Proell Governor

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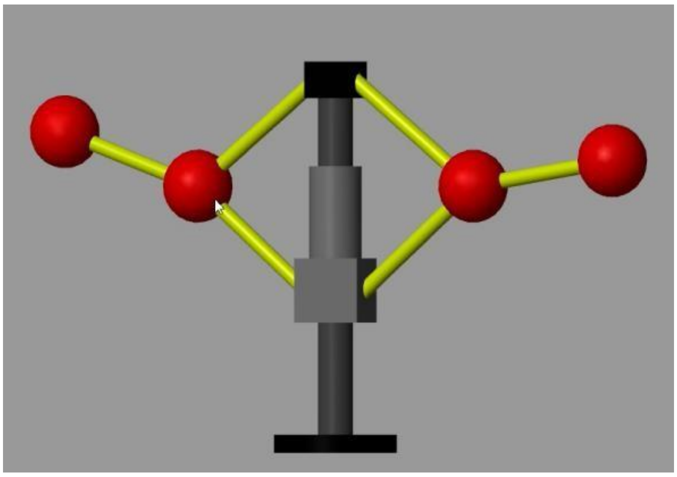
Objectives: 1) Understanding Operation Principles: Exploring the theoretical foundations of Proell governors, including equations and control mechanisms.
2)Building A Simulation Model: Construct a dynamic simulation model in MATLAB to replicate the behaviour of a Proell governor under different conditions.
3)Investigating System Performance: The simulation model is used to analyse the performance of the Proell governor system under various scenarios, such as changes in load, speed setpoints, and system parameters

Assumptions: 1) Friction at all joints is negligible. 2)Air resistance is ignored. 3)Gravity acts in -z direction.

Scope: Governors are employed to maintain engine speeds within specified boundaries, ranging from no load to full load conditions. Their function is to regulate the throttle of the carburettor in gasoline-powered engines and the fuel pump in diesel engines. Among the various types, centrifugal governors that rely on flyweights are the most prevalent. The positioning of these weights is dependent on the speed at which they are rotating. The dynamic system comprises a spindle that is mounted in a vertical orientation. The governor linkages are connected to a sleeve that undergoes upward movement due to the outward force exerted by the balls as a result of centrifugal force. The extent of this sleeve's lift is determined by utilizing a scale. There exists a category of governors known as dead weight governors, which are controlled by the force of gravity and are a form of centrifugal governors for example Porter Governor and Proell Governor

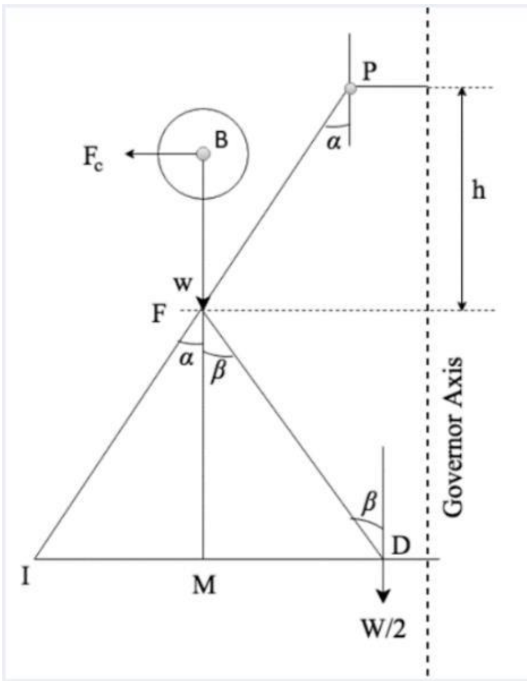


Description: The Proell Governor is a centrifugal governor variant featuring an elongated arm carrying the rotating balls, moving at the extended arm's rotational velocity. Moreover, dead weights augment the rotation speed, facilitating accurate high-speed operation. This governor's design ensures consistent functioning devoid of fluctuations.

Construction: The Proell Governor's construction comprises two arms joined at a pivot point, plus an extended arm supporting the balls, also connected to the other arms. A connecting rod links the sleeve and arms, causing sleeve lift when balls rotate around the fixed pivot. Key components include: Pivot - linking arm point. Arms - rotating with attached balls. Extended arms - straight arms at ends supporting balls. Balls - predetermined weight atop extended arms, moving sleeve up/down via connecting rod. Connecting rod - joining sleeve to balls. Sleeve - linked to balls by rod, sliding along spindle to regulate fuel tank-to-engine flow. Fuel pump - supplying engine fuel from tank.

Working principle: When engine load decreases, the spindle's faster rotation causes the governor arms and balls to move outward due to increased centrifugal force. This lifts the sleeve, triggering a mechanism closing the throttle valve, reducing fuel supply to maintain engine speed. Conversely, increased engine load slows the spindle and ball rotation, lowering the sleeve and activating a mechanism opening the throttle valve, increasing fuel supply and engine speed. The Proell Governor's height is given by: h = FM BM (m + M/m) / 895ω^2. The governor's derivation is shown below.

Kinematic Analysis:



m - Mass of each ball (kg)
W - Weight of each ball = m*g (in N)
M - Mass of central load (in N)
r - Radius of rotation (in m)
h - Height of governor (in m)
w - Angular speed of the ball in (in rad/s)
F_c - Centrifugal force acting on the ball (in N)
T_1 - Tension in the arm (in N)
T2 - Tension in the link (in N)
α - Angle of inclination of the arm (in rad)
β - Angle of inclination of the link (in rad)

In above figure, on considering equilibrium force on half of the governor. The instantaneous center (I) is located to the left of an extension of PF and MD. A perpendicular line BM is drawn to ID. Taking moment of inertia through I,

$$F_c \times BM = w \times IM + \frac{w}{2} \times ID = mg \times IM + \frac{Mg}{2} \times ID$$

$$F_c = mg \times IM + \frac{Mg}{2} \times \frac{(IM + MP)}{BM} \qquad -(1)$$

Where, ID = IM + MD

Multiplying and dividing both sides by FM we get,

$$F_c = \frac{FM}{BM}[mg \times \frac{IM}{FM} + \frac{Mg}{2}(\frac{IM}{FM} + \frac{MP}{FM})]$$

$$F_c = \frac{FM}{BM}[mg \times tan\alpha + \frac{Mg}{2}(tan\alpha + tan\beta)]$$

$$F_c = \frac{FM}{BM} tan\alpha [mg + \frac{Mg}{2}(1 + \frac{tan\beta}{tan\alpha})]$$

$$mw^2r = \frac{FM}{BM} \times \frac{r}{h}[mg + \frac{Mg}{2}(1 + q)]$$

Where tan α = r/h and q = tan β/tan α

$$w^2 = \frac{FM}{BM}[\frac{mg + \frac{Mg}{2}(1 + q)}{mg}]\frac{g}{h} \qquad -(2)$$

$$w^2 = \frac{FM}{BM}[\frac{mg + \frac{Mg}{2}(1 + q)}{mg}]\frac{895}{h}$$

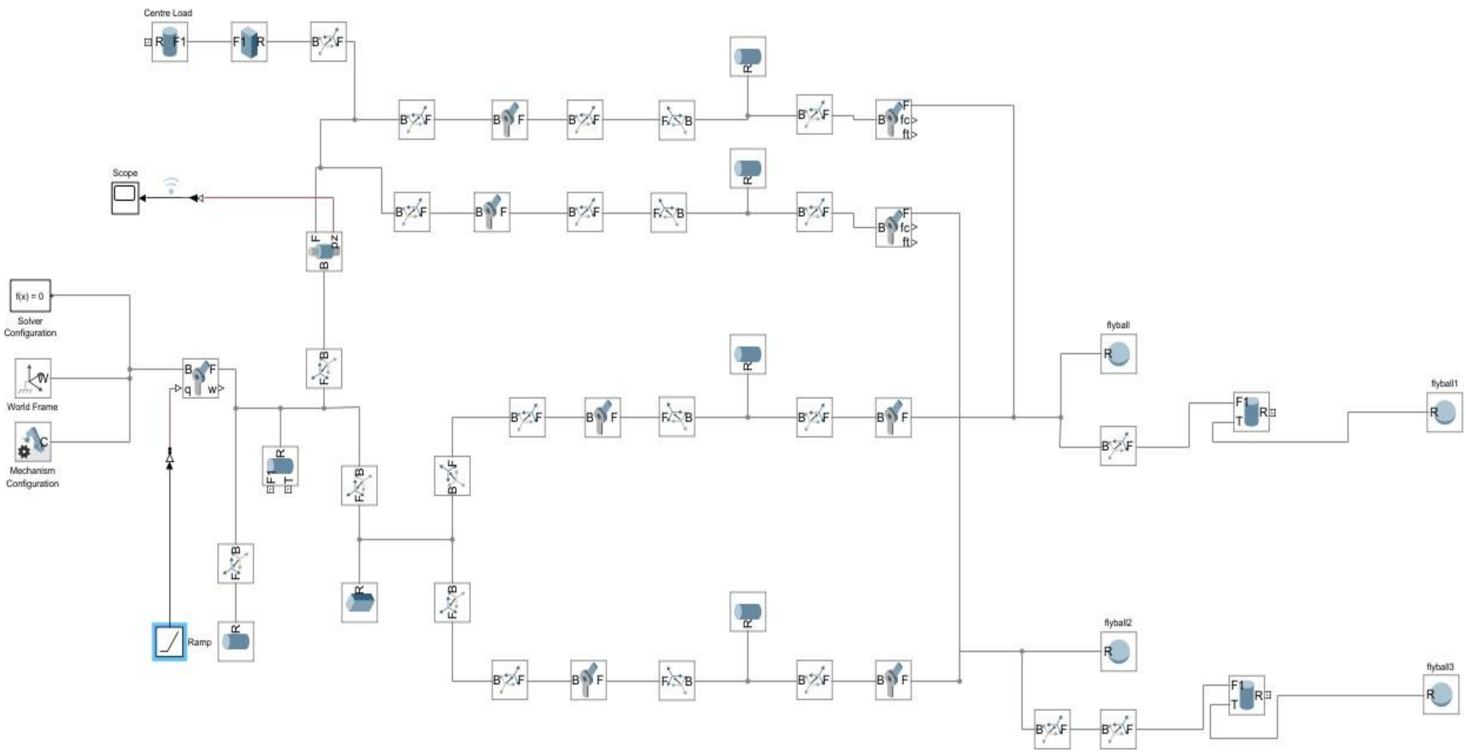
Where α = β then q=1

$$w^2 = \frac{FM}{BM}[\frac{mg + \frac{Mg}{2}(1 + q)}{mg}]\frac{895}{h}$$

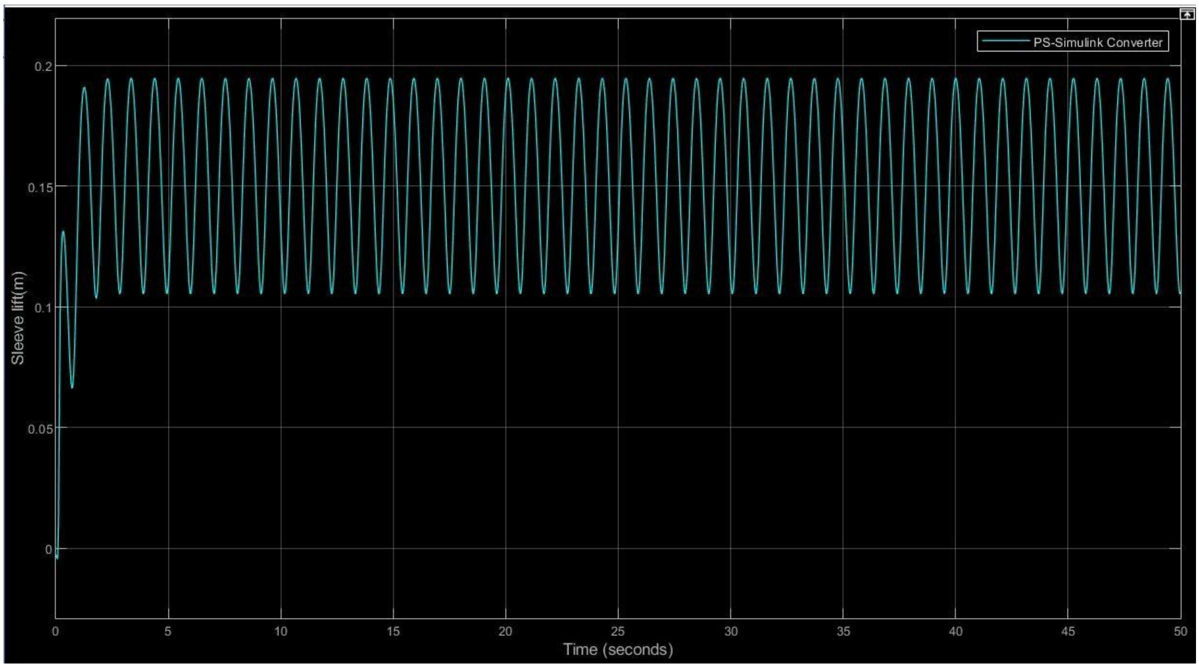
$$h = \frac{FM}{BM}[\frac{mgh + \frac{Mg}{2}(1 + q)}{mg}]\frac{895}{w^2}$$

Modelling procedure: MATLAB Simscape was utilized to develop the project model. The model construction process involved either importing CAD files or using the solids tool to create the necessary parts. Initially, the solver configuration block, world frame, and mechanism configuration were added. Various parts like solid bricks, cylinders, and spheres were created using the Simscape library. Cylinders were used to create the central rod, arms, sleeve, and other links. Spheres represented the spherical side weights. Bricks were used to create the top solid. Joints, such as revolute and cylindrical joints, were necessary to connect different parts of the model. The Rigid Transform tool in MATLAB Simscape was employed to correctly position the created bodies, obtaining the desired shape of the model. The parts were added in a specific and required order. The center weight was linked to the rod through a cylindrical joint, and the top connection was made through a revolute joint. Two rods and two balls were added as extensions to the current arms. The entire system was connected to the ground via a revolute joint. A ramp block can be used to provide input and adjust the rotational speed. To organize the mechanism, the primary blocks needed are the World frame and Mechanism configuration blocks, which enable Solver Configuration. The body parts of the mechanism can be created using the solid tool. Graphs can be plotted using the scope and multiplot graph. The data inspector is used to analyze the graphs. The mass of the sleeve is 0.37 kg.

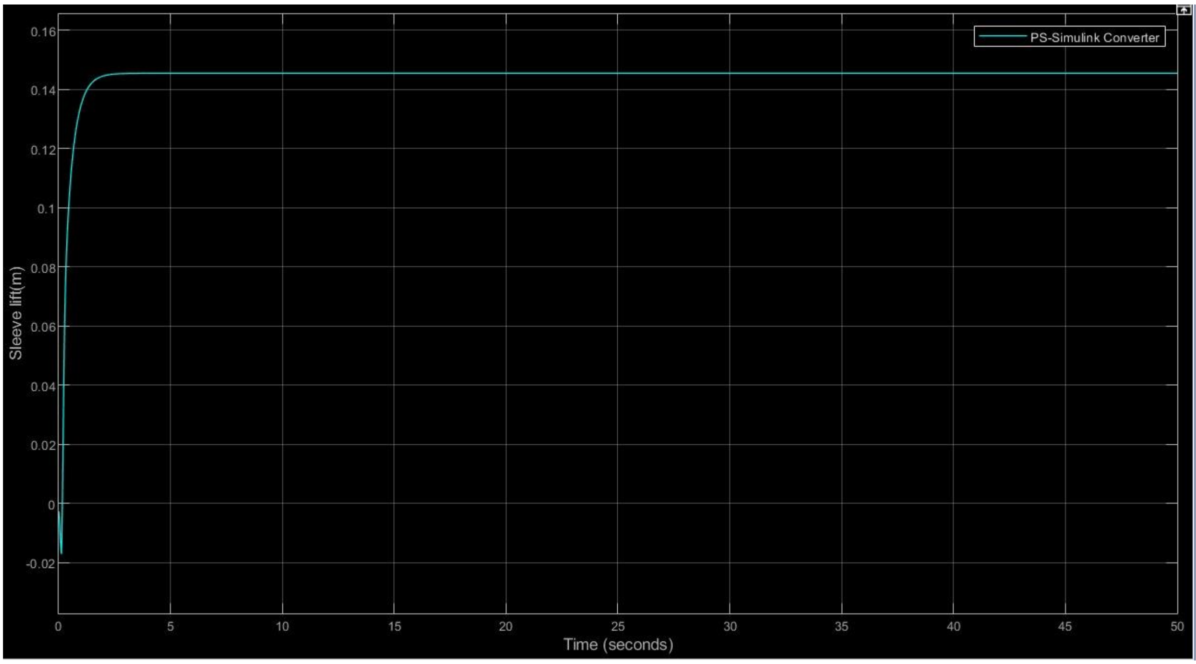
Simscape Multibody Model:



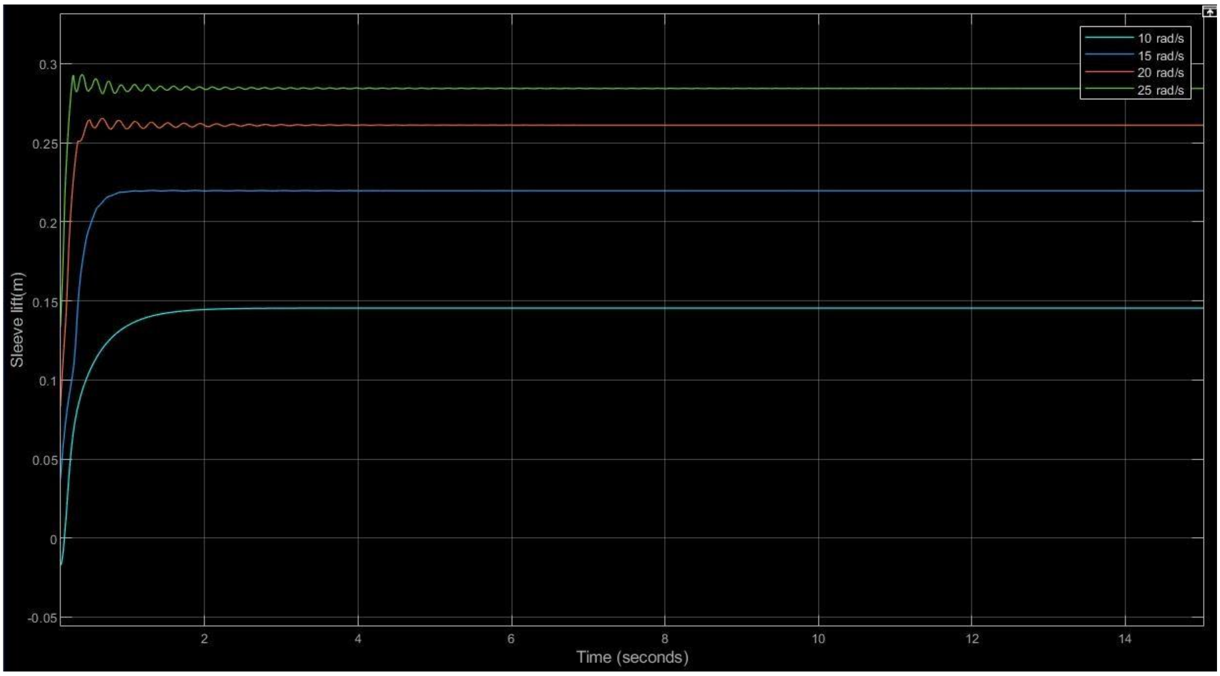
Graphs:



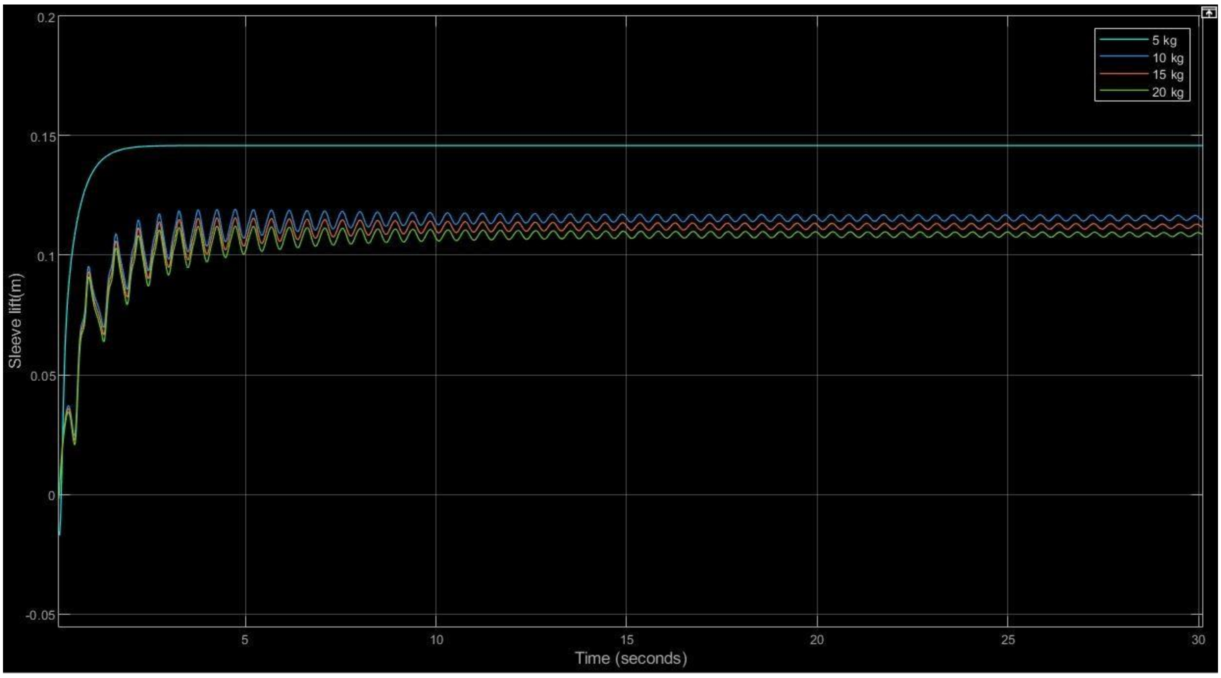
Variable angular speed vs time



Constant angular speed vs time @ w=10 rad/s



Variation of lift with angular velocity



Effect of deadweight on lift @ w=10 rad/s

Inference: Increasing the spin velocity leads to an increase in the lift of the sleeve. The lift of the sleeve increases when the mass of the balls (dead weight) is increased.