gain matrices and Based on the Hamilton-Jacobi-Bellman (HJB) equation's solution, a performance index is constructed and minimized that is quadratic in control and polynomial of any order of structural states[34]. The linear quadratic regulator is the most fundamental and often utilized adaptive controller (LQR). The allowable range of structure displacement and acceleration is taken into account as the cost function that needs to be minimized for structural control applications. Structures' states are occasionally assessed indirectly by means of observers like Kalman filters. Linear Quadratic Gaussian (LQG) is the result of adding a Kalman filter to an LQR control method [35]. To put it another way, LQG is created by fusing LQR and the linear quadratic estimator. Typically, these LQG are used in systems with Gaussian white noise[36].

Sliding mode control (SMC): It is one of the powerful control approaches that is employed the most frequently. Using a switching control rule to steer the system's state trajectory onto a preset surface in the state space and to sustain it there over time is the way to achieve a globally asymptotically stable system. This can be done to achieve a worldwide asymptotically stable system. When it comes to the control of structural vibration, this surface corresponds to the dynamics of the system that one would want to see. For structural control applications, SMC is a superior option due to its tolerance to uncertainty and parameter changes. It is stated that the nonlinear control force is

$$u = u_{eq} - \eta \operatorname{sgn}(\sigma(t)) \tag{8}$$

where η is the design parameter that ensures the system trajectories arrive at the sliding surface in a finite amount of time[36], $\sigma = [\sigma 1, ..., \sigma_n]$ are the n sliding variables, and u_{eq} is the linear term that represents the equivalent control force.

2.2. Intelligent Control

Large nonlinear structure vibration management is still a difficult challenge because (a) external stresses and identification of the structural system are both subject to uncertainty, and (b) the time-varying features of the structural systems are unknown. Complex and substantial mechanical systems can be controlled nonlinearly using artificial intelligence algorithms computational intelligence-based (CI) stands for Computational Intelligence, which refers to a set of methodologies and techniques used in artificial intelligence and machine learning to solve complex problems and sophisticated signal processing methods.

Neural Network Control: The massively parallel nature, learnability, and promise for solving problems in various fields have made Neural Network (NN)-based systems very popular in recent years [53-56]. They offer a broad framework for the modeling and management of nonlinear systems, including those found in building structures. In order to forecast upcoming structural reactions and the sensitivity of the control signal to forecasting those responses, Ghaboussi and Joghataie[37] worked on learning the relationship between the control force signal sent by the actuator and the structural response, the proposed NN-based control algorithm was applied to a three-story structure with active tendon systems that are subjected to ground movements. Their results serve as a demonstration of NN-based model efficacy. A nonlinear three-DOF steel frame model was used by Bani-Hani and Ghaboussi [37], and the control technique provided by Ghaboussi and Joghataie [38] was applied. In[39] work,

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Vadtala, Soni, and Panchal used a semiactive controller based on the integration of Artificial Neural Network ANN and LQR control to tackle a six-story benchmark problem.

Fuzzy logic controllers FLC: Fuzzy logic theory and related membership functions serve as the foundation for fuzzy logic controllers[40]. *Fig. 8* shows the basic organization of fuzzy logic controllers. An inference engine uses fuzzy logic operations to determine the control activation, a defuzzifier creates the necessary crisp control value from the determined fuzzy control action, and Fuzzy logic is used by a fuzzifier to convert the sharp values of the input into the values of the linguistic variables. All of these steps are performed using fuzzy logic. The FLC design incorporates fuzzy sets, rules, inference methodology, and defuzzification [41].

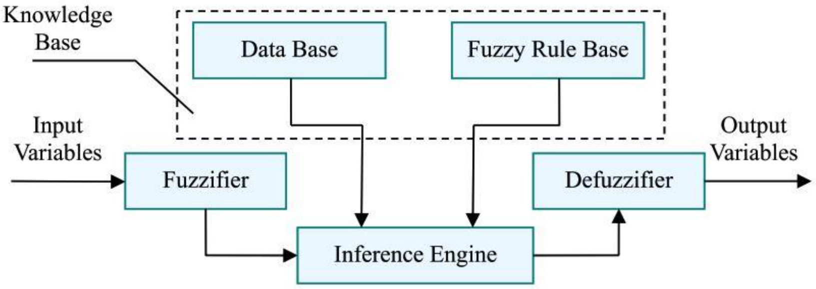

FIG. 8. FUNDAMENTAL ELEMENTS OF A FUZZY LOGIC CONTROLLER.

Peak inter-story drift and floor acceleration serve as the two-goal functions in Ahlawat and Ramaswamy's [41] multi-objective optimal design formulation using the FLC to control seismically excited nonlinear building systems in both active and hybrid modes. Applying the FLC to benchmark control challenges, such as three conventional steel structures, three nine-story buildings, and 20-story building structures has increased FLC-driven active and hybrid control systems' performance.

Huek and Narenathreyas [42] propose a fuzzy logic controller for the longitudinal motion of an airplane based on the Takagi-Sugeno model. Its usefulness was demonstrated by its application to a transport aircraft with a shorter range. To determine the best values for the controller gains in a power system, the Particle swarm optimization PSO method is used. Tavakolpour- Saleh and Haddad [43] To adjust the control gain using the fuzzy robust control technique, propose it for a flexible plate system with nonlinear electromagnetic actuators.

2.3. Algorithms for Decentralized Control

A total failure of the centralized control system is also possible since it contains a single non-redundant point of failure that can be harmed by external forces powerful enough to harm controller components like the computer system, actuators, or sensors. Decentralized control, which divides the control system into a number of smaller decentralized systems managed locally by decentralized controllers, has been developed to address the aforementioned drawbacks. For instance, the massive structural system depicted in *Fig. 2* can be broken down into the group of substructures depicted in *Fig. 9*, Control calculations can be run concurrently in a distributed computing environment in a decentralized system. When compared Control systems that are centralized and decentralized (a) improve the control system's robustness and reliability against operational and power failures, (b) due to the fact that each control unit is given its own computing unit, computational efficiency is increased., (c) lowers the amount of communication needed, and (d) uses less energy[44].

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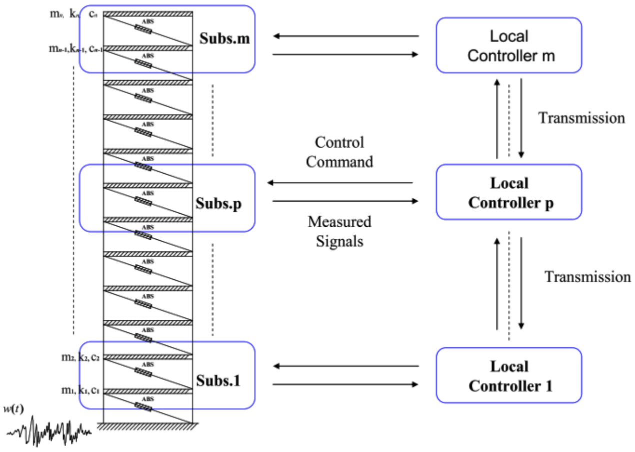

FIG. 9. SCHEMATIC OF DECENTRALIZED CONTROL SYSTEM[44].

Rofooei and Monajemi- Nezhad[45][46] used instantaneous SMC and optimal control algorithms to determine each substructure's control force, it has suggested 15-story and 30-story building constructions subjected to subsurface motion: decentralized vibration control. By using the LQG control method to gather control data from each substructure, Loh and Chang[48] analyzed both centralized and decentralized control of a standard building with 20 stories using the four different control systems. A small-scale model of a high-rise building with sixty stories was used in an experiment involving a shaking table and a vibration control system[47]. The goal of the experiment was to reduce the amount of vibration in the model., Giron and Kohiyama [47] described a decentralized control method based on SMC. A decentralized networked switching control approach based on LQG and neural network control algorithms was described by Bakule, Reh'ak, and Pap'k[50] for the purpose of controlling ground vibrations that affect building structures.

VI. MAIN CONTRIBUTIONS AND RECOMMENDATIONS FOR FUTURE WORK

This study provides a historical overview of structural vibration control techniques. However, it should be noted that in each field a study of the current state of the art is required and that the search for new ideas is obligatory. In contrast, in the field of structural vibration control, there is an ongoing drive for improvement and performance. Recent publications, studies, and efforts continue to explore and construct novel control techniques and methods. A frequency domain analysis and decomposition can be utilized to create passive control devices. Moreover, the emergence of adaptability, observability, hybridization, and optimization technologies can promote the development of novel concepts for civil engineering-controlled structures. This is a brand-new field of study that can be evaluated with an improved control algorithm and the right actuators and dampers for outrigger structural control. Big data techniques used to improve the performance of tall building vibration control techniques can be employed to regulate the damped outrigger structure by combining adaptive control, stochastic optimum control, robust control approaches, and other structural forms and can be included. Application of machine learning techniques[48][49] such as deep neural networks [50][50][51] for creating learning-capable adaptive control systems. Robust decentralized control algorithms are a viable control method for big intelligent mechanical and civil structures and can be used in multi-objective and many-objective optimization methods to design for sustainability, maximize structural system effectiveness, and minimize controller energy usage[52].Table II provides a summary of the key benefits and drawbacks of the control algorithms examined in this study. The main contributions of the paper compared to other relevant previous works are illustrated by the

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following points: a) The study included all types of control systems used in controlling vibration in structures and clarified the mechanism for each system, while most of the studies included a study of reviews related to a specific control system without the other .b) The summary of the paper included an explanation of the advantages and disadvantages of 8 main theories of control strategies used effectively in control systems controlling vibrations resulting from earthquakes and various external disturbances. c)Focusing on the study of the semi-active system and clarifying the mechanism of the control device MR Damper in all its details, and mentioning the previous reviews regarding the use of this type because it is an effective and commonly used system.

TABLE II. SUMMARY OF THE BENEFITS AND DRAWBACKS OF THE CONTROL ALGORITHMS

Method of control	**Benefit**	**Drawbacks**
1-PID control	Simpleness of the design Simpleness of execution	Linear structural model that is accurate used primarily to regulate linear constructions Need for full-state feedback
2-Pole arrangement control	Simpleness of the design Simpleness of execution	Linear structural model that is accurate mostly utilized to regulate linear structures Need for full-state feedback
3-LQR control	Simpleness of the design Simpleness of execution	Linear structural model that is accurate used primarily to regulate linear constructions Need for full-state feedback
4-LQG control	Simpleness of the design Simpleness of execution There is no need for full-state feedback.	Linear structural model that is accurate assuming the disturbance is caused by mechanisms producing Gaussian white noise Used primarily to regulate linear constructions
5-$\boldsymbol{H}_{\infty}$Control	No need for a precise structural model Simpleness of execution enhanced robustness	The design's complexity Used primarily to regulate linear constructions
6-SMC control	No need for a precise structural model Simpleness of execution enhanced robustness Work with linear and nonlinear structure	Effect of excessive chattering
7-Intelligent control	No need for a precise structural model Enhanced reliability and robustness Enhanced control effectiveness	The design's complexity
8- Decentralized control algorithms	Improved durability and dependability Increased computational effectiveness Less energy is needed	The design's complexity

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VII. CONCLUSIONS

Due to the evolution and recent advancements in intelligent materials, intelligent dampers, improved sensors, contemporary signal processing techniques, and more powerful computers, active and semi-active vibration control of intelligent structures has been recognized as one of the most active and challenging areas of structural engineering research. This is because active and semiactive vibration control of intelligent structures has been recognized as one of the most active and challenging areas of structural engineering research. An efficient active control algorithm is the key to effectively employing active control technology in intelligent structures. An overview of the primary active control algorithms utilized in intelligent mechanical and civil constructions was provided in this work. Despite being a developing practice and a relatively recent development in construction. The behavior of large structural systems is presented in a brief discussion of stochastic vibration control, big data analysis on tall structures, and some comparative research. To regulate the tall structure, more study is needed on the linear and non-linear analysis of tall structures with efficient actuators and dampers. It's also vital to compare the capabilities of different control systems, like robust optimum control and stochastic optimal control.

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