

Mini Review

The Watt Governor Express

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Abstract: It is the opinion of the authors that, as the first issue of a new journal regarding Automatic Control, an appropriate remark is due to the history of the topic. Giving focus to the history allows both to stimulate young generations to reflect on the past and to note that, even with non-truly modern devices, further concepts can be reviewed and new ideas can arise, both for research projects and to develop innovative educational programs. In this letter, the Watt governor is discussed with the aim of emphasizing that from simple principles, outstanding revolutions can arise.

Keywords: automatic control; watt governor

1. Introduction

This letter had been inspired by a recent visit of the authors to the Museum of Engines and Mechanisms at the University of Palermo (<https://museomotori.unipa.it/index.php?lang=en>). In particular, the reported Watt governor system, represented in Figure 1, has been of great stimulus to address this special communication.

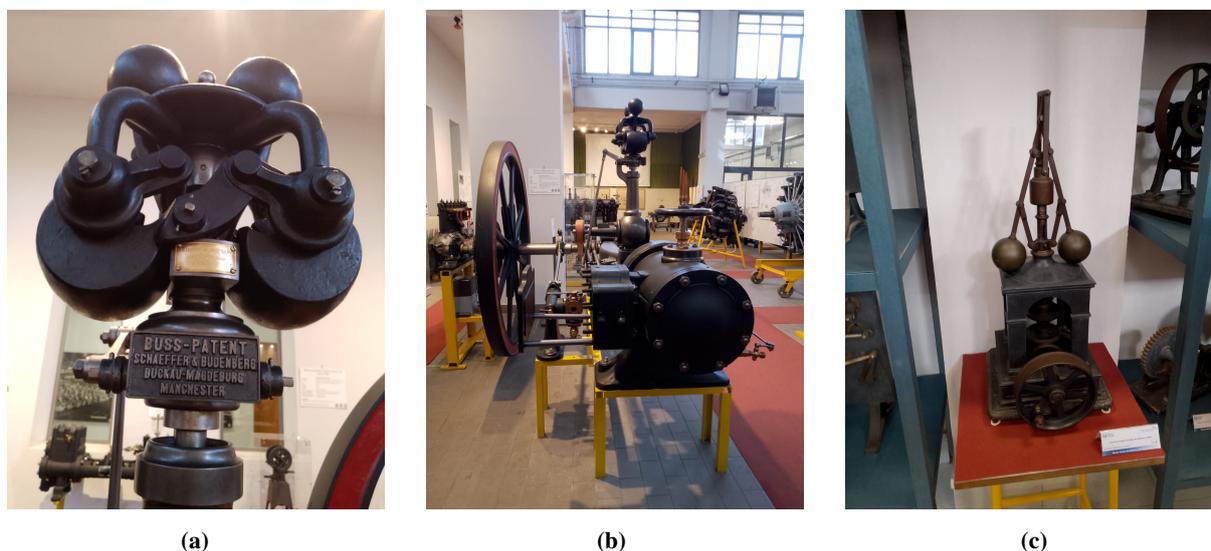


Figure 1. Watt governors in the Museum of Engines and Mechanisms of the University of Palermo. (a) Historical Watt governor mounted on a steam engine assembly. (b) Standalone Watt governor mechanism showing flyball and linkage structure. (c) Different Watt governor configurations preserved at the Museum of Engines and Mechanisms of the University of Palermo.

The Museum of Engines and Mechanisms of the University of Palermo (Italy) represents one of the richest mechanical engineering collections in Europe. With more than hundreds of artifacts, the collection illustrates the evolution of the steam and internal combustion engines from the late nineteenth century to modern times. It includes both stationary and transportation power units, with a particular focus on automotive and aircraft engines.

Moreover, the collection includes both the complete systems and the specific devices used to make the equipment. In the museum where turbine designs are represented, giving an exhaustive view of the significant examples, both in aircraft engines and in automotive ones, are also present collections of micro engines used in aircraft modeling.

In 2017, the American Society of Mechanical Engineers (ASME) 2017 gave the museum the prestigious international recognition as the Mechanical Engineering Heritage Collection.

The visit to both the engines and the mechanisms developed in two centuries, and the role of automatic control in the power management emerged in a strong manner. Therefore, the sentence “*Power is nothing without control*” strongly sounded, and the communication had been conceived.

The paper is organized as follows. In Section 2, we will briefly draw some historical details on automatic control equipment [1]. Section 3 will be dedicated to the classical Watt Governor [2], including its mathematical model detailed in the subsequent Section 4. The numerical simulations of the system, including some practical examples, are presented in Section 5. The last section contains the actual perspectives of research that the Watt governor recently inspired. The conclusions will briefly summarize the main features of the communication.

2. Key Historical Steps in Automatic Control

In this part of the communication, we introduce the main key historical periods that indicate where the human mind started to conceive the automatic control features [3].

The first automatic control system that had been conceived was the Clepsydra of Alexandria, also known as the “*water clock*”, introduced by Ctesibius of Alexandria (around 300 BC). Essentially, it is an instrument that measures time by the flow of a quantity of fluid. The aim had been to maintain a constant level of liquid by using negative feedback. It has been considered the first float valve

Philon of Byzantium (280–220 BC) applied the principle of the clepsydra to control the oil in a lamp in order to maintain the light. Hero of Alexandria (60 BC) conceived a mechanism that opened temple doors automatically using heat from an altar fire to create pressure in a water-filled vessel.

It is remarked that in the medieval period (500 to 1500 AD) the focus on automatic control moved from Mediterranean countries to the Islamic world, in China, and in Central and Southern Europe. The transition from simple float regulators to programmable machines and self-regulating clocks is granted by the following events.

In the year 900 AD, the three Banu Musa brothers published the Book of Ingenious Mechanical Devices in Baghdad. They invented linear valves and proposed the first programmable machines to control notes, similar to a music box working on air pressure.

Other studies made by Ismail Al-Jazari show advanced progress in automatic control that led to: segmental gears and cranks, the Castle of Clock, and the Elephant Clock.

Moreover, in 1094 AD, Su Song designed and built an astronomical clock tower which, by using mechanical regulation in a start and go mechanism, allowed the rotation of a wheel driven by water pressure.

The automatic control revolution started in Europe towards the end of the Middle Ages. The Verge and Foliot experiment (around 1300 AD) [4] introduced mechanisms in which the control power was provided by weights, instead of being directly derived from the power flow. This led to speed gear regulation in order to obtain a more constant motion.

Indeed, automatic approaches for controlling wind energy represent one of the most impressive examples developed during the late Middle Ages and the Industrial Revolution. In this case, the main problems were direction and speed control.

Automatic orientation was addressed by the invention of Edmund Lee in 1745 and later patented by Fantail. The mechanism was based on a small auxiliary wind wheel mounted at a 90-degree angle with respect to the main sails, acting as a sensor. If the wind hit the main sails head-on, the equipment maintained the axis of the sails parallel with the wind direction.

The control of the sail position was strongly addressed by Andrew Meikle (1772) and by William Cubitt. Moreover, the mentioned control equipment with high energy was devoted to control power derived from natural sources, such as water and wind. With the advent of steam and the Industrial Revolution, more advanced control schemes were required. The modern era of automatic control started with Watt’s steam engine governor.

3. The Watt Governor in Brief

The Watt regulator is universally considered one of the most important inventions in the area of automatic control [2]. In fact, the invention established a key technological feature in the steam era, particularly during the Industrial Revolution [3].

In fact, the invention had been pushed by the use of steam engines in the industry. The control of the power in the engine becomes fundamental in the power factories, in the mill industry, and in all the industrial applications that need rotational power for machinery.

Indeed, the first applications of steam used for pumping could tolerate speed fluctuation, but machinery like spinning frames required a constant, smooth speed to prevent breaking or damaging the products. This was the main reason for the industrial success of the Watt Regulator in the Rotative Steam Engine (1789).

In fact, in that system, pressed steam engines started to be applied in the flour mills and in the textile factories, respectively preventing the grain from scorching due to the speed of rotation and precise tension needed for the automation of weaving and spinning.

In the schematic representation shown in Figure 2, the labeled points identify key mechanical components of the governor. In particular, points A and A' represent the joints connecting the rotating arms to the linkage mechanism, B denotes the rotating masses (flyballs), O is the rotation axis, D indicates the sliding sleeve that translates vertically in response to centrifugal force, M represents the main shaft connected to the engine, and L indicates the linkage connected to the steam valve actuator. These elements, together, implement the feedback mechanism that regulates steam flow and stabilizes engine speed.

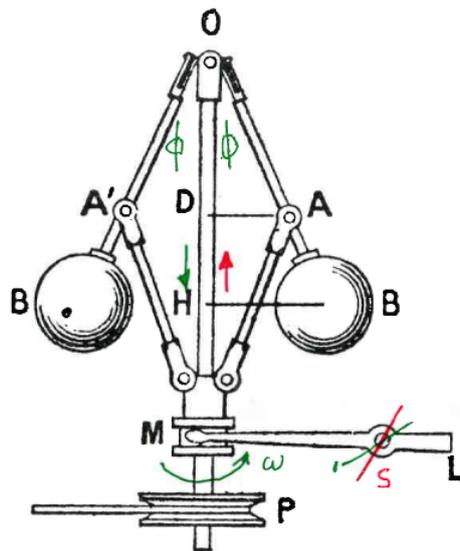


Figure 2. Scheme representing the watt regulator

This allows for an automatic decrease in power and a stabilization of the speed that decreases. The opposite condition occurs when the engine speed decreases. The mechanism works thanks to the centrifugal force of the rotating balls, proportional to the speed, and to the balance with the gravitational force that leads the balls downward, determining a balance of forces that leads to the equilibrium acting on the valve position.

The essential feature of the Watt governor is that it directly measures speed; therefore, no external equipment or energy sources are needed for sensing. Moreover, the ball motion drives a linkage mechanism that actuates the steam throttled valve. Therefore, both sensing and actuation are integrated into the system and do not require an added energy source for the control action.

Essentially, the Watt governor attempts to maintain a constant speed despite disturbances, instantaneous load decreases or increases, depending on the engine's behavior, using centrifugal force sensing and mechanical actuation thanks to the negative feedback principle. The Watt regulator in 1868 established a real bifurcation in the dynamic evaluation of the control system, and even if it has been improved by the Porter governor that added a central weight in the body to improve both the sensitivity of the governor and its use to higher speed, and by the Pickering governor that used leaf springs instead of gravity, the principle of the Watt regulator and its success established the truly spread out of the automatic control and automation age.

the governor is driven by a speed given by $c \cdot \omega$. The second term gives the gravity pulling the balls back downward. The third term represents the damping friction in the mechanism.

The Equation (1c) is derived by a mechanical torque balance. It essentially indicates that if ω changes due to a load F , this perturbation interacts with the Equation (1b), establishing a mechanical feedback and therefore a self-regulating mechanism.

The other parameters included in the model are:

- l : the length of the governor arms;
- m : the mass of each ball;
- b : the frictional damping coefficient;
- J : the moment of inertia of the engine flywheel;
- μ : indicates a proportionality constant that gives the position of the valve that regulates the steam and therefore the active torque.

The dynamical system model is nonlinear. It represents a proportional (P) regulator for the angular speed ω . Therefore, assuming a reference value of $\omega = \omega_0$, any torque disturbance does not destabilize the system; moreover, the final speed ω will not reach ω_0 . The parameter μ plays a role similar to the proportional gain. In fact, increasing μ could reduce the error, but it also leads to instabilities. The reduction of b leads to oscillations. Increasing J improves stability and reduces the time response. The system, from an input/output perspective, can be schematically represented as shown in Figure 4, where F denotes the load profile.

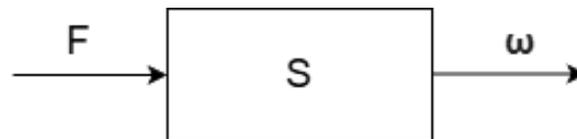


Figure 4. Block representation of the Watt governor system showing the interaction between load torque F , governor dynamics, and resulting angular speed ω . The feedback mechanism regulates the valve opening to compensate load variations.

5. Numerical Examples

In the appendix, the Matlab code that simulates the mathematical model discussed in the previous section is reported. It also included the function that describes both the function and the load trend, which can be easily modified to get different working conditions of the Watt Governor.

The following numerical examples are proposed.

5.1. Example 1

The Watt governor parameters are, and the nominal initial conditions are reported in the appendix. The load profile is depicted in the bottom plot of Figure 5a.

By looking at the simulation plots present in the Figure, we can make a few remarks:

- The Watt governor does work in a stable condition.
- The steady state represented in the figure does agree with the values derived by the relation
- the governor does work. In fact, corresponding to the load perturbation, it responds with a stable behaviour by adjusting the working condition.

The decreasing speed due to the load increasing in the interval $10 \leq t \leq 20$ leads to a decreasing angle ϕ that will open the steam valve to increase the power in the system, avoiding a fall. Moreover, when the disturbance disappears ($t > 20$), the increase in speed leads to an increase in the angle ϕ , which determines the valve position, decreasing the power within the system and resulting in a further speed reduction.

5.2. Example 2

This example shows how a small damping term is enough to lead to oscillations of the system.

Parameters:

$$M = 0.5 \text{ kg}, \quad L = 0.4 \text{ m}, \quad g = 9.8 \text{ m/s}^2$$

$$b = 1, \quad I = 1 \text{ Km}^2, \quad \mu = 15.0$$

The dynamical behavior is shown in Figure 5b. Assuming the same parameters, but increasing I to 5 km^2 the oscillating behavior disappears, as is shown in Figure 5c. In order to get a faster transient for $t \leq 10$ an increase of gain $\mu = 25$ is adopted. This is shown in Figure 5d. The example demonstrated to us that, given the mechanical parameters of the governor, setting the parameter μ , we initially can achieve suitable performances.

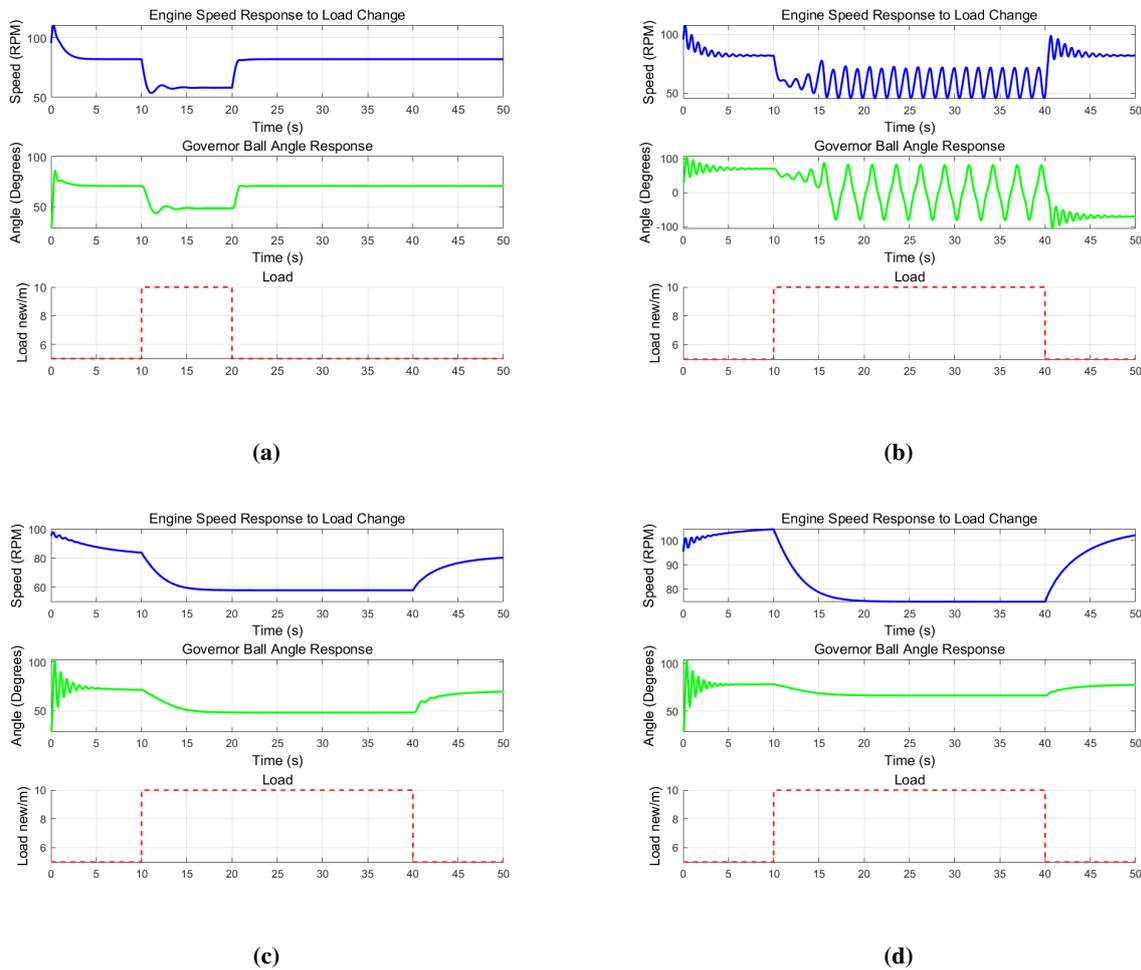


Figure 5. Numerical simulations of the Watt governor under different parameter conditions: (a) nominal parameters showing stable regulation, (b) reduced damping leading to oscillatory behavior, (c) increased flywheel inertia suppressing oscillations, and (d) increased gain improving transient response. Each subfigure shows the engine speed, governor angle, and load profile. The results illustrate stable behavior, oscillatory dynamics, and improved transient response depending on inertia and gain values.

5.3. Example 3

The following parameters are assumed:

$$b = 1, \quad I = 5 \text{ Km}^2, \quad \mu = 15$$

$$M = 0.5 \text{ kg}, \quad L = 0.3 \text{ m}, \quad g = 9.8 \text{ m/s}^2$$

The simulation results are reported in Figure 6, showing how good performances are being obtained in terms of: appropriate transient for $t \leq 10$ and limited oscillations. This means that conceiving a watt governor with the possibility of positioning the arm could be useful as a trimming procedure in order to get appropriate performances.

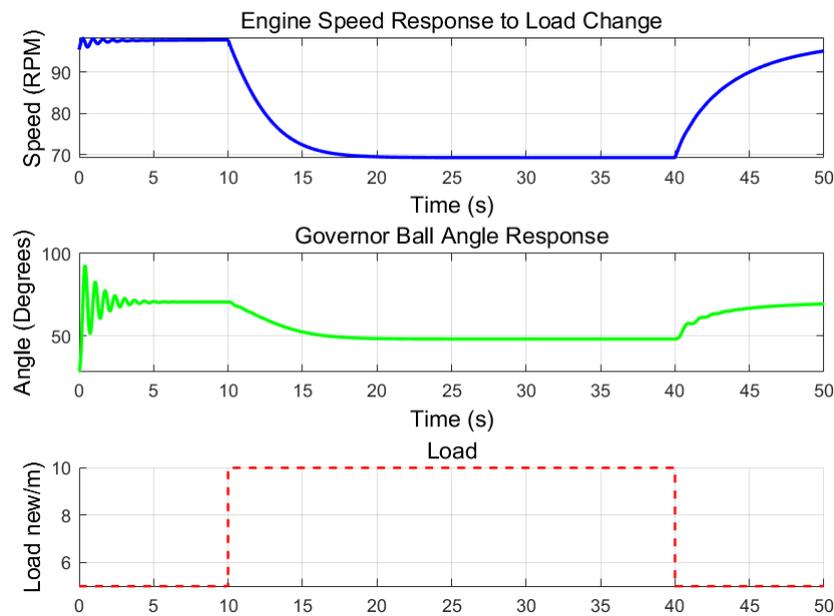


Figure 6. Simulation results showing improved transient response and reduced oscillations for optimized mechanical parameters. The plots illustrate engine speed regulation and governor angle adaptation under load disturbances.

6. Actual Perspectives on Watt Governor

This brief section aims to emphasize some recent trends in the study of the Watt governor, together with a few perspectives for future investigations. In the discussion carried out in Sections 3 and 4, and in the topics addressed throughout the critical reconsideration of the Watt governor system, it has emerged that, in the last decades, the nonlinear behavior of the device has not been exhaustively dealt with.

Recently, in [6], the complexity of the dynamics of the Watt governor has been widely studied. Its richness, in terms of the presence of both strange attractors and bifurcations, had been strongly investigated, making the Watt governor a topic of research in the area of complex systems and circuits.

In fact, in [7] an electronic emulator of the Watt governor has also been proposed. Indeed, in the same contribution, more references that investigate the nonlinear behavior of the Watt governor are reported.

Moreover, recent studies have proposed investigating the frequency response of the nonlinear behavior of the Watt governor [7]. The topic has also been strongly developed in the contributions [8,9], where very recent asymmetries are considered. Experimental studies have been proposed in [6]. The area of investigating jumping resonance in Watt governor behavior does represent an interesting subject of research [10].

Moreover, the topic of Watt governors under harmonic perturbations has been the subject of recent research in [11]. However, what appears as new is the interest in the Watt governor in the area of neuroscience, and in that of theoretical biology, as pointed out in [12]. In fact, in [13], the Watt governor paradigm has been proposed to explain human behavior based on observation, in the context of behavioral research.

In the complexity of explaining homeostasis concepts, the Watt governor is strongly used in [14]. Finally, from an information point of view, the outstanding contribution given in [15] limits both the homeostatic behavior and the main cybernetic concepts related to the Watt governor. Moreover, as remarked in [16], the Watt governor remains a pivot in the mechanisms and machine fundamentals. Recent investigations have also addressed the Watt governor from a structural and modeling perspective, combining mathematical formulation and numerical analysis to evaluate its mechanical performance and design implications in modern engineering contexts [17].

7. Conclusions

This communication has aimed to stress the interest that until now has been devoted to the Watt Governor. Even if in this period the interest in the field of automatic control is dominated by AI issues, humanoid robots, and autonomous vehicle networks, the basic principles of control and their history are at the center of the scientific community. In particular, the Watt Governor has, until today, had a strong impact on research and educational programs. Moreover, in preparing this communication, the authors greatly appreciated the recent contributions to the history of automatic control equipment and theory, which provided the basic concepts and ideas for developing modern cyber systems in robotics and factory automation. This contribution has also been conceived as an article

for the first issue of a new journal, with the hope of stimulating people, particularly young generations, to investigate classical control topics. There are a lot of undiscussed problems and a great quantity of fascinating details that must be furtherly studied.

Author Contributions

L.F.: conceptualization, methodology, software; A.S.: data curation, writing—reviewing and editing. All authors have read and agreed to the published version of the manuscript

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Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

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Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

Appendix A. Matlab Implementation of the Watt Governor

```
% run_governor_simulation.m
% Main script to simulate the Watt Governor

% --- 1. Set Up Parameters (Constants) ---
p.m = 0.5;      % Mass of each ball (kg)
p.l = 0.4;      % Length of arms (m)
p.g = 9.81;     % Gravity (m/s^2)
p.b = 5;        % Friction coefficient (damping)
p.I = 1.0;      % Moment of inertia of engine flywheel (kg*m^2)
p.mu = 15.0;    % Proportionality constant for torque input (valve gain)

% Time parameters
T_sim = 50;     % Total simulation time in seconds
t_span = [0, T_sim];

% Initial conditions [omega (rad/s), phi (rad), psi (rad/s)]
% Starting near a stable operating point
initial_omega = 10.0; % approx 95 RPM
initial_phi = 0.5;    % approx 28 degrees
initial_psi = 0.0;
initial_state = [initial_omega; initial_phi; initial_psi];
```

```

% --- 2. Run the Simulation ---
% ode45 is MATLAB's robust ODE solver
% We pass the parameters 'p' to the function handle
using an anonymous function
[t, y] = ode45(@(t, state) governor_dynamics_func(t, state, p),
t_span, initial_state);

% y is a matrix where each column is a state variable:
omega = y(:, 1);
phi    = y(:, 2);
psi    = y(:, 3);

% --- 3. Generate Load Profile for Plotting ---
% The solver uses the load function dynamically; we need to recreate
% the load profile to plot it against time.
F_load_vals = zeros(size(t));
for i = 1:length(t)
    F_load_vals(i) = load_profile_func(t(i));
end
% Scale load value for plotting visual comparison (optional)
F_load_scaled = F_load_vals * 0.1;

% --- 4. Visualize the Results ---

figure;

subplot(3, 1, 1);
% Convert rad/s to RPM for readability: omega * 60 / (2*pi)
plot(t, omega * 60 / (2 * pi), 'b', 'LineWidth', 2);
hold on;
%plot(t, F_load_scaled, 'r--', 'LineWidth', 1.5);
%xline(10, '--', 'Load Increase Event');
title('Engine Speed Response to Load Change');
ylabel('Speed (RPM)');
xlabel('Time (s)');
%legend('Engine Speed (RPM)', 'Scaled Load Input');
grid on;

subplot(3, 1, 2);
% Convert angle from radians to degrees for readability
plot(t, rad2deg(phi), 'g', 'LineWidth', 2);
%xline(10, '--', 'Load Increase Event');
title('Governor Ball Angle Response');
ylabel('Angle (Degrees)');
xlabel('Time (s)');
%legend('Ball Angle \phi (degrees)');
grid on;
subplot(3, 1, 3);
hold on;
plot(t, F_load_vals, 'r--', 'LineWidth', 1.5);
title('Load');
ylabel('Load new/m');
-----
function d_state = governor_dynamics_func(t, state, p)
    % Unpack state variables: state = [omega; phi; psi]

```

```

omega = state (1);
phi   = state (2);
psi   = state (3);

% Get the current load value based on time
F = load_profile_func(t);

% --- The Dynamical Equations ---

% d(omega)/dt: Engine acceleration equation
d_omega_dt = (p.mu * cos(phi) - F) / p.I;

% d(phi)/dt: Angle velocity equation
d_phi_dt = psi;

% d(psi)/dt: Angle acceleration equation
centrifugal_term = omega^2 * sin(phi) * cos(phi);
gravity_term     = (p.g / p.l) * sin(phi);
friction_term    = (p.b / p.m) * psi;

d_psi_dt = centrifugal_term - gravity_term - friction_term;

% Return derivatives as a column vector
d_state = [d_omega_dt; d_phi_dt; d_psi_dt];
end
-----
function F_load = load_profile_func(t)
% Starts at 5 N*m load, increases to 10 N*m at t=10s.
if t < 10
    F_load = 5.0;
else
    F_load = 10.0; % Sudden load increase
end
end

```

References

1. Kumar, G.M. *Theory of Machines & Mechanisms*; Khanna Publishing House: New Delhi, India, 2025.
2. Hannavy, J. *The Governor: Controlling the Power of Steam Machines*; Pen and Sword Transport: Barnsley, UK, 2022.
3. Khaki-Sedigh, A. *Control Systems: A Historical and Philosophical Perspective: History and Philosophy of Control Systems*; Springer Nature: Berlin/Heidelberg, Germany, 2025.
4. Fang, Y.; Rong, D.; Lou, Y. The Principle of Automatic Control in Ancient Hydraulic Engineering Works: A Comparative Study of the Dutch Beemster Polder and China's Dujiangyan Irrigation System. In Proceedings of the 2025 IEEE 26th China Conference on System Simulation Technology and its Applications (CCSSTA), Shenzhen, China, 11–13 July 2025; pp. 696–702.
5. Maxwell, J.C. I. On governors. *Proc. R. Soc. London* **1868**, *16*, 270–283.
6. Sotomayor, J.; Mello, L.F.; Braga, D.D.C. Bifurcation analysis of the Watt governor system. *Comput. Appl. Math.* **2007**, *26*, 19–44.
7. Marcôndes, D.W.C.; Comassetto, G.F.; Pedro, B.G.; et al. Extensive numerical study and circuitry implementation of the Watt governor model. *Int. J. Bifurcation Chaos* **2017**, *27*, 1750175.
8. Big-Alabo, A. On the nonlinear asymmetric vibrations of the unforced Watt governor: An exact analysis. *Adv. Mech. Eng.* **2025**, *17*, 16878132251349038.
9. Rosa, L.A.; Prebianca, F.; Hoff, A.; et al. Characterizing the dynamics of the Watt governor system under harmonic perturbation and Gaussian noise. *Int. J. Bifurcation Chaos* **2020**, *30*, 2030001.
10. Darmawan, S.; Muharni, R.; Alghani, I.; et al. Design and development of a governor test device to analyze the effect of speed variation on centrifugal force. In The Fifth International Conference on Innovations Social Sciences Education and Engineering, Bandung, Indonesia, 26 July 2025; Volume 5, pp. 027–027.

11. Fortuna, L.; Buscarino, A. *Book on Jump Resonance*; World Scientific: Singapore, 2024.
12. Billman, G. E. Homeostasis: The Underappreciated and Far Too Often Ignored Central Organizing Principle of Physiology. *Front. Physiol.* **2020**, *11*, 200.
13. Mansell, W.; Gulrez, T.; Landman, M. The prediction illusion: perceptual control mechanisms that fool the observer. *Curr. Opin. Behav. Sci.* **2025**, *62*, 101488.
14. Weinberger, N. Homeostasis and Causal Control. *PhilSci-Archive* **2025**, <https://philsci-archive.pitt.edu/25288/>.
15. Bechtel, W.; Bich, L. Rediscovering Bernard and Cannon: Restoring the Broader Vision of Homeostasis Eclipsed by the Cyberneticists. *Philos. Sci.* **2025**, *92*, 584–605.
16. Manik, D.N. Governors. In *Fundamentals of Mechanisms and Machines*; Springer Nature: Singapore, 2024; pp. 391–414.
17. Choudhary, T.; Nauriyal, S.; Gupta, V.; et al. Structural Analysis of Three-Flyball Watt Governor Using Mathematical and Finite Element Analysis. In *Advances in Materials and Manufacturing*; Springer: Singapore, 2025.